Chapter 7

UPSTREAM SETTLEMENTS & POPULATION

7. UPSTREAM SETTLEMENTS AND POPULATION

7.1 INTRODUCTION

The catchment directly above Grand Falls includes the sub-basins of the Kathita River, the Mutonga River and the Ena River (see Figure 7-1). In addition there will be some direct input from the sub-basin below Kiambere Dam. These sub-basins fall within three districts, Meru, Tharaka Nithi and Embu (and to a very minor extent to the East of the proposed reservoirs, a small part of Mwingi District).

Any pollutants generated by the populations in these sub-basins will feed directly into the Mutonga and Grand Falls Reservoirs. Pollutants generated in the catchments above Kiambere Dam will have been moderated by the biotic processes occurring in the up-stream reservoirs.

The catchment feeding directly into the proposed reservoirs is predominantly rural, with one major town, Meru, and a number of smaller urban centres and markets. The present pattern of small urban centres is one of ribbon development concentrated along the main Embu-Meru road, with smaller market centres along the minor rural feeder roads. This pattern is expected to dominate the future urban growth within the upper catchment.

Projected development patterns are based on the current district development plans (MPND 1994). For the purpose of this study, the planning period is taken to be to the start of reservoir impoundment in the year 2005.

7.2 POPULATION AND POPULATION GROWTH

The 1989 census indicated that the total population in the upper catchment was approximately 807,000. The only major urban centre is Meru Town, which had a population of around 95,000 in 1989, however there are in addition two other settlements defined as urban centres in the national census[1], Nkubu and Chuka which had populations of 5,150 and 4,250 respectively. The populations of the smaller market centres have been estimated from the difference between the average population density of adjacent sub locations and the population density of the sublocations containing the market centre. This gives an additional urban population of 14,000 people distributed among 16 other centres. The total urban population in 1989 was therefore in the region of 119,000.

Following from this, the rural population has been estimated to have been about 689,000 at the time of the census.

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[1] The national census defines urban areas as City Councils, Municipal Councils, Town and Urban Councils, District Headquarters and trading centres with a minimum population of 2,000 people, and aggregates the population of all urban centres with less than 2,000 people.

The average population growth rate over the inter-census period for the districts concerned was 3.5% per annum[1]. However this overall growth rate has to be seen in the light of an increasing trend to urbanisation. The national figures for urban growth show an annual increase of 5.2%, with the greatest growth of over 9% per annum occurring in the smaller centres with populations of less than 5,000. This process of accelerating urbanisation is expected to continue and to increase, as land pressure forces ever-increasing sections of the population to look for alternatives to small-scale farming. The national figures are also reflected in the district figures, with population growth rates of 11.1% pa for Chuka and 7.1% pa for Nkubu.

For the purpose of this analysis, the present trends in population growth and urbanisation are assumed to continue with a rural population growth rate of 3% pa and an urban population growth of 8% pa. The total population in the upper catchment could have increased to around 1.5 million people by the year 2005, of which an estimated 400,000 could be in urban or peri-urban settlements.

Although the urban analysis is based on the growth of the existing settlements without differentiating between their size, in practice it would be expected that the highest rate of growth would be in ribbon development along the main road from Embu to Meru and along the rural feeder roads, both in existing urban areas and in the development of new trading centres and market places.

Table 7-1 Population by Sub-Basin

Sub-Basin	Urban 1989	Rural 1989	Urban 2005	Rural 2005
Kathita	105,750	234,200	362,300	375,800
Mutonga	8,350	300,650	28,600	482,500
Ena	4,400	130,250	15,100	209,000
Thura	0	23,550	0	37,800
Total	118,500	688,650	406,000	1,105,100

Clearly the increased population both rural and urban will lead to increased demands for public water supplies, and most significantly the urban areas will generate considerably greater volumes of domestic and industrial waste water.

7.3 AGRICULTURAL DEVELOPMENT

The farming systems in the upper catchment are dominated by the small-holder sector and include mixed farming systems based on the two main cash crops, tea and coffee, and maize and other food crops in the wetter, higher parts of the upper catchment. In the lower drier areas, and immediately adjacent to the proposed reservoir body, the agricultural system is more extensive and is based on maize and beans with additional dryland grain crops, and with cotton and tobacco as cash crops.

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[1] The recorded urban population growth rates for the period 1979 to 1989 are as follows: Embu 3.1% pa; Meru 4.0% pa; Tharaka Nithi 3.3% pa.

Both systems are already fairly intensive and there is little available land for the horizontal expansion of the present systems.

Any changes in the present farming systems will therefore be through intensification, with a likely change in the cropping mix to favour high value horticultural crops in the wetter parts of the catchment. This is acknowledged in the district development plans which propose a strategy of promoting intensive cultivation which will involve a trade-off between the production cash of crops and food crops ***as a result of increasing competition for land resources***. The District Development Plans all refer to intensification - "...increased production per hectare...", and for the drier areas to the promotion of drought resistant crops. It is assumed that the production of all crops will be increased. However, Tharaka Nithi recognises that intensification is likely to change the balance of crops with a possible loss of some of the traditional cash crops.

The use of fertilisers and pesticides can therefore be expected to increase, although at rates below the increasing population pressure. The cropping mix is likely to favour food crops, and as a result although the productivity per hectare for the two main cash crops, tea and coffee, may increase, the gross production is not likely to significantly change and may actually decrease.

Table 7-2 Typical Farm Sizes and Cropping Systems in the Upper Catchment

District	Upper Sub-Basin	Lower Sub-Basin
Embu	1.2 ha coffee, tea, passion fruit, bananas, Irish potatoes, horticultural crops	5 - 7 ha maize, beans, millet, cotton, tobacco
Meru	1.3 ha coffee, tea, bananas, maize, beans, Irish potatoes	Not Applicable
Tharaka Nithi	1.0 ha coffee, tea, bananas, maize, beans	6 ha maize, beans, sorghum, millet, cotton, sunflower

The predicted increasing intensity of land use should reduce levels of run-off as ground cover is maintained by expanded mixed farming systems. As a result, the mechanism for transfer of any agro-chemicals to the stream flow should also be reduced, which may to some extent counteract increased levels of use.

Considerable concern has been expressed over the discharge from seasonal processing of coffee in small factories within the upper catchment. This may not be as serious as at first considered, as it is reported that much of the discharge is directed to irrigation within the farm areas, rather than released directly into streams[1]. The predicted change in the farming mix to favour food crops is likely to lead to a gross decrease in the are under coffee, although production may be maintained by intensification. The implication of this is that the present number and distribution of small coffee factories is not likely to increase, and therefore the level of discharge of pollutants from these factories will not change during the planning period.

7.4 IRRIGATION

The additional development proposals for the drier parts of the upper catchment are generally based on an expansion of irrigation, using surface water from the tributaries of the Tana River. The Water Master Plan (MOW 1991) gives projected gross irrigation demands by sub-basin, both in terms of monthly water demand and in terms of total area. Monthly water demands, by the year 2010, are projected to reach a maximum of 4 m^3/sec in March for the Kathita sub-basin (4FA), 2.7 m^3/sec for Mutonga (4EA and 4EB) and 0.5 m^3/sec for Ena (4EC).

The actual development of irrigation will, of course, depend on major investments becoming available. So far irrigation investment has been limited in these areas.

More realistically, the present district development plans identify four irrigation schemes for immediate priority development in Tharaka Nithi and one in Embu, all within the upper catchment. These schemes are described as small-scale/community based schemes using surface delivery. However funding sources had not been identified.

Investment in irrigation can only be justified if it is in conjunction with the promotion of high yielding / high value cropping systems. The implication of any increased irrigation development will be the increased use of fertilisers and pesticides, which will enter surface water systems leading into the proposed reservoirs. In addition, the reduced gross flow of water will lead to higher concentrations of pollutants.

Table 7-3 Projected Irrigation Development in the Upper Catchment (ha)

Sub-Basin	1995	2005	2020
Kathita	5,370	27,730	38,540
Mutonga	270	2,980	4,890
Ena	180	870	1,290
Total	7,815	33,585	46,740

[1] The timing of this phase of the Environmental Study has not allowed for the direct measurement of discharge from the coffee factories.

7.5 INDUSTRIAL DEVELOPMENT

There are no major industrial developments in the upper catchment[1]. All urban settlements have evolved as market centres servicing a rural farming population.

As a result the only industrial development that has occurred has been in processing agricultural products, coffee and tea factories, dairies and abattoirs, and saw mills processing timber from the Mount Kenya and Imenti forests, and in service industries.

Unless there is a specific subsidised programme to attract medium to heavy industry to the area, it is likely that the present pattern of urban commerce, trade and manufacturing will remain[2]. The district development plans propose to continue to promote the establishment of low level service industries (Jua Kali enterprises).

The main service industries include garages, workshops, carpentry enterprises, general stores and butcheries and bakeries and bars and hotels.

The conclusion is therefore, that the future urban populations will continue to support themselves through these small-scale enterprises, at lower levels of returns as competition expands with the growing population.

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[1] The development plan for Embu gives the following reasons for the lack of investment in medium and large scale manufacturing enterprises: closeness to the major manufacturing centres of Nairobi and Thika; and lack of demand for goods and services leading to little incentive for investment.

[2] The development plan for Tharaka Nithi states "...it is not expected that the industrial development pattern for Chuka Town will experience a major shift towards other types of industries in the near future except perhaps, in the informal small scale sector."

Figure 7-1 Irrigation Expansion by Sub-Basin: Projected to 2020

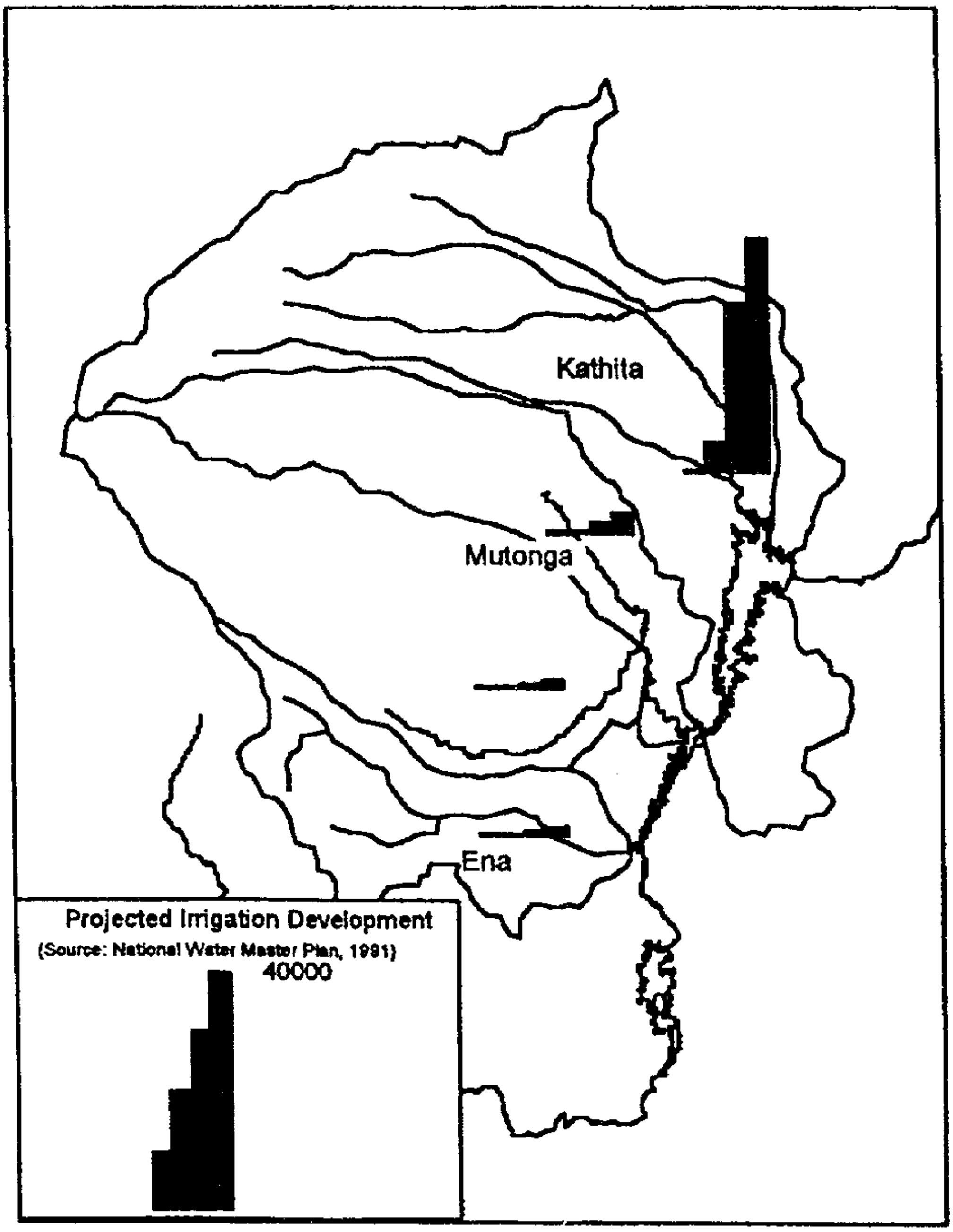
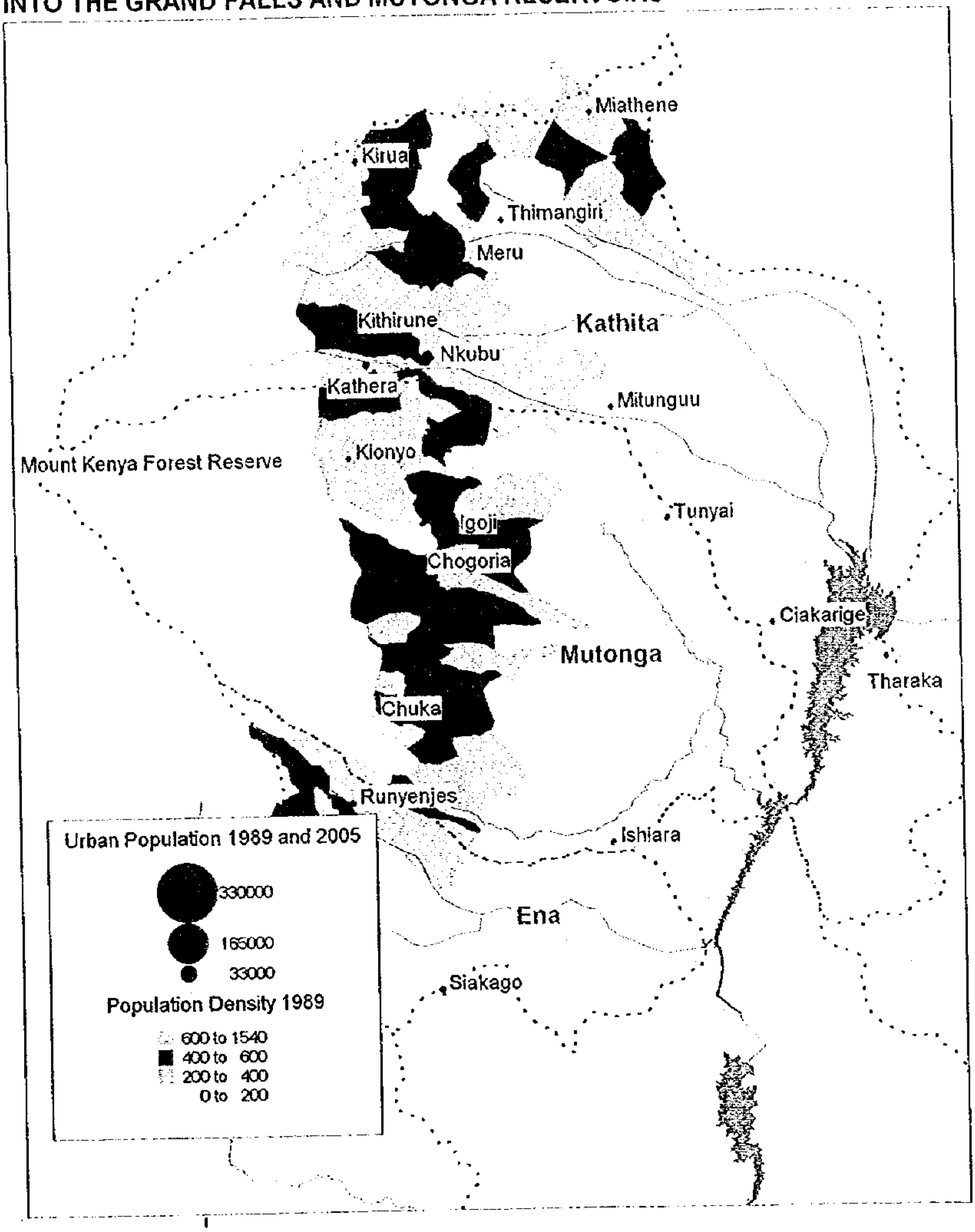


Figure 7-2

URBAN AND RURAL POPULATION
IN THE UPPER CATCHMENT FEEDING DIRECTLY
INTO THE GRAND FALLS AND MUTONGA RESERVOIRS



Chapter 8

HOUSEHOLD SURVEYS

8. HOUSEHOLD SURVEYS

8.1 INTRODUCTION

The objective of the household surveys was to provide information on the impact of the proposed Mutonga and Grand Falls hydropower projects on the residents of the areas likely to be affected. Residents affected include those living within the proposed reservoir area as well as those in the Special Management Zone and surrounding areas. The household survey complements other studies to provide a complete view of the project impact on the community and government. The information gathered is then intended to be used in the creation of various scenarios and mitigation measures.

Preparation for the household surveys involved development of the questionnaire and selection of sites to visit for interviews. The questionnaire to be used was developed, incorporating previous surveys, typical census formats and a review of project requirements as stated in the Terms of Reference. This was reviewed by experts on the projects team in light of each project study to be undertaken. Maps and databases were developed to support and manage this process.

The team to undertake and manage the actual enumeration and survey was recruited and assembled. The team was trained and tested the survey in the field before beginning the broad survey activity. A database for compiling and reporting the results of this survey was developed. These results are linked to the GIS application for map production, analysis and reporting. Requirements for analysis and outputs were identified in conjunction with the study team experts in each of the project tasks.

The interview process selected a representative sample from the study area population. Thirty villages within the reservoir zone were surveyed. Survey questions and field enumeration of structures, services, etc. were developed and reviewed. This process was designed to collect information to determine appropriate compensation and mitigation measures , enumeration for resettlement activities and capture the opinions and issues regarding the project in general.

8.2 METHODOLOGY

Collecting information on the population and infrastructure within the proposed reservoir, buffer and special management zones was a critical task. GIS and database tools were used to support theses activities. Information gathering and enumeration activities were co-ordinated to ensure complete information was collected without redundant interviewing. A standard interview and enumeration process was undertaken using enumeration staff from the area. This assured that the interviewers could communicate effectively with the sample group, perform the tasks more efficiently and in a more costs effective manner.

8.2.1 Survey Methodology

The survey covered 30 villages within the proposed reservoir area in three districts: Embu, Tharaka-Nithi and Mwingi. A sampling size of 10% within each village was used for selection of interview sites.

8.2.2 Village Selection

Village-level maps were prepared using GIS tools to indicate the location of villages with respect to the reservoir. These maps were then used to prepare a list of affected villages for the household survey exercise.

8.2.3 Selection of Households

Maps developed by JICA, from the 1:5,000 aerial photographs prepared during an earlier phase of the project, were digitised to indicate structures (and indirectly households) within the affected villages. Village level maps indicating the location of household clusters were produced to aid selection of households for the interview process. These maps were carried to the field by the interviewing teams.

8.2.4 Community Mobilisation

Meetings were held with local administrators to explain the importance of the project for the community and the country as a whole. These informal discussions were used in place of formal community meetings as earlier specified due to the importance of getting candid responses from the interviewees and the difficulty in arranging large public meetings.

8.2.5 Selection and Training of Interviewers

Local administrators assisted the survey team in the identification of interviewers. Interviewers underwent two day's training in basic interviewing techniques and the administration of the household questionnaires.

The questionnaire was used in the training exercise both to introduce interviewers to the correct techniques and to make modifications, where necessary, to the questionnaire. These results are not included in the reported findings.

During field-testing of the questionnaire it was discovered that some questions would not yield results that could be analysed easily. These were either modified or noted in such as way to be taken into account during analysis. For example, questions dealing with the use of land do not adequately account for multiple-use or multi-cropping and therefore might yield higher total acreage results.

8.3 SUMMARY OF SURVEY FINDINGS

The detailed results form the survey findings are attached in an annex. Key findings of the survey are highlighted below:

1. Most of those interviewed had heard of the project (98%). However, the idea of the project is clear to only about 10% of the interviewees with 44% stating that it was either Not Quite Clear, Not Clear or had Never Been Explained.
2. The project is acceptable to the majority (90%)
3. Major expected benefits of the project included, Irrigation (33%), Infrastructure (40%), and Employment (20%)
4. of households have members belonging to some self-help group. The main activities include savings/ credit, tree nurseries and soil conservation.
5. of families have been displaced by previous projects
6. The main reason for concern and lack of acceptance of the project is the fear that
7. Residents might lose land without receiving suitable replacement (35%).
8. Household Composition. 13% of the interviewed household members were heads of household. 12% were spouses. 59% identified as sons or daughters.
9. 30% of population is in school, while 30% are adults not in school
10. The main ethnic groups are Kamba (30%), Embu/Mbeere (52%), Tharaka (15%)
11. Religion is mainly Protestant (70%) and Catholic (30%)
12. The two week morbidity incidence is 30%. The main causes of morbidity include malaria which accounts for 40% of cases.
13. Most land is inherited (78%). 13% of households bought land.
14. Most land is individually owned (64%). 9% is communally owned.
15. 74% of respondents stated that their land (soil) is of high quality
16. Ox-plough and land implements are the most widely used farm implements (97%) for ploughing, sowing and weeding.
17. Produce is primarily transported by human labour (39%), by road (33%) and by animal of burden (26%)
18. Most families produce enough food for subsistence
19. Primary crops, based upon frequency of respondents growing, include millet (21%), sorghum (20%) , maize (19%) and green grams (14.5%)
20. Livestock, based upon frequency of responses, include poultry (22%), goats (20%), indigenous cattle (19%), sheep (15%) and bee hives (14.5%)
21. The majority of farmers use local seeds (82%) and rarely use fertiliser (19%)
22. Housing. 82% of houses are made of mud walls, 68% are grass roofed
23. Water. The main source of water is rivers (42% during the wet season and 68% during the dry season). Water is within 1 km for 24% of households and within 3 km for 50%.
24. Excreta Disposal. 83% of households use ordinary pit latrines.

8.4 COMMUNITY INVOLVEMENT

Although it was not possible to hold large public meetings, the field teams worked closely with local administrators to arrange and conduct smaller community meetings. These more informal meetings allowed a much freer flow of information and resulted in a broad knowledge of the project.

Maps of the reservoir area , including affected villages, were prepared for use during meetings with Provincial and District Commissioners. These maps highlighted the areas of villages to be flooded by the reservoirs as well as the general perimeter of the proposed three kilometre Special Management Zone around the reservoir.

Specific aspects of the project beneficial to the community were discussed, including improved infrastructure, employment opportunities and the possibility of developing irrigation schemes. The administration organised public meetings in which project objectives and potential benefits of the project to the community were explained. The project seems to be relatively well-understood and accepted by both the local leaders and the community at large.

8.5 HOUSEHOLD INTERVIEWS

Preparations for the interviews were completed. The questionnaire for the interview process was reviewed and modified for use in the field. The questionnaire includes questions regarding:

- Identification of the interviewee
- General Information about local knowledge and opinions of the project
- Demographic information
- On-farm income
- Information on land usage
- Livestock income
- Housing types
- Distances from local amenities
- Household income and expenditure
- Resettlement opinions

8.6 HOUSEHOLD ACTIVITIES AND INCOME

This information was gathered and entered into a database during the interviews. |At this time, interview questions concerning household activities and income were drafted, reviewed and added to the questionnaire. Data available form the 1989 census and previous studies was incorporated in the analysis.

8.7 PERCEIVED COMMUNITY PROBLEMS

Collection of this information was part of the interview process. At this time, interview questions concerning perceived community problems were drafted, reviewed and added to the questionnaire.

8.8 FUELWOOD AND OTHER NATURAL RESOURCE REQUIREMENTS

Interviews and information gathering concerning fuelwood and natural resource requirements were part of the household interview process. A review of existing studies concerning fuelwood was conducted. Part of the information gathered included use, source and prices of fuel in the area.

Firewood is used as the primary cooking fuel by 86% of respondents. The effect of the proposed reservoir on firewood supplies is therefore a critical issue for study. Kerosene is the light source used by 82% of respondents.

Chapter 9

LAND USE SURVEYS

9. LAND USE SURVEYS

9.1 INTRODUCTION

This component of the study looks at current land uses in: the proposed reservoir area; and areas adjacent to the proposed dams considered as special management zones. Land in this report is seen both as a dwelling place and a place where production processes take place. Land use survey is perceived as the processes of enumerating and analysing the uses made of the land and the factors that determine and influence these uses. The surveys further identify possible intervention measures by spelling out land use problems/constraints and opportunities available in the areas within and adjacent to the proposed dams.

The area lies within the three districts of Embu to the South, Tharaka-Nithi to the North and Mwingi to the East. The population of the proposed dam and special management areas is on the average comparatively lower than other parts of the districts. This is because the land is marginal for agriculture, mostly Agro-Ecological Zone 5 (See section 9.5).

In general, land use in the area can be termed as agro-pastoral, with crop production and livestock rearing contributing varying proportions for subsistence and income generation in the different areas and between different households. Important to note is that the two production modes are closely interconnected. Other land uses are: natural forests, both gazetted and non-gazetted, and other natural vegetation occupy a significant proportion of the total land area. Settlement (dwelling place) and infrastructure are other important land use attributes as they occupy land space but also influence production.

Major factors influencing land use include (a) physical factors such as: topography, soils and geology, climate and hydrology and (b) socio-economic cultural factors such as: human resources, human population, cultural inclinations, infrastructure and economic well-being or availability of capital.

The survey has relied heavily on existing secondary data/information. Only limited primary data collection has been undertaken for cross-checking the secondary information and 'ground truthing' information from satellite imagery.

This section is arranged in 5 Sections. Section 2 examines the methodology used in the study. Section 3 analyses land uses and farming systems, while Section 4 briefly touches on the existing rural economy. Finally, Section 5 looks at the carrying capacity of the area under consideration.

9.2 METHODOLOGY

The survey has relied heavily on secondary information i.e. previous studies, maps, GOK annual reports and other unpublished materials. It has also made use of formal and informal discussions with different subject matter specialists. Limited primary data collection in the form of field surveys has been undertaken to crosscheck and to enhance existing information. Use has been made of satellite imagery together with limited use of aerial photographs.

9.2.1 Literature Review and Secondary Data Collection

Literature reviewed included GOK sectoral Annual Reports. Of special interest are the Department of Agriculture, and Livestock Development and Marketing Annual Reports. The Farm Management Handbook of Kenya, volume II, Part C, East Kenya is particularly useful in providing information on carrying capacity and other biophysical information. The Dryland Applied Research Project (DAREP), Kenya Agricultural Research Institutes (KARI), have undertaken recent work on farming systems in Tharaka-Nithi and Embu districts[1]. This has provided useful baseline information and has helped in the analysis of the constraints and opportunities in the area. Various other reports and maps have been made use of to provide a picture of the land use practices in the dam area and its environs.

9.2.2 Field surveys

The field survey was undertaken between 18 and 23 November 1995. A 'quick reconnaissance' tour of the area was conducted, on the first day, this enabled the team of two, the Land Use Specialist and an Assistant to reflect on the best approach to use to maximise on information collection in view of the short time and the expanse of the area under consideration.

Sites for more detailed information collection were then identified. A checklist of important issues and corresponding information collection techniques were developed.

Three areas selected for detailed information were identified. Besides accessibility, the areas were seen as representative of the general area:

1. Kimandi, near Kathenge Primary School on the foothills of the Kiburu Hill, in Kamarandi Location, Ishiara Division;
2. A site 10 Km north of the Katama bridge, on the foothills of the Mumoni hills in Mwingi district;
3. Site 3 was at Katama ka Munanda, between the foot hills of the Kiajege hills to the Tana river.

Besides the above 3 sites, the team visited the three District Headquarters of Embu, Tharaka-Nithi and Meru. Mwingi district was not visited. Besides the above, the team also visited the KARI Regional Research Centre, Embu, for a discussion with the DAREP team.

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[1] Sutherland and Ouma, eds., 1995. Various reports

9.2.3 Sources of Information

Three major sources of information were identified i.e: field observations; Key informants (mainly government officers, and local opinion leaders), individual (farmers encountered in the farms or grazing), group discussions (groups including a few women).

For the key informants, individual farmers and groups, semi-structured interviews were used to solicit information. These interviews and field observation applied Participatory Rural Appraisal Techniques such as:

- Time Lines to collect historical information and to establish land use trends;
- Seasonal Calendars for information such as labour demand, food availability, farming activities, marketing of produce over a year.
- Farm Mapping to show; farm layout and farming system.
- Transects to show: relationships between land use, soils and topography in addition to estimating area under different land uses.
- Wealth Ranking to establish the economic status and the perceptions and aspirations of the farmers.
- Problem and Opportunity ranking for establishing the local people's perceived problems and ways of solving the problems.

9.2.4 TM Image Interpretation

An unsupervised digitally processed SPOT image was available and the recommended image. However, manual classification of a TM image covering the same area proved more useful for mapping land use and land cover. In addition, an aerial photo mosaic of the area further assisted in the delineation of the different land use/cover types. This interpretation was done in collaboration with the Ecologist. Limited ground truthing observation were undertaken during the field work phase.

9.3 LAND USE AND FARMING SYSTEM IN THE AREA IN AND ADJACENT TO THE RESERVOIR AREA

Before 1900, most of the area was not settled, it was used mainly for hunting by different ethnic groups including the Meru, Tharaka, Embu and Kamba. However around 1900, people started settling in the area for various reasons. Settlers came from three ethnic groups. The earliest people to settle in the area came from Meru. A section of this group settled in the present day Tharaka, while the other section continued into the lower part of Embu in Mbeere area. This group was interested mainly in farming land. The second group came from Kitui, they were predominantly pastoralists in search of grazing land. Some settled on the East bank of the river while others crossed the river to settle on the Mbeere and Tharaka areas. The third group, mainly crop cultivators came from lower Muranga area to settle in lower Embu.

From the initial hunting and gathering, today most of the inhabitants of the area practice a form of shifting agro-pastoral land use system, which varies from a dominance in crop production in the more favourable crop production areas to a more dominant pastoral economy in the more marginal lowland areas. Very few families practice any one form of land use exclusively.

In the area under consideration within Mwingi and Tharaka-Nithi Districts, land is under a Trust Land tenure i.e. held under trust by the local councils for the area residents, while most of Embu is under free hold titles. Under the Trust land arrangement, access to and use of land (use rights) are governed under traditional clan arrangement. Access to land is based on membership to a clan. The process of adjudication has been initiated in most of these areas, with informal adjudication, i.e. with family clear boundaries demarcating family lands. This tenure arrangement has significant impact on land use e.g. access to grazing, inheritance, investment into land rehabilitation and conservation measures, settlement etc.

The area has a low population density compared to other higher potential areas of the Districts. With an estimated population increase of 3.9% there has been a marked pressure on land resulting in a more permanent type of farming system, increasing pressure on grazing land and, as a consequence, overgrazing and land degradation.

9.3.1 Land cover/land use units

Seven main land cover / land use units were identifiable in the area as follows:

I	Moist Forest	Covers the hilltops of the main hills in the area, i.e. Mumoni and Kiajege. The major use in this cover type is honey gathering and grazing in extremely dry years. The areas under this cover type also play an important function as water catchment area.
II	Dry Forest / Dense Wooded Bushland	Covers the hillslopes of most of the hills found in the area. It is used primarily for dry season grazing and honey gathering. Other uses are indicated in Table 9-7.
III IV V	Heavily Cultivated Bushland Moderate Cultivated Bushland Partially/Minimally Cultivated Bushland	These three categories of cultivation occupy most of the arable land in the area. They form a patchwork of cropland and fallow vegetation at various stages of secondary vegetation i.e. grassland, bush and bush thickets. These cover classes are used as both agricultural and pasture land.
VI	Dense Bushland/Bush thickets	Mainly at the foothills of the hills and other high grounds. Used for extensive grazing. It is particularly suitable for browsers e.g. goats.

VII	Riverine Vegetation	Covers a narrow strip along the main river course. Uses include protection of the river banks. It is also important as a source of palm fronds for weaving and a habitat for wildlife especially primates.

9.3.2 Livestock Production

Livestock production in the dam and surrounding areas is both a way and a means of life. Livestock keeping is deeply embedded in the social, cultural and economic fabric of the local residents. Hence, livestock has implicit social cultural values e.g. social status and prestige, over and above economic values. It is pertinent to recognise and acknowledge this values while considering the social impacts of the proposed developments.

Interviews on the history of the residents indicate that, most of the local residents were traditionally hunter gatherers, then pastoralists and the trend is towards a dominance of crop production in most of the areas. However, when interviewed on preference, most indicated livestock as the most preferred form of land use.

Suitability

Given the bio-physical conditions of the area i.e.; low and bimodal rainfall, high temperature, high evapotranspition, limited plan growing days, and poor moisture holding capacity of most of the soils, and bushland dominated plant vegetation structure, low input traditional pastoralism is the most suitable form of use in most of the areas, except for the few higher potential, high altitude areas (AEZ 3-4). Livestock carrying capacity ranges from about 0.3 ha/Livestock Unit (LU) in the upper midlands, to over 3 ha/LU in the lowland (See section 9.5 for more details).

The most suitable cattle types are traditional cattle zebu and sometimes cross-bred with the boran, predominantly for beef. Goats of various breeds are particularly suited to the lowland *Acacia-Commiphora* bushland. The area has a moderate to high potential for bee-keeping.

Range condition and trends

From historical profiles/insights derived from interviews, there has been a continuous trend of bush encroachment from grassland and bush grasslands to more predominant bush cover over the years. This increase in bush cover and bush species has been particularly evident in the last couple of decades due to increasing human and livestock populations. Bush encroachment has also been coupled with an increasing intensity in soil erosion. Sever degradation of the range was observed throughout the study area during the field work.[1]

Livestock types and preference

Almost all families keep different types of livestock, for different uses. Cattle and goats are kept in significant numbers by over 90% of the families in the area. Only a few young families claim no cattle or goats. The herd size in the Katama Ka Munanda area is shown in the Table 9-2 bellow. A small number of farmers in the area had herds of over 70 cattle whilst the average herd size was estimated at 20 per household.

The importance of honey is increasing. However most families have only a few bee-hives. A few individuals have large numbers of bee-hives scattered in various places including the nearby Kiajege hills.

Livestock numbers (ownership, herd size and composition)

From the above table, goats and cattle are seen as the main types of livestock. Their demography is dominated by calve/kids, followed by female breeding stock (cow/does) and only a few mature bulls.

Table 9-1 Livestock Species and Their Relative Importance to the Farmers

Type	Rank	Breed	Preference
Cattle	1	Boran, Zebu	Boran
Goats	2	Galla, Small East African	Galla
Donkey	3	Local	n/a
Bees	4	African honey bee	n/a
Sheep	5	Fat tailed	n/a
Poultry	6	Local	n/a

Trends over time

In general, there is an increase in the total number of livestock and their diversity in terms of breeds and types. It was however noted from the various interviews that, the average herd per family is decreasing. The following trends were mentioned by the Divisional Extension Livestock Officer, Chiakariga:

[1] The Divisional Livestock Extension Officer notes the need for range rehabilitation. (Tharaka South and North. Department of Livestock Development and Marketing).

Cattle:	herd size decreasing; total numbers increasing;
Goats:	herd size increasing; total numbers increasing;
Donkeys:	herd size no difference; popularity increasing;
Bee-hives:	holding, increasing; total numbers increasing;
Poultry:	holding increasing; total numbers increasing
Sheep:	herd size decreasing, total numbers decreasing.

Table 9-2 Herd Size Estimate (Katama Ka Munanda area)

Type	% Households keeping Livestock	Range	Average
Cattle	Over 90	0-75	20
Goats	Over 90	0-100	30
Sheep	50	0-40	10
Donkey	40	0-5	2
Poultry	Over 90	0-20	8
Bee-hives	30	0-50	20

Grazing patterns and pasture/fodder use

Spatial distribution of cattle is based on land ownership, water resources and season. In time of adequate pasture, there is no much movement of livestock. Grazing is mainly within the clan and family lands. However in times of scarce pasture resources i.e. at the end of the dry season (July-September and January-March), there is significant movement of cattle and shoats, especially into the forest reserves in the hills.

An important feature is the use of crop stovers after harvests of major cereals such as sorghum, maize and the various pulses. Except for the stovers, few farmers supplement their stock with other feeds. Slash and burning during cultivation facilitates bush clearing. The best pastures encountered were fields left fallow for about 2-3 years.

Main livestock related activities

One of the reasons why livestock is preferred over crop cultivation is because of its low labour requirements. Table 9-3 lists the main livestock related activities, by month and gender

Table 9-3 Livestock Related Activities

Activity	Time Preiod	Gender
Grazing	All year	MC/M
Milking	Daily	W/FC/MC
Marketing	Jan-March, Aug.	M
Deworming	April-May, Nov-Dec	M/W
Disease control	April-May, Nov-Dec	M
Watering	Daily	MC/FC
Calving, Kidding, Lambing	April-May, Nov-Dec	M/MC
Honey harvesting	Feb-March, June-July	M

M Male; W Woman; MC Male Child; FC Female Child

Note that most livestock activities are male dominated.

Inputs (availability, cost and application)

All the individuals and groups interviewed mentioned inputs availability, especially veterinary drugs as a major constraints. Inputs are only available at divisional headquarters such as Ishiara and Chiakariga. Others such as improved bee-hives are not available locally and can only be purchased in Meru or Embu. Because of this lack of adequate supply, such inputs are comparatively expensive. The respective veterinary departments assist in the distribution and sale of veterinary drugs during the main market centres. Application is hindered by technical advice as extension personnel from the divisions are not always accessible.

Disease and routine management practices

Table 9-4 indicates most common livestock diseases by livestock type

Table 9-4 Livestock Diseases By Species

Livestock Species	Common Diseases
Cattle	ECF, Anaplasmosis, Heart water, Pneumonia, Helminthiasis
Goats	Mange, Pneumonia, Heart water, Helminthiasis, Foot rot, Dysentry
Sheep	Enterotoxaemia, Helminthiasis, Lamp Dysentry, Scabies
Poultry	Newcastle, Fowl Pox, Fowl Typhoid, Coccidiosis, Infections Coryza

Source: Divisional Livestock Expansion Officer, Chiakariga

Control of these diseases is mainly by chemical applications i.e. spraying, hand dressing and vaccination. Stock movement also reduce incidents of infection.

Improvements

Other forms of management include stock improvement of breeds by for instance through use of better bulls. Exchange of bulls is a common practice in the area. Other forms of improvement are, castration to enhance beef production, and in some cases on-farm growing of fodder species such as napier grass. Use of draft animals for transport and ploughing is increasing. As indicated above, access to improved forms of management technologies and know-how is limited to farmers close to the main trading centres.

Products and by-products

Table 9-5 give an indication of livestock products and by-products production levels in two divisions of Tharaka-Nithi.

Table 9-5 Estimate of Sales of Livestock Products and By-Products in Tharaka North and South.

Product Type	Tharaka North	Tharaka South
Cattle	17,000	7,000
Goats	20,000	21,000
Sheep	5,000	4,700
Chicken	19,000	40,000
Milk (ltrs)	10,000	198,000
Meat (kgs)	77,700	139,000
Offals (kgs)	29,400	54,000
Eggs	48,000	100,000
Honey (kgs)	37,000	35,000
Bees-wax	5,000	4,000
Hides	8,300	9,400
Skins	21,000	31,000

Source: Divisional Livestock Extension Officer, Chiakariga, 1994.

Marketing

Cattle and shoats find their outlet through the main market centres in the area. Marketing of poultry is more local, while honey, which has a very high demand, and bees-wax is sold locally and in the main markets through a series of middlemen.

Market prices are erratic. Cattle prices ranged from Ksh 2,500 to 15,000, goats from Ksh 350 to 1400, sheep from Ksh 275 to 1000 and chicken from Ksh 50 to 200, in 1994. Prevailing honey prices range from Ksh 100/kg to 150/kg.

Market information is poor. this contributes to poor prices and speculation of livestock and their products.

Institutions and institutional support

There is no organised livestock cooperative. Most of the support to the sector is from the relevant government department i.e. the National Extension Program II (NEP II), National Poultry Development Program (NPDP), National Dairy Development Program (NDDP), and goats and Sheep Project (GASP) in Marimanti. NGOs support is minimal and mainly concentrate on training and extension work.

Major constraints

Livestock mortality was ranked first by the farmers. Disease management is rudimentary due to lack of technical support and poor veterinary supplies. There are possibilities of improvements in the supply and costs of drugs and improved extension services.

Low levels of production, a result of low technological levels, lack of awareness, and climatic factors is recognised as key constraint by the farmers. Farmers strategies has included, improvement of breeds, diversification into off-farm income generating activities, moderate pasture improvements etc.

Livestock prices in the area are comparatively lower when compared to the high potential areas. This is mainly due to the low purchasing power and poor marketing infrastructure. Exploitation by middlemen is acknowledged but unavoidable due to the above problems. Infrastructure development and marketing information could greatly improve the market prices of key livestock types and livestock products.

In areas neighbouring Isiolo and Garrisa, cattle rustling was identified as a serious constraint/problem to production. The problem is especially acute in some parts of Mwingi and Tharaka North.

Other problems mentioned include: long distances to watering points, lack of dips, lack of support leading to poor awareness, poor range condition, availability of grazing lands and insecurity of tenure, unavailability of inputs, and limited numbers of draft animals. A few farmers mentioned labour and credit as being of concern.

Impact of the proposed dam

The proposed dam is seen as a major risk, and more so to the livestock economy. Some major grazing areas will be inundated. Most of the pastoral farmers have as yet not started appreciating the significance of this or if they have they are not willing to accept it. Attitudes towards the dam seem to be divided according to age categories with the elders indicating fear and uncertainty and hence rejection while the younger people, especially men, are anticipating new opportunities.

9.3.3 Agriculture

There are two main forms of agricultural systems in the area: Shifting cultivation, with slash and burn as the main form of bush clearing. The shifting from one area to another for clearing and the fallow duration and length of stay in a specific site is determined by the availability of family and clan land. As mentioned earlier, the trend is towards shorter fallow periods, and longer use of farmed land. This system is common in the lower parts of Tharaka-Nithi and Mwingi.

In Embu district, where land is held under 'freehold title', and in the more suitable areas with adequate soil moisture i.e. in the hills and along the riverine areas a more permanent form of agriculture is practised.

Agricultural suitability/potential

Most of the area is of marginal agricultural potential with main crops being early maturing dryland crops such as bulrush millet. Cotton is grown in specific suitable area. Section 9.5 discusses in more detail the carrying capacity of the various crop production zones in the area.

Farming systems

Suitable agricultural land is scarce as soils are not suitable in most of the erosional plains which occupy a major proportion of the area, while the terrain in the hills and scarps landscape is in most cases to steep and ragged for agricultural production. In addition, labour is a major constraint in opening large areas for crop production.

Agricultural plots range in size from 0.5 to 5 acres. From a transect in a characteristic area in Tharaka South, it was estimated that only about 30% of the land was under cultivation at any one given time. The rest was under farrow or was unsuitable for cultivation. While clearing, large trees a left on the farm. These have several values including providing feed/fodder for livestock i.e., Acacia tortilis, shade, firewood and other products.

The farms are used for 3-4 seasons before abandoning to fallow due to the poor soil fertility. Tillage methods are traditional and basic. Occasional, draft animals are used for ploughing on suitable fields.

In the Tharaka people have a preference for cultivating in moderately steep hillslopes. Interviewed farmers mentioned that soils in the area are more fertile on the hillslopes and output was higher on such areas. Soil erosion measures to reduce erosion include, trash lines where after harvest crop remains and cleared bush materials are arranged in lines along contour; contour tillage/ploughing and terracing using stones and boulders.

Cropping calendar/activity pattern

There are two main rain season with the October-December rains being higher and more reliable as compared to the April-June rains. The main crops include some key cereals such as: sorghum, considered as the most important food crop in the area; millet and maize, mainly Katumani. Other important crops include cow peas, pigeon peas and green grams which are used for both subsistence and for sale. Early maturing ground nuts are also grown in light soils. Other crops include a variety of vegetable, tuber crops such as cassava and sweet potatoes, pumpkin, and bananas. Cotton is an important cash crop.

Table 9-6 Seasonal Cropping Trends.

April rains	millet, greengrams, sorghum, cowpeas. Cotton spraying and harvesting, pigeon peas harvesting.
October-November rains	millet, sorghum, maize, cowpeas, greengrams, pigeon peas and cotton planting.

Major farming activities are listed below. Table 9-7 indicates the activity calendar for various crops found in the area, and hence demand for labour.

a) September is mainly a period of clearing and farm preparation awaiting the long rains. It is a low labour demand period.

b) October through to December rains mark busiest time of the year. Planting of the majority of crops is in October and November. Weeding starts in late November and proceeds on to December. Bird scaring for the early maturing cereals i.e. sorghum and millet also takes place in December. Other activities include harvesting of sweet potatoes and cassava, and spraying of cotton.

c) Bird scaring proceeds on into January, while harvesting of most of the pulses i.e. cow peas, beans and green grams start and continue to February. Harvesting of Maize and sorghum also takes place in February. This is a period of moderate farm activities and labour demands.

d) In March start land preparation i.e. ploughing , clearing and burning in readiness for the March to June (Nthano) rains. There is also limited planting and harvesting. This is also the marketing period for most of the farm produce.

e) April to June is another busy period with most crops being planted and weeding following subsequently in mid April and May. In May weeding is accompanied by bird scaring. June is the month of bird scaring and harvesting of the early maturing crops. Harvesting continues to July.

f) July and August is a period of very low on-farm activities and low labour requirements. This period is also used for marketing of farm produce.

Food supplies

Supply of food follows the cropping calendar closely, with severe shortages during the planting, weeding and bird scaring periods of October-December and April-June.

Farming methods (including technology, awareness and availability of technical assistance)

Farmers in the area use basic farm implements. The hand hoe is the most common implement. Draught animals are used for ploughing and planting in more favourable terrain and soil types. Most of the other farming activities are by hand eg. planting, weeding, bush clearing, harvesting and threshing. Draught animals are used for transport of crop produce.

Major farm inputs include: seeds, pesticides, ploughs and hired labour. Fertiliser is rarely used, while only limited use is made of manure. During periods of high labour demand, labour is scarce and expensive. Many poor residents leave their farm activities to provide paid labour to their neighbours.

To alleviate the labour shortage, farmers especially women work in communal groups on a rotational basis. See Table 9-8 for labour calendar.

Table 9-7 Crop Activities Calendar In Lower Midlands And Lowland Zones

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
cow peas	H	H	P	PW	WS	SH				P	W	W
beans	H	H		PW	WS	SH				P	PW	W
G/grams	H	H		PW	WS	S	H			P	PW	W
ground nuts										P	P	
millet		H	PH	PW	WB	B				P	PW	W
	B			PW	W	H				P	PW	WB
maize	B	H	H	PW	W					P	P	B
sorghum	B	H		PW	W		H			P	PW	WB
bananas			PH	PW	W		H			P	W	W
vegetables												
pumpkins			H						H	P	PW	W
arrow-roots	A	A	A	A	A	A	A	A	A	A	A	A
sweet potato					H	H	H			P	PW	W
cassava							H			P	PW	WH
P/peas					SB	SB		H	H	P	PW	W
cotton		H	H							P	PW	WSB

H - harvesting, B - bird scaring, P - planting, W - weeding, S - spraying and pest control

Farm inputs (availability and cost)

As in the case of livestock, access to farm inputs, especially seeds and agrochemicals is a major constraint due to distances to the markets, the costs and lack of finances/credit. Inputs are also comparatively expensive especially in areas far away from the main trading centres.

External assistance

Little if any assistance or advice is sought from outside. Only influential farmers have access to extension services and other advisory services. National Extension Program (NEP II), an initiative of GOK and World Bank has provided limited assistance in some areas. Church organisations have also provided some assistance especially near the market centres. Other NGOs operating in the area include World Vision and the Christian Children's Fund.

Markets and marketing

Most of the produce is sold on the local market centres. This like livestock are constrained by poor infrastructure, lack of marketing institutions, and lack of market information. Cereals board sometimes buy cereals produce, but it is not reliable. Cotton was formerly bought by the Cotton Lint and Seed Marketing Board which is no longer active in the area, resulting to a slump in the cotton prices and the subsequent decrease of production. Organised marketing of produce will assist greatly in ensuring better prices for the farmers. This might be activated by improvement of infrastructure with the proposed dam developments.

Major constraints, opportunities and risks

a) The problem ranked first in the area is the low and unreliable rains. This coupled with poor soils which have a low fertility level, poor water holding capacity, poor soil and water conservation, and high evapotranspiration result in unreliable harvests.

   Major opportunities include improved technologies for soil and water conservation, and the planting of appropriate varieties suitable to the soils and climatic conditions. there is room for awareness creation.

   A major risk from the proposed development could be increased intensity in the use of hillslopes due to land pressure with the resultant increased in soil erosion and degradation.

b) Insects and crop diseases contribute significant losses. this is a result of lack of technological options such as agrochemicals, lack of awareness of farm management practices that reduce infestation.

Opportunities include, developing a regime of shifting cultivation that enhances reduced pests, crop rotation, and other suitable farm management practices such as using proper salified seeds.

With expected improvements in communications, availability of inputs and technical advice will be more available.

c) Lack of security of land tenure in most of the areas (non-adjudicated) results in limited farm developments such as construction of physical structures for soil conservation.

With adjudication, this problem will be resolved. However, there is need for intensive extension services to change attitudes.

d) Lack of labour with the resultant poor farm management, results to serious losses from weeds, late harvesting and lack of proper post harvest treatment.

The problem will continue to intensify, especially with increased employment opportunities with the proposed developments.

Table 9-8 Labour Calendar Gatunga Area

Activity	Nthano Rains						Muratho Rains						
clearing & burning				a	a	a			a				
ploughing				m	m				m	m			
planting	a	a	a					w c	w c	w c			w c
weeding		a	a						a	a			
bird scaring				a	a					a	a		
harvesting					a	a	a	a				a	a
livestock dealing	m w	m w	m w				m w	m w	m w	m w		m w	m w
marketing crops	m w	-	-	-	-	-	-	-	-	-	-	-	-
herding livestock	c	-	-	-	-	-	-	-	-	-	-	-	-
honey harvesting	m	m	m	m					m	m			
making & placing hives					m	m							

T Throughout the year; m Men; W Women

Source: Sutherland and Ouma, 1995 (a)

Table 9-9 Average output estimates of major crops in Gatunga area

Food Crop	Varieties	Yields Oct-Nov Rains (90 kg Bag)
millet	kiraka, githaraka, mugui	6-10 bags/acre
greengrams	local kimeru, mugachi, N26	4-7 bags/acre
sorghum	mugeta (white), maguaki (agr) kaguru, mucharama, red variety, muchiri	12-20 bags/acre
cowpeas	gacoki (red type), local	4-7 bags acre
maize	katumani, kimeru	2-5 bags/acre
pigeon peas	two season types (unknown)	-

Source: Sutherland and Ouma, 1995 (a)

9.3.4 Other land uses

Forests

There are several indigenous forest in the area adjacent to the dam area (special management zone). Six of the forest are gazetted as forest reserves under the Forest Department. these are Mumoni forest in Mwingi, Kikangoi and Mutejwa forest in Gatunga and Gatue respectively, Ntugi in Kanyuru, Kiajege in Chiakariga, and Kierera forest in Kamarandi.

This forests have importance not only for their functional role as water catchment areas, but also as sources of a number of forest products such as medicinal plants, firewood, timber, building materials, honey, and wild fruits, besides providing dry season grazing.

Besides these main forests, other smaller indigenous bushed dry forest and bush thicket vegetation, mostly on hills in the environs of the dam area play a crucial role as dry season grazing areas, and for honey collection. Table 11 shows the uses made of both forest and other vegetation resource.

Major problems in the management of these forests and other tree resources include:

a) Frequent fires caused mostly by honey hunters while in the processes of harvesting honey.

b) Encroachment is imminent especially with increasing pressure on land for farming.

The development of the proposed dam will increase pressure on these forests.

Table 9-10 **Use Of Tree Resources And Relative Importance**

Sale Of Tree Products	Relative Importance
baskets	***
fibres	***
gums	*
fruits	**
chairs/tables	***
leaves from doum palm	***
poles	***
timber	**
carving (bows, hives)	

Source: Sutherland and Ouma, 1995 (a)

9.3.5 Systems interactions

Agriculture and livestock

As noted above the two land use system are closely inter-linked and operate as one system i.e. agro-pastoral. Both complement each other in generating income and providing for subsistence, with the relative importance of each varying with area (land potential) and individual interests and capability. In the drier areas, livestock keeping is dominant while in the more higher potential areas, agriculture plays a more significant role.

Both the systems compete for land. The general trend is the reduction in pasture land at the expense of crop land. the two also compete for labour.

It is likely that livestock keeping will suffer most with the proposed developments.

Livestock/Forest

Forests act as a source of pasture for livestock especially the dry season. They are also rich sources of honey.

Frequently, forests are damaged while grazing or collecting honey. Overgrazing is also resulting to change in species composition of the natural vegetation in the lower hillslopes.

Agriculture/forest

Agricultural expansion, as is anticipated with the proposed development could mean encroachment into both gazetted and other forests.

Forest/Settlement

Forests provide building materials for shelter. However increased demand of these resources could result to forest and tree resources degradation

9.4 EXISTING RURAL ECONOMY

The predominant economy in the area is based on livestock keeping and agriculture. Assets considered of value are land (size and potential) and livestock. Land being the more valued asset and playing a significant role in the determination of the socio-economic status and wealth ranking of the people.

Crop production is considered as important in providing for subsistence. It also provides significant income for most of the families living in the area. There is potential for its improvement with the development of the area.

More details on: on-farm income; off-farm income; assets and Investments; household income and expenditures; impacts of markets and other infrastructures on the local economy will be further analysed with the results of the field surveys of the socio-economic team.

9.5 CARRYING CAPACITY AND CONSTRAINTS

Carrying Capacity is an indicator of the ability of a given area of land to sustain a given form of use or a multiple of uses at a given level or degree of use. In the case of livestock and crop production, the carrying capacity is determined mainly by biophysical parameters such as: the landscape or topography, soils, climate and hydrology. Socio-economic and cultural variables such as the level of technology, infrastructure, preferred land uses may influence how much the potential of the land is exploited.

Given the complexity of the above variables in space and time, carrying capacity should only be seen as indicator of land potential which is normally derived from looking at the biophysical attributes of the land.

9.5.1 Biophysical set-up

Landscapes

The area lies to the east of Mount Kenya, an has three determinable landscape units i.e.: (a) hills and scarps; (b) Hilly to undulating erosional plains; and (c) alluvial bottom lands.

(a) The hills and scarps are a prominent landscape in the area. These hills are consist mainly of granatoid gneisses remnant from the easier to weather banded gneisses.[1] Significant hills include: the Mumoni Hills (5731 feet

[1] Republic of Kenya, 1978. pp 2:3

asl) and Kiajege hills (4781 feet asl). These and other hill form important wet season grazing lands among other uses and has a strong influence on land uses in the other landscapes.

(b) Hilly to undulating erosional plains occupy the biggest proportion of the area. The landscape is a peneplain made up of mainly basement system.[1] Rock outcrops are a common feature in this landscape.

(c) Alluvial bottom lands which are flat to gently sloping, form a narrow strip along parts of the Tana river and other main rivers.

Climate

The climate of the area especially rainfall, air temperatures and evapotranspiration vary with altitude. Generally, rainfall decreases eastwards as one goes away from Mount Kenya.

The isolated hills are cooler and receive higher precipitation (an annual average of over 750) with some of the hills e.g. the Mumoni receiving over 800 mm. Sometimes some of the hills receive annual rainfall of over 1000 mm (See Map 1. Average Annual Rainfall).[2]

Most of the other area is semi-arid (Agro-ecological AEZ 5), with an average annual rainfall of less than 750. Rainfall is bimodal with an erratic short season (mid March to June) and a more reliable season (October to December). The area also experience high air temperatures. With low rainfall and high temperatures the area experience high potential evapo-transpiration and hence fewer plant growing days. Moisture supply for plant growth is estimated at 24-40 percent of the annual potential evapo-transpiration in this region.

Vegetation

Vegetation is a result of all the above attributes i.e. topography, soils and climate. In general terms the vegetation cover ranges from grass bushland to bush thickets, dominated by Commiphora and Acacia species, through dry forest on the lower and middle slopes of the hills to moist forest on the upper slopes and hill tops. A narrow belt of tall lowland riverine forest line the river bank. Ficus sycomorous and Phoenix species are conspicuous in this vegetation community (See Chapter 12, Natural Resources for more details).

Soils

Soils of the area correspond closely to the landscapes. Eight major soil types can be identified[3] as follows.

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1 ibid

2 Maps prepared by Thunder and Associates.

3 As per Jaetzold and Schmidt (eds), 1983. Reconnaissance Soil Survey map of the area by the Ministry of Agriculture, 1978, identified 5 major soil types.

Class[1]	Description
Soils of the Hills and Scarps	These are soils developed predominately on gneisses. In most cases these soils are moderate to high in fertility.
26H	Sandy clay loams which are somewhat excessively drained, shallow, reddish brown, friable, rocky or stony. This soil type is characteristic of the soils on the hills between Gatunga and Kalangachini in Tharaka North division, and the Mumoni hills in Mwingi.
27Hx,m-h	A complex of shallow dark red to brown, friable, sandy clay loams which are excessively drained to well drained; rocky, bouldery and stony in many places; with acid humic top soil. This are common on the hills north of Thuchi river around Chiakariga area including Kiajege hills.
96F	Coarse loamy sand to sandy clay loam, well drained, very deep, yellowish red to dark reddish brown. This soils are to be found on most of the foothills, for instance on the foothills of Mumoni and Kiajege hills.
Soils of the erosional plains	This soil type is developed on undifferentiated basement system.
255 PdA	complex of well drained, shallow to moderately deep, dark red to yellowish brown, stony to sandy clay loams over petrocalcic material or quartz gravel. This are the dominant soils of the area.
Soils of the alluvial bottom lands	
255 Pd	Also dominant in the bottom lands, but with higher proportions of alluvial silts.

H Hills; P Plains; U Uplands

h heavy soils; m medium soils; x stony of bouldery soils; m-h medium to heavy; x,m medium and heavy.

AEZ and Carrying Capacity

As mentioned above the concept of Carrying Capacity attempts to indicate the production potential of a given piece of land. This is determined by the biophysical parameters mentioned above. Agro-ecological Zones (AEZ) are used to delineate land according to its production potential for agricultural purposes (See Map 3. Agro-Ecological zones).

1 Classification by Jaetzold and Schmidt, 1983, adopted from Kenya Soil Survey, 1982, Exploratory Soil Map and Agro-climatic map of Kenya, Scale 1:1,000,000.

Most of the area is within Agro-ecological Zone 5, i.e. semi-arid.[Suprscpt]1 By using topography i.e. altitude and agricultural potential in their classification, Jaetzold and Schmidt, 1983 further refine the classification into 4 zones i.e.:

UM4 Upper Midland (Sunflower - Maize Zone)

This zone has two short cropping period and together with Zone LM4 occupies the Mumoni hills.

Carrying Capacity: crop production Good yield potential For dryland maize varieties early maturing millets, sorghum, and beans; and dwarf sunflower in the first rains (March-June). For the second rains, the same is applicable with an addition of dolichos and sisal. Fair yield potential Can be expected of other crops such as sweet potatoes, tomatoes, pigeon peas, papaws, pineapples, citrus and castor. Carrying Capacity: Livestock Between 0.28 ha/Livestock Units in areas of good forage to 2 ha/Livestock Unit in areas of poor forage. Other Potential While this is the potential given the agro-ecological zone, the area under this zone is actually a gazetted forest and therefor only used for dry season grazing. It is however important for timber and other shelter construction products. It is also useful for honey production and other forest produce such as wild fruits and medicinal products besides being useful as a water catchment. The area is also rich in biodiversity.

LM4 Lower Midland Zone (Marginal Cotton Zone)

This zone covers the lower slopes of the Mumoni hills and the Kiajege hills and surrounding areas. the zone experience two short to very short cropping periods.

Carrying Capacity: crop production Very good potential For dryland maize varieties in the first planting season starting in March and millets, and early maturing dwarf sunflower in the second planting season starting in

[Suprscpt]1 Sutherland and Ouma, 1995.

October.

Good yield potential

For the above plus early maturing sorghum in the first rains, and early maturing onions, beans, groundnuts and chick peas.

Fair yields

For Katumani maize, early maturing sorghum, beans, green grams, soya beans, dolichos, barbarra groundnuts and sweet potatoes in the first rains. The same for second rains.

Carrying Capacity: Livestock

3 ha/Livestock unit in unimproved mixed grass savanna which can be increased to 1.2 ha/Livestock Unit with the use of crop residues and improved pastures and fodder.

Other potential

Like UM 4 above, the area is used as dry season grazing especially the upper slopes. It is also important as a source of forest products including honey, medicinal herbs, timber and other building materials, besides a rich biodiversity especially in the gazetted forest areas. Its function as a catchment is well appreciated by the local people.

II.5 Lowland (Livestock-Millet Zone)

The zone covers most of the erosional plain and the biggest proportion of the area, especially in Tharaka-Nithi district. It experiences two very short to short growing seasons.

Carrying Capacity: crop production

Good yield potential

for very early maturing millets, moth beans, and sunflower for both growing seasons.

Fair yield potential

For very early maturing dwarf sorghum, bulrush millet, black and green grams, cowpeas and chickpeas and very early maturing pumpkin, onions and castor.

Poor yields

For dryland maize including Katumani.

Carrying Capacity: Livestock Production

More than 3 ha/Livestock unit on mixed short grass savannah. carrying capacity can be increased to 0.6 ha/Livestock unit with added feed from crop residues such as fodder sorghum in dry season.

Other potential

Mixed shift cultivation of crops and livestock keeping is the most common farming system in the areas covered by this zone. This maximises on good cultivable soils while using the poor soils and steep slopes unsuitable for cultivation to pasture. Stovers are used as fodder during the dry season. Where water is available, bee-production has reasonable output even with unimproved traditional hives and minimal management. Poultry production has a high potential due to the favourable weather.

Table 9-11 Transect: Tana River to Katama Ka Munanada

Tana River	Farm 50m Gently sloping	Fallow 200m Gently sloping	Fallow 50m Undulating	Fallow 200m Undulating	Fallow 200m Gentrly sloping	Fallow 200m Steeper 7% slope	Farm 50m Steeper 7% slope	Fallow 1000m Steeper 7%slope	Fallow 60m Depression	Farm 100m Gentrly sloping	Farm Housing 100m Steeply sloping
Soils	Dart brown to brownish red, deep, easy to work, alluvial sandy soils	Well drained brown to light brown sandy silts	Well drained easy to work, light reddish brown silt sands. Signs of erosion	Same but more stoney	More stoney	Shallow reddish brown, with boulders.	Brown to light brown friable with a top crust, silt sand. Poor and degraded	Well drained, reddish brown sandy silt with a good humus layer.	Dark brown sandy silt with moderate erosion	Well drained light brown sandy silts with a crust and hard surface	Excessivly well drained light brown silty sand, with a hard top crust. Shallow highly stony, bouldery hard top crust.
Vegetation	Riverine Ficus, Delonix, Adonsonia, Phoenix sp. A variety of forbs where not under cultivation	Shrub grassland A. tortilis, Combretum dominant trees. Eragrostis dominant grass	Cleared for agriculture Phoenix. sp.	Combretum A. tortilis with a good layer of Aristida keiensis & other forbs.	Bush thicket, Commiphora africana dominant woody species with Duosperma & A. tortilis	Bush thicket Commiphora & Acacia dominant, with Balanitis & Lemea sp	Phoenix, Cassia species, Cyperus	Secondary growth, fallow grass dominated by Aristida keniensis with Tephrosia, Combretum & A. tortilis woody species	. Dominated by Sterculia africana, Terminalia brownii & A. tortilis, with Cassia & Grewia virosa bushes and Clitoris sp. as conspic. vine.	Under cultivation with Cyperus, Cerosia & Oxygonum species as weeds	Cleared land Adonsonia digitata

continued ...

Table 9-11 Transect: Tana River to Katama Ka Munanada (continued).

Farming System	Farm size 300x50 m, use of plough, hand hoe for weeding. Maize, beans, bananas, green grams millet intercrops	2 to 3 yeards under fallow	Farm size 50x70 m hand dug, crop residue as trash lines for soil erosion control, manure use evident. Millet, sorghum, cow peas	2 to 3 years fallow. signs of slash & burn.	6 to 8 years fallow	3 to 5 years fallow. Burning evident	Beans just planted. Pigeon peas Planting along contours	2 to 3 years fallow	3 to 5 years under fallow	Poorly managed sorghum field & green grams Approx 2 acres	Well managed farm approx 1.5 acres on steep slope. Maize, sorghum, green grams. No intercrops. Trash lines of sorghum & maize stover. Erosion
Livestock grazing / browsing	None Drinking point	Good pasture. Intensive grazing. Good range rehabilitation	Evidence of grazing after last harvest	Good pasture land	Bush too thick for grazers. Good for browsers, e.g. goats.	Poor grass cover. Bush clearing	Only used after harvest	Good pasture area	Good forb / herbaceous layer	None	None
Constraints & opportunities	Hippo & weeds a major problem	Invasion by bush species	Low soil fertility, high labour inputs for weeding. Use of manure & better seeds	Signs of overgrazing Aristida used for thatching. Eragrostis good for livestock	Bush species dominant. Poor grass cover. Control bush encroachment	Same	Poor soils	Good possibility for bee keeping	Good for grazing & bee keeping	Better farm management is required	Improved seeds are required. Needs erosion control.

Chapter 10

POTENTIAL BENEFITS

10. POTENTIAL LOCAL BENEFITS RESULTING FROM THE PROJECT

10.1 IRRIGATION POTENTIAL

10.1.1 Introduction

Irrigation is one of the factors that has the potential to boost agricultural production and increase the carrying capacity of possible resettlement areas adjacent to the proposed reservoirs. This section also provides an overview of the historical perspectives, policies and role of irrigation schemes, as well as typology of irrigation technologies. Ultimately, it shows the multitude of natural and human resources which must be used as indicators of the irrigation potential. Because of the considerable difficulties associated with irrigation schemes, appropriate irrigation technologies need to be applied, both in order to minimise costs and to minimise environmental and human health impacts of such schemes. Efficient organisation of potential irrigation schemes is seen a necessary prerequisite in order to realise lasting benefits.

10.1.2 Objectives and Scope

The main objectives of this section were:

- To assess the potential for irrigation scheme(s).
- To provide an outline of potential irrigation scheme.
- To estimate the cost of the potential irrigation scheme.

Within the above framework, this study was limited to:

- Examination of the historical perspectives, policies and role of irrigation in the economy;
- Assessment of natural and human resources for the evaluation of the potential of the environs of the reservoir area;
- Outline and organisation of irrigation scheme within the vicinity of the reservoir area;
- Assessment of the typology of irrigation technologies.
- Estimation of the cost of irrigation scheme.
- Environmental impact assessment and provision of irrigation measures for the undesirable negative impacts.

10.1.3 Historical Perspectives of Irrigation Development

Traditional and modern irrigation systems have both been practised in Kenya. Historically, traditional irrigation systems based on flood inundation have been practised by the Pokomo and Malakote for over 400 years in the lower Tana River. Furrow systems, involving the diversion of water by means of temporary dikes were practised in Elgeyo Marakwet, West Pokot and Baringo. Moreover, the Vanga cluster irrigation schemes at the coast is a remnant of river valley irrigation around Kipini, Malindi and Vanga in which Arabs initially used slave labour to grow rice and other crops under irrigation (Alila 1990).

Formal irrigation started with the construction of the Kenya Uganda Railway between 1901 and 1905 when Indian coolies who had been working on the railway construction were each allocated about 30 ha in Kibwezi/Makindu area along the railway, to produce horticultural crops for supplying the railway construction crew using local springs and streams. These schemes were abandoned with the completion of the railway. During the Second World War irrigation activities were initiated in Taveta, Naivasha, Karatina and on the shores of Lake Victoria to cater for the British troops in East Africa. These were, however, deserted at the end of the war.

Organised irrigation development started in 1954 following the Swynnerton (1954) recommendation to create a consolidated rural water and irrigation department to undertake irrigation under the Ministry of Agriculture. The irrigation schemes were drawn up against the background of the land policy of the colonial administration, which reserved the more favoured highlands for the "Whites" and tended to allocate to the indigenous people regions less favourable from ecological aspects (Obara 1984). The official organisation which undertook the development of irrigation was the African Land Development Organisation (ALDEV) whose responsibilities later shifted to land reclamation, conservation and intensive farming under the Land Development Board from 1958 onwards. The Mau Mau crisis resulted in the use of surplus prisoner labour to initiate a number of irrigation schemes, and schemes like Mwea, Ishiara, Perkerra, Yatta and Hola were implemented during the 1952-1960 period (Chambers and Moris 1973, Kimani 1984, Alila 1990). The above developments paved way for the progressive investment in sprinkler irrigation in large-scale coffee plantations in the 1960's and to some extent shaped irrigation to its present state.

Historically, there have been government directed irrigation schemes with policies not commensurate with the local needs. Besides traditional irrigation systems, modern planned irrigation schemes have been initiated without the involvement of the local people in planning, implementation and management of the schemes. This is the point of departure for the current study which stresses the involvement of the local communities in the proposed reservoir region in the planning and management of the irrigation scheme.

10.1.4 Irrigation Policies

From the review of the historical development of irrigation it is clear that there is lack of a coherent policy on irrigation. This is exemplified by the way irrigation schemes were established in a rather haphazard and ad hoc fashion, devoid of clearly defined and consistent goals (Ssenyonga 1990). However, the Government recognises the important role irrigation plays in agricultural intensification and food production (Republic of Kenya, 1986). There is considerable irrigation potential of which only 10% or about 53,000 ha has been exploited (Republic of Kenya 1994a). Within the current policy framework of resource mobilisation for sustainable agricultural development, a target of 2,500 ha is expected to be irrigated every year (Table 10.1)

In previous years, irrigation has focused on the establishment of large schemes under the centralised management of the National Irrigation Board. However, these schemes have been faced with prohibitively high cost, poor cost-recovery, management shortfalls, environmental hazards and deteriorating social welfare (Chambers and Moris 1973, Obara 1984, Alila 1990, Ikiara 1990, Riugu and Migot-Adholla 1990, Ssenyonga 1990, Odero 1992). This poor performance has undermined the resettlement objectives of large-scale irrigation as living standards have continued to deteriorate in schemes, such as Bura and Hola, while Perkerra, Ahero and West Kano have suffered in a similar manner.

In view of the past experience, the sessional paper No.1 of 1986 gave high priority to small-scale irrigation to meet set targets since they are characterised by more optimum unit costs, both in implementation, operation and maintenance; technologies that are closer adapted to farmer skills; and farmer involvement in operation and maintenance. Smallholder irrigation schemes currently constitute about 50% of total irrigation and policy favours the support of commercially orientated smallholder group-based irrigation, which are more geared towards employment generation, local food security and increased incomes. owing to their relatively low implementation and operational costs. However, priority is further given to the irrigation of strategic commodities, such as horticultural crops and those crops which show high irrigation yield potential with assured markets since these translate into high farm income and foreign-exchange earnings (Republic of Kenya 1994a).

Table 10.1 Projected Irrigation and Drainage Targets to the year 2000

Category	Expected Annual Development (ha/year)	Existing (ha)	Projection (ha)					
		1994	1995	1996	1997	1998	1999	2000
Irrigation	2500	52,790	55,290	57,290	60,200	62,790	65,290	67,790
Drainage	2000	10,000	12,000	14,000	16,000	20,000	20,000	22,000

Source: Republic of Kenya (1994a).

According to Ikiara (1990) the Government's support is a necessary prerequisite to the development of smallholder irrigation in order to provide essential infrastructure whose costs are often high, formulate by-laws with regard to communal systems, establish marketing systems and provide an extension service.

The formulation of a clear policy framework for irrigation development in Kenya is imperative. Therefore, the following suggestions have been made for incorporation in to such a framework (Alila 1990, Kimani 1990):

- Systematic planning of irrigation in order to optimise benefits accruing from land and water resources;
- Restructuring the existing institutional framework for irrigation in order to avoid duplication of responsibilities;
- Interagency sharing of resources so as to ensure that machinery lying idle in some irrigation schemes, particularly Bura and Hola are used in other schemes lagging behind for lack of land development machinery;
- Reduce the infrastructural costs of future irrigation schemes.
- Inclusion of institutions that enhance community participation at the grassroots.

The background information on irrigation policies indicates that unless the existing policies are properly streamlined, the initiation of new irrigation schemes - whether in the vicinity of the proposed reservoirs or elsewhere - may be doomed to failure.

10.1.5 Role of Irrigation Schemes

The role of irrigation in Kenya's predominantly agricultural economy cannot be overemphasised. This is because the country has limited productive land with only 17% of the 585,000 km^2 of the land area in the medium and high potential areas being considered suitable for rainfed agriculture. And given the current population growth rate of about 3.5% and consequent pressure on high-potential land resources, irrigation is increasingly expected to play an important role in the future expansion of agricultural production into the semi-arid lands and in the crop intensification in the high potential areas. Experience from recent droughts have also served to emphasise the importance of irrigation.

Because of the low and erratic rainfall, irrigation can overcome and allow the semi-arid areas of the reservoir area to be used productively for the production of food, as part of the broad objective of food security and also for the expansion of output of cash crops. Moreover, irrigation is important as a means of providing employment and income to the rural populations. Through intensification of the production of high-value crops, irrigation would contribute to increased foreign exchange earnings and provide infrastructural facilities for accelerated rural development.

Although the semi arid areas have until recently been largely used for livestock production, the problem of developing dry areas such as the proposed reservoir area cannot be resolved simply by restructuring of stock raising on economic principles *per se*. Increasing population growth in the area together with resettlement of the displaced population in areas already occupied cannot allow extensive use of the land. Without agricultural intensification through alternative development strategies partly based on irrigation, the inhabitants of the reservoir area will increasingly face a situation where they depend heavily on receiving food aid from the government and international organisations.

Rainfed agriculture obviously cannot be the basis of existence, in view of the poor and highly variable precipitation in the reservoir area. Greater reliability can be expected from investment intensive irrigation in spatially restricted regions running alongside the rivers and/or within the vicinity of the proposed dams. The Tana is currently the principal river for irrigation and intensification of agriculture. Most of the current planned and potential irrigation areas are located along its course.

Irrigation increases agricultural productivity through double or triple cropping and promotes the use of inputs (fertilisers, improved seeds, etc.) in a synergistic manner. Irrigation, when compared to dryland farming in Zimbabwe, is capable of increasing maize yields by 41%, cotton by 58%, tobacco by 21% and groundnuts by 108%. This increase is attributed to the lengthening of the growing season though irrigation which offsets a late start or early cessation of the main rains (Pilditch 1990). Ultimately, through the reduction of hazards, irrigation stabilises production and farm-incomes against climatic uncertainty.

Despite being an expensive innovation, the local communities in the reservoir area have expressed that the proposed dam would beneficial to them if it incorporated an irrigation scheme.

10.1.6 Typology of Irrigation Technologies

Irrigation technologies are the various methods employed in the capture, conveyance and application of water in the process of irrigation. The different irrigation technologies applied are determined by the topography, soil, climate, crop, cost and water sources. For convenience, irrigation technologies in Kenya can be classified into two main categories, namely: traditional and modern irrigation technologies. The former technologies embrace hand watering, inundation, flood recession agriculture, and traditional furrows. There are three modern irrigation technologies: gravity, sprinkler and gravity/sprinkler irrigation.

- Hand watering involves drawing water from a source by a bucket or pot, carried to the cropping site and sprinkled onto the crop using calabash or watering can. This is considered to be the only appropriate irrigation technique employed by the rural poor to exploit the water resources. Its labour-intensive nature limits its application to vegetables: kales, onions, tomatoes, etc. This mode of irrigation is practised widely in the Lake Victoria basin, along perennial rivers and in semi-arid regions.
- Inundation is based on the impounding of water in basins for paddy irrigation. It is more popular with subsistence small-scale farmers growing cereal crops. Inundation is facilitated by the occurrence of natural floods and is widely practised in the Tana River Delta, the Kerio River Delta, and along the Dawa River. However, the water may also be conveyed by canals to fields as is the case at Katilu Irrigation Scheme in West Pokot.

- Flood recession agriculture is a technique whereby as the flood recedes, seeds are sown in the areas from which the flood water have receded but utilising the available moisture. This technique is most popular in the flood plains and deltas in arid regions. It constitutes an important mode of food production for the Malakote and Pokomo people who inhabit the riverine areas of Tana River, Turkana of the Turkwell River Delta, and Somalis who exploit hinterland lagoons.

- Traditional furrows are well-known irrigation techniques practised, particularly in Elgeyo Marakwet, Kajiado, Nakuru, West Pokot, Taita Taveta and Machakos Districts. This mode of irrigation involves diversion of water by small rudimentary furrows from sources high up in the hills then conveyed downhill and distributed by a network of relatively smaller furrows to the fields of sorghum, maize, millet, citrus fruits, mangoes and other crops adaptable to the local environment.

- Free flooding where water flows by gravity from the highest point of the field to the lowest as in Mwea Rice Irrigation Scheme. It requires favourable conditions, such as less porous soil and often a good site for construction of a reservoir. Although the initial costs of developing the method may be relatively high, the relatively low costs of operation and maintenance makes gravity irrigation cost effective in the long-term. Despite its low efficiency, it has a low risk of salinization.

- Sprinkler irrigation constitutes a sizeable portion of total irrigated land in Kenya, and covers approximately 20,000 ha (Arao 1990). Because of its adaptability to a wide range of topography, the sprinkler is employed notably to irrigate sloping lands. It is also the only appropriate mode of irrigating pasture lands, such as is carried out in the Naivasha area to grow alfalfa. Owing to the high costs inherent in the establishment, operation and maintenance of a sprinkler system, it is customarily employed by commercial private firms and financially capable individuals to irrigate high value cash crops, such as coffee, pineapples, onions, tomatoes, French beans, courgettes and several other vegetables, as well as fruits (oranges and passion fruits) in Central, Coast, Eastern and Rift Valley Provinces. Sprinkler irrigation is probably the most efficient method as the water input is utilised optimally and secondary salinization is less probable. It is estimated that the water efficiency is 75%.

- Gravity/sprinkler combination systems are used where the water source is high enough above the command area. This means that the water can be captured and conveyed by gravity downhill in a pipe as to obtain pressure high enough to drive one or several sprinklers. The technique has been applied to two modern schemes at Mitunguu Scheme (480 ha) and Kibirigwi (90 ha) in Meru and Kirinyanga Districts respectively. Apart from these schemes, the principle has been employed on the slopes of Mt. Kenya, particularly in Laikipia and Nyeri Districts. These systems could be developed in other localities with similar topographical features, but such development can only be stimulated through education of the inhabitants of these areas in the art of irrigation and drainage.

The reservoir area has not benefited from either traditional or modern irrigation systems. This implies that the introduction of irrigation schemes would require a significant effort in education of local communities of the necessary management skills. An important question is whether the experience gained by traditional irrigation can be blended with modern irrigation. The answer is that this can be done by incorporating traditional irrigation techniques in every stage of planning for modern irrigation depending on the local environmental conditions.

10.2 POTENTIAL FOR IRRIGATION SCHEMES

Semi-arid environments of Kenya have largely been used for livestock raising and partly for subsistence arable agriculture with high production risk in view of the considerable variation in annual precipitation. Nonetheless, in four decades these areas have increasingly become a significant factor in an export-orientated national agrarian economy in spite of poor agro-ecological potential of the land and their unsuitability for commercial rainfed agriculture (Jaetzold and Schmidt 1983, Obara 1984). However, the Government has embarked on irrigation as a significant strategy for the development of small-scale agriculture in these areas.

The estimated irrigation potential in Kenya varies considerably depending on the parameters used for the assessment (Table 10.2 and 10.3).

Table 10.2 Estimated Irrigation Potential in Kenya, 1980 and 1987

Drainage Area	Estimates in 1980	Estimates in 1987
Tana River	205,000	90,000
Athi River	40,000	49,500
Lake Victoria	200,000	57,400
Kerio Valley	64,500	31,200
Ewaso Ngiro	30,000	15,700
Total	539,500	244,700

Source: Republic of Kenya (1992)

Table 10.3 Estimated Irrigation Potential in Kenya, 1992

Drainage Area	Surface water		Groundwater
	monthly mean flow	80% dependable monthly flow	
Tana River	132,700	89,200	250
Athi River	22,400	21,000	650
Lake Victoria	214,000	178,500	900
Kerio Valley	84,300	52,000	500
Ewaso Ngiro	16,000	9,300	160
Total	469,000	350,000	2,400

Source: Republic of Kenya (1992).

Estimated potential area for irrigation development in the country varies from 244,000 to 539,500 ha. Discrepancies in the figures may be explained as follows:

- In 1980 the assessment did not consider the groundwater supplies and ignored the role of basins in supplying water for domestic use. Therefore more water was considered available for potential use in irrigation. The potential was based on 7 typical cropping and 12 water requirement patterns evaluated from only a part of Kenya (covered in the average soil map).
- The 1987 assessment considered the use of the basins to supply water for domestic use based on some typical cropping patterns and an unknown number of water requirement patterns in each project area.
- The 1992 assessment considered the potential of surface water and groundwater discretely taking into account the provision of domestic water supplies. In this case the evaluation covered the entire country and it was based on 72 water requirement patterns and the cropping pattern of a green-grass cover throughout the year.

Despite the above reasons for the discrepancies in the statistics for potential irrigation, there is likely to be an underestimation of irrigation potential in the country. Therefore there is need for further estimates in the future. However, it is worth noting that besides the Lake Victoria Basin, Tana River Basin has more irrigation potential than any other river basin in the country. But the potential in the Tana River Basin is confined mainly to the upstream areas and downstream environments of the proposed reservoirs. This implies the need for an assessment of natural and human resources for the purposes of establishing the irrigation potential in the reservoir area.

10.2.1 Assessment of Natural Resources

Topography, vegetation, climate, soil and water resources can be used as indicators of land potential for irrigation scheme in the reservoir area. The topography of the area is dominated by hills and scarps, footridges and plateaux due to extensive volcanic activity over part of the area. The landform in the rest of the area is characterised by uplands, plains and bottom lands and valleys. Both plains and bottom lands occupy a small area. Because of the limited undulating landscape and lack of suitable land below the proposed dams, gravity irrigation is not possible in the immediate reservoir areas. Moreover, the nature of the topography accounts for the susceptibility of the land to accelerated erosion.

Much of the reservoir area is classified as Agro-Climatic Zone V. This is arid area characterised by *Acacia-Commiphora* bushland, where given suitable soil depth and moisture-holding capacity, drought-tolerant cereals and legumes can be cultivated, although with significant risk of failure.

To the south-west patches of land in Marimanti and Chiakarika (Kamanyaki) locations of Tharaka Nithi District and across the Mutonga River in Evurore location of Embu District are classified as Ecological zone IV. This is a semi-arid environment characterised by dryland acacia with some broad-leaved trees or shrubs where, despite relatively low and erratic rainfall, there is some potential for agriculture, particularly sunflower, cotton, beans, or early-maturing cereals. These areas lie west of the Tana and will be directly affected by the project where some settlers may have to vacate better land than can be found in the rest of the reservoir area.

A very small area of land in Tharaka Nithi, bordering the Tana River east of the Thangatha and adjoining the border of Meru National Park is classified in zone VI. This is arid area, mostly low thornbushland, shrub grassland or thicket, unsuitable for rainfed agriculture, although with moderate potential for extensive livestock production and wildlife. Although quite distant from the reservoir, this land is part of the thinly populated area of Tharaka Nithi which has been depopulated as a result of insecurity. Besides being used for extensive grazing, its productivity could be increased through irrigation.

Besides being arid, the vegetation distribution in the different ecological zone clearly indicates that the reservoir area is of low to moderate potential for irrigation. High potential land is almost non-existent.

Most of the areas in the vicinity of the proposed reservoirs receive a bimodally distributed rainfall of about 400-1400 mm per annum. The rainfall is received in months of October-November and March-May which are the crop growing seasons under normal circumstances. However, an average 50% of each season's rainfall occurs in the first 22 days and this necessitates the use of irrigation to augment water supply for arable agriculture. Because of high temperatures, evaporation rates are high. This climatic condition combined with the low soil moisture retention considerably reduces the effectiveness of rainfall and probably justifies the need for irrigation.

A survey of the water resources shows that the area is traversed by the tributaries of river Tana flowing from the Mt. Kenya catchments with high precipitation. These tributaries include Mutonga, Kaithita, Ura, Ena and Rojewero, which cover an area of about 15,700 km^2. The water quality from these rivers is satisfactory for both irrigation, domestic and industrial purposes. It is reported that these rivers contain adequate water which when harnessed properly would greatly expand irrigable areas (Republic of Kenya 1994b). However, there could be conflict in water use for irrigation and the proposed hydropower project if there is no proper planning. Of course pumping of water from the dam for irrigation would be quite uneconomical as shown by experience from existing irrigation schemes.

Soil characterisation is an important consideration in irrigation planning because it determines the type of crops to grow and methods of irrigation. The soils found in the area surrounding the proposed reservoir are varied. They consist of Nitosols, Cambisols, Lithosols and Luvisols (republic of Kenya 1980). Nitosols are characteristic of Mt. Kenya forest and the volcanic footridges. They are fertile soils of very good structure and much less erodible than the soils derived from the basement complex. The soils are also deep and well-drained and are suitable for irrigation. However, the nitosols are found only in very limited areas around the reservoirs.

Cambisols are young soils which have not been extensively weathered. As a result they are shallow and consist of sand and gravel. They have low fertility and poor retention and, therefore, unsuitable for agriculture. Similarly, lithosols are shallow soils overlying the parent material which is within 25 cm of the surface. They are rocky and as a result are well-drained but have low moisture retention. Consequently, these soils have a poor structure, and are low organic matter. The above properties make lithosols susceptible to erosion. Furthermore, the shallow depths and poor moisture retention may be a hindrance in irrigated agriculture.

The luvisols are well-drained, deep and generally of good fertility. The erodibility of the luvisols is, however, nearly 10 times greater than that of a nitosol. Nevertheless, these soil are suitable for irrigation. This is the major soil type in Tharaka Nithi and Mwingi Districts which represent a considerable area in the environs of the proposed reservoirs. Most of the sites covered by luvisol lie between 600 and 900 metres above sea level. On the basis of soil classification, the sites are moderately suitable for irrigation.

10.2.2 Assessment of Human Resources

The assessment of human resources is based on agriculture, livestock, population, labour availability, management skills, infrastructural and marketing systems. Previous studies indicate that Mutonga/Grand Falls reservoir area is predominantly inhabited by the Tharaka who constitute about 60% of the total population (Table 10-4). The ethnic composition of the reservoir area is both district and location specific except Katse location in Mwingi District which comprises of both Tharaka and Kamba ethnic groups. Tharaka-Nithi and Embu Districts are comprised of Tharaka and Mbere ethnic groups.

With the exception of a few migrants from areas of land pressure and/or insecurity, the majority are indigenous inhabitants. The entire area is sparsely populated and this means that the agricultural labour potential is relatively low. However, labour availability is not a major constraint on initiating an irrigation scheme because household labour may be supplemented with migrant labour from adjacent districts. Besides the labour issue, the ethnic variations require careful planning for an irrigation scheme in order to avoid confrontations.

Table: 10.4 Human Population in the Reservoir Area

District	Division	Area (km_2)	1989 Population	1989 Density (per km^2)	1995 Projected population	1995 Density (per km^2)
Meru	Tharaka	1,561	74,929	48.0	91,000	58.3
Kitui	Kyuso	6,453	103,325	16.1	125,500	19.4
Embu	Siakago	783	56,932	72.7	69,200	88.4
	Total	8,799	235,186	26.7	285,700	32.5

Source: Nippon Koei Co. and Pasco International (1995)

Most of the areas adjacent to the reservoir is found in the agro-climatic zones IV and V which are least suitable for farming (Republic of Kenya 1980). These areas lie mainly between marginal cotton zone and livestock-millet zone, and are characterised by low and unreliable rainfall and the potential for agriculture without irrigation is extremely low.

The farming systems are currently based on small-scale agriculture and/or livestock husbandry. Farming has for a long time been characterised by shifting cultivation or bush following, but these have degenerated due to increasing population pressure on the land resources and land adjudication which has introduced proprietary rights to land contrary to the communal land ownership rights. However, most areas have not been adjudicated to date.

Despite the high climatic risks, maize is the main crop. Other common food crops include sorghum, millet, pigeon peas, green grams, sweet potatoes, beans, cowpeas, cassava, etc. However, cotton, millet and green grams are locally important cash crops.

Experience from the arid lands of Kitui District show that irrigation may render the reservoir area suitable for the growing of vegetables, such as karella, brinjals, okra, turia, dudhi, chillies, cabbage, onions, tomatoes, kales, spinach, etc. In addition the area has high potential for fruits, particularly mangoes, pawpaw and citrus. Nevertheless, the growing of the above crops may be determined by the cultures of the different ethnic groups.

The agricultural potential in the area is influenced by the land ownership. Land in Tharaka Nithi and Mwingi areas adjoining the reservoir has not been adjudicated, and therefore, it is "trust land" under the care of the county council. Trust land is currently used on communal basis. The portion in Embu District has been adjudicated and freehold title deeds issued for some areas. The land tenure system is an important factor in irrigation because it determines the extent of farmers participation in the operation and management, and thus the success of irrigation scheme.

Livestock rearing is practised under a semi-pastoral system where farmers live in definite areas but constantly move in search of pasture and water for their animals. The number of livestock in the reservoir area is currently unknown, although the majority of farmers keep poultry, goats, sheep, donkeys and indigenous cattle which are adapted to the harsh climatic conditions. There are no organised ranches which would ensure a high level of livestock production. Bee-keeping is an important cash activity and may be severely affected by an irrigation scheme if there is no provision for agro-forestry.

Infrastructure is multifaceted and refers to such aspects as education, health, housing, administration, security, roads, transport, communications, water supply, etc. Available data indicate that all these aspects of infrastructure are underdeveloped in reservoir area. Much of the area is inaccessible as roads are few and often impassable during the rainy seasons, and consequently transport is dominated by draught animals. This implies that the improvement of the road system would greatly facilitate transport, marketing and trade.

The initial environmental assessment of the reservoir area revealed that several schools and health centres would be affected by dam construction and inundation. These facilities will need to be relocated to the areas of resettlement. Moreover, the health impacts associated with irrigation demand the establishment of proper health facilities and health education targeted at communities involved in irrigation schemes.

The farmers around the reservoir area have traditionally practised subsistence-based shifting cultivation and bush fallowing. They have not been exposed to cash cropping and therefore, lack the commercial orientation that facilitates the acquisition of agricultural skills. This clearly suggests that farmers in the area lack the necessary skills to manage the irrigation scheme on their own unless they are given appropriate training through extension workers.

Despite the many constraints emanating from human resources mentioned above, the local communities in the three districts bordering the reservoir are have expressed the desire for an irrigation scheme but without understanding of the full implications of such a scheme. However, the assessment of natural and human resources indicate that the area has moderate potential for irrigation scheme.

10.3 OUTLINE OF IRRIGATION SCHEME

10.3.1 Overview of Planned Irrigation Schemes

Current development plans have singled out priorities for various irrigation schemes in the districts bordering the reservoir area. These irrigation plans will be carried out in areas where rainfall is considered to be the main inhibiting factor to agricultural production, particularly in Tharaka Nithi District. Planned irrigation schemes are enumerated below in order of priority.

- Nthamba Irrigation in Magumoni Location of Chuka Division intended for small-scale irrigation scheme aims at producing horticultural crops: tomatoes, onions and vegetables, for the local market and raising farmers' incomes. This scheme is given top priority but its size and the expected number of farmers are lacking. Furthermore, it is located in a generally high agro-ecological potential area where the displaced population from the reservoir area cannot be absorbed due to land pressure and high population concentration.
- Iriamakithi Irrigation in Nkondi Location of Tharaka South will be based on high pressure gravity irrigation planned to cover 400 ha of land for the development of horticultural food crops. Although this is a reasonable small irrigation scheme in terms of its size, it is not intended for the affected population from the reservoir area.
- Tungai-Nkarimi in Tungai Location of Tharaka South will have water piped for irrigation according to the needs of the community. There are no details on its plan.
- Mara Gaitiu Irrigation in Kiera Location of Mwimbi Division is a small irrigation scheme that is community based where furrow or surface impaction is to be used. However, there is no mention of its size and, it is located in a relatively high agro-ecological potential area with high population concentration and land pressure. This means that it cannot absorb the displaced communities from the reservoir area.
- Rwancece irrigation in Chogria Location of Mwimbi Division is a community based scheme intended to raise farmers' incomes. Nevertheless, the scheme is located in a high agro-ecological potential zone with high population concentration and land pressure. It cannot cater for the displaced people from the reservoir.
- Tharantu valley irrigation in Gikingo Location of Tharaka North Division envisages irrigation using high pressure gravity fed sprinklers to raise agricultural production. Although this site could be suitable for the displaced population its size is not given and no details on farmers' participation.
- Rungu Irrigation in Tharaka South Division is a surface irrigation scheme aimed at increasing agricultural production for both food and cash crops.

Besides the above proposed irrigation schemes, there are other small-scale schemes including Ishiara, which is almost dormant, and irrigation based on boreholes in Mwingi District. Ishiara irrigation scheme is based on pumped water from the Tana River, while the planned irrigation schemes in Tharaka Nithi District are expected to utilise the water of the various tributaries of the Tana River. They will largely be based on gravity irrigation. These schemes are probably planned with a target population of farmers in mind and are unlikely to cater for extra people from outside. However, they are likely to benefit from the provision of infrastructural facilities accruing from the Mutonga/Grand Falls Hydropower dams. Conversely, there is need for small scale irrigation scheme which would increase agricultural production in the resettlement areas. Because of this need, an attempt is made to provide an outline of such a scheme below.

10.3.2 Irrigation Area

The irrigation area and perimeter are described by Figure 10-1. There are two sites A and B, which are located in Tharaka Nithi and Mwingi Districts respectively. Both sites lie on the downstream side of the proposed Grand Falls dam. Site A is about 300 km^2 while site B is approximately 350 km^2. These figures are quite high but a larger area has been deliberately identified to facilitate adjustments during the planning for the scheme. This is necessary because some areas will be inhabited and there are commercial centres. Even the topography will limit the size and perimeter of the scheme. But both sites are sparsely populated trust lands.

Because of the poor rainfall effectiveness in the region, the irrigation schemes will have to depend on the Tana River, especially the proposed reservoir.

The selected sites are composed of luvisols and ferralsols which range from sandy loam clay to clay and sandy clay to clay in texture, respectively. These soils are suitable for the production of cereals, legumes and horticultural crops, which are included in the cropping patterns in the region. The mode of irrigation technology will have to be decided, but topographical considerations show that the water will be pumped if it emanates from the dam. And sprinkler irrigation quite ideal.

The need for and benefits of irrigation depend on the amount of natural rainfall (Walker 1984, Schliephake 1987). If the latter is less than 500 mm per annum as is the case in the proposed sites, irrigation is absolutely necessary for agricultural production. Irrigation will improve the yields and eventually make more than one harvest a year possible. It is estimated that production value on irrigated fields is 2.5 to 3 fold in comparison with rainfed agriculture. Furthermore, it is a commonly held opinion of TARDA and the local communities that the proposed reservoir would supply enough water for generation of hydropower energy and irrigated agriculture.

If we consider the cereal yield for irrigated agriculture to be 2,100 kg/ha (using the figure for maize in Table 10-5) and the average cereals consumption in East Africa to be 110 kg/year per capita, then the following area of irrigated land would be needed to produce the cereals demand in the reservoir area. Considering the reservoir may displace 10,000 inhabitants who will depend on irrigated cereals, then cereal requirements are 1,100,000 kg and the required area is 520 ha of irrigated fields, with double cropping and 50% of the irrigated area being given over to non-cereal and cash crops. This, of course, is a preliminary figure and one that is highly dependent on potential yields and cropping patterns.

10.3.3 Water Requirements

Water requirement is the quantity of water, regardless of its area, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at specified sites. This implies that irrigation requirement of crop is the water requirement of crops exclusive of effective rainfall and contribution from soil profile. The requirement of the site area includes the irrigation requirement of individual farm holdings and the losses in the conveyance and distribution system.

Evaporation, transpiration and consumptive use are important parameters in estimating irrigation requirement and in planning irrigation systems. But in determining water use by crop plants, evaporation and transpiration are combined into evapotranspiration ET, which is also referred to as consumptive use. More specifically, the total amount of water used in evapotranspiration by a cropped area during the entire growing season is called seasonal consumptive use, expressed as depth of water in cm. Of course, ET is influenced by incoming solar radiation which supplies energy for the evapotranspiration process.

The crop water requirement is also determined by the type of crop grown and the phenological phases including germination, emergence, growth initiation, budding, flowering, fruiting and maturing. The different phases require different amounts of water. And the phenological phases of the crop performance have considerable influence on the consumptive use rate. This means that the peak period for various crops may occur at different times in the crop growing season. Maximum rates of soil moisture use by crops under arid conditions is estimated to 8 mm/day (Michael 1978).

In drawing the seasonal or monthly net irrigation water requirements for a given crop or cropping pattern, the main variables to be considered for the identified site(s) are:

- crop water requirements as determined by climate and crop characteristics;
- contribution from precipitation;
- groundwater if any; and
- carry over of soil water, so that the deficit in the soil water balance is compensated by the net irrigation requirement.

During the current study, it was not possible to perform the water requirement calculations without field experiments. However, the water balance equation provided by Hounam et al. (1975) is useful for determining the crop water requirements at specific times. Application of the water balance equation in irrigated agriculture provides an economic way of supplying water to the crops. The equation is expressed as:

$$P = Q + U + ET + DW$$

where P = the irrigated water.
Q = runoff.
U = deep drainage passing beyond the root zone.
ET = evapotranspiration.

DW = change in soil water storage.

When P, Q, and U become zero in the absence of irrigation water then:

ET = - DW.

Normally, water would be required when the crop reaches the wilting point. On the other hand, gross irrigation requirement is important. This is expressed as:

$$\text{Gross irrigation requirement} = \frac{\text{Net irrigation requirement}}{\text{Field efficiency of irrigation system}}$$

Losses are due to leaks in the water conveyance system, non-uniform distribution of water over a field, percolation below crop root zone and wastage due to surface runoff. In the case of sprinkler irrigation losses may be caused by evaporation from the spray and by retention of water on the crop plant foliage.

It is also important to consider the frequency of irrigation which could be solved through rigorous calculations based on the water balance equation. This requires determining the number of days between irrigations during periods without rainfall. It depends on the consumptive use rate of a crop and on the amount of available moisture in the crop root zone.

Sprinkler irrigation could be used in the proposed irrigation schemes where the soils tend to be of sandy texture.

10.3.4 Cropping Patterns

The cropping patterns showing a wide range of food crops in the reservoir area, reflect the farmers' desire to spread production risks. Besides different food crops, cotton is the most important cash crop, although both maize and millet are sold in the local markets. The communities living in the area also keep livestock, including bee-keeping. It is assumed that the design of the proposed irrigation schemes would encourage the current traditional patterns of cropping including crop rotation and intercropping.

Based on the recent survey of the reservoir area and the information in the Farm Management handbook of Kenya (Jaetzold and Schmidt 1983) a tentative cropping pattern is provided (Table 10.5). Cropping patterns are further determined by

- the need for sufficient food production for the farmers' family;
- the climate aspect and availability of rainwater;
- the need for cash income, and
- the balanced production to alleviate crop pathology aspects.

The above patterns may be irrelevant in the irrigation scheme. However, irrigation based on a monoculture should not be encouraged. Nevertheless, cereals, legumes and horticultural crops should be given priority for the purposes of food and cash requirements.

Table 10.5 Cropping Patterns

Crops	Long Rains Area (ha)	Short Rains Area (ha)	Average Yield (kg/ha)
Maize	0.8	0.7	2,111
Cotton	0.5	0.5	948
Tobacco	0.6	0.9	3,188
Millet	0.4	0.5	1,019
Sorghum	0.8	0.4	1,000
Beans	0.7	0.7	994
Sunflower	0.2	0.2	900
Sweet potatoes	0.1	0.1	-
Cowpeas	0.3	0.2	693
Cassava	0.8	0.4	-
Green grams	0.6	0.4	-
Maize & Millet	0.7	0.4	1,500
Maize & beans	0.7	0.5	1,286
Maize & cowpeas	0.2	0.2	-
Maize & others	0.8	0.7	-
Groundnuts	0.2	0.2	-

Source: Adapted from Jaetzold and Schmidt, 1983.

10.3.5 Irrigation Infrastructure

Much has been said about the state of infrastructure in the reservoir area. Infrastructure required by the irrigation schemes include engineering infrastructure for irrigation supplies, roads, transport, communications, public water supply, energy, education, health, housing, administration, security, commercial centres, industrial centres, and bank facilities.

Available data indicate that the above facets of infrastructure are underdeveloped or non-existent in the proposed irrigation scheme sites. Deficiencies of roads and communications present one of the greatest obstacles to irrigation development in the proposed sites.

There would be no irrigation development without adequate all weather access, feeder and primary roads linking the scheme with markets within and outside the reservoir area. Land tenure that enables efficient management of the scheme should be adapted as well as provision of extension officers who would educate the farmers on agronomic practices required for irrigation schemes in arid regions.

10.4 ORGANISATION OF IRRIGATION SCHEMES

The reasons for the lack of success of irrigation development projects are many and varied (Walker 1984). One fundamental cause is to be found in the bias towards the technical components of irrigation commonly observed in the planning and execution of projects of this kind. Underlying this is the attitude of many irrigation scheme planners and managers, who measure the efficiency of the scheme primarily on the basis of the effectiveness of the hydraulic-engineering infrastructure, i.e. against the technical criteria of water procurement, delivery and distribution. Such a view disregards the fact that irrigation systems are not only of a technical nature, but they also include an important social dimension. Therefore, irrigation systems are socio-technical systems which can lead to the desired results only through effective co-operation between the people involved, using the available resources.

10.4.1 A Systems Approach to Irrigation Scheme

Figure 10.2 shows that in an irrigation scheme, certain inputs (input system) are transformed within organisational structures and processes (transformational system) and converted into outputs. The input system comprises of:

- Human resources system embracing irrigation farmers and administrators, financiers, politicians and experts.
- Material resources embracing non-personal inputs.

Both human and material resources form action units whose formation leads to problems of co-ordination and adaptation. The adaptive machinery for a given technology is provided by the management system in conjunction with the transformational system. It is the management of the scheme which will control the procurement of personnel, and material input and influences the organisational structure.

On the basis of the organisational structure, organisational processes are at work, and of particular interest is the participation of organisation members in decision-making, problems relating to delegation of powers, and the system of material flows (logistics) and informational (communication). This kind of systems approach to irrigation schemes can be more successful in the reservoir area than directed irrigated agriculture.

The objective of the management activities within the transformational system is to produce output, which embraces agricultural products, and services contributing to personal satisfaction and ecological stabilisation of the irrigation environment. The irrigation scheme in the vicinity of the reservoir will be subject to environmental conditions. However, the effect of these conditions upon the irrigation scheme organisation is a function of four subsystems:

- Socio-cultural system embracing, *inter alia*, specific social structures, value systems of individuals and social structures, such as village communities, ethnic groups and interested parties, as well as codes of behaviour, distribution of status and roles.
- Ecological system embracing the natural factors, such as vegetation, topography, climate, soil and water. These factors are correlated with cultivated crops.

- Technological system embracing all installations and processes that are needed for the transformation of input into output within irrigation scheme.
- Political system which constitutes the policies and laws of the country. In this regard the legal framework pertaining to ownership and utilisation of natural resources in the reservoir area is of paramount importance.

Theoretically, a systems approach to irrigation scheme in the reservoir area is very complicated, but practically integration of natural and human resources including the participation of all interested parties in the scheme planning and management is more realistic.

10.4.2 A Model of Farmers Participation

The participation of farmers in an irrigation scheme within the environs of the reservoir can be illustrated by a model showing different degrees of participation (Figures 10-3 to 10-5). The model indicates the area within which the social system of the administration and the social system of the farmers impinge upon each other. To enable decisions to be prepared and taken jointly, to regulate the distribution of water, to settle disputes, persons must be decided upon who can work as agents, i.e. as representatives to deal with the affairs of the administration and farmers.

Figure 10-3 shows the case of an irrigation scheme organisation which is managed authoritatively. At the interface between administration and farmers is an employee of the administration who is selected by the management, whose rights and duties are decided without any consultation with the farmers and who is accountable to the administration only. This has been the situation in the large-scale irrigation schemes owned by the National Irrigation Board. In such a situation the farmers do not recognise the agent but will regard him as someone imposed on them. Ultimately, a scheme of this nature is associated with low participation of farmers. This type of scheme organisation is not recommended for the irrigation scheme in the reservoir area.

Figure 10-4 shows a situation in which the agent can, in principle, come from either side; but both sides are effectively represented in the process of selection. However, the administration is still in stronger position. This implies that accountability to the administration is obligatory and the agent is remunerated from the budget of the scheme corporation. But at least part of the disputes between administration and farmers can be solved through the agent. This kind of model has not been used in Kenya, but in Asiatic irrigated agriculture. We do not encourage this type of model to be used in the irrigation scheme of the reservoir area.

Figure 10-5 corresponds to a high participation-orientated irrigation scheme organisation. The farmers nominate jointly a representative from among themselves who is fully accountable to them. This accountability of the agent to the farmers is in many cases ensured by the fact that the agent is paid by the farmers themselves and can also be dismissed by them. This kind of model is rare in Kenya, but numerous examples from Asia are cited in the literature. This model is considered to be most appropriate for irrigation schemes associated with the proposed reservoirs.

10.4.3 Economic Consideration

Optimal utilisation of irrigation facilities by farmers takes time since certain conditions necessary for profitable irrigation may only be realised in the medium and long terms through:

- A farming attitude based on group co-operation;
- Integration of irrigated cropping into a new, balanced farming systems;
- Adequate physical and institutional infrastructure; and
- Knowledge and skills in irrigated technology and water management.

The issue is what should be charged to the scheme farmers in order to realise the benefits. It is not fair to recover from the farmers the initial investment costs of irrigation development in the reservoir area since the Government is equally a beneficiary from such a scheme. Successful irrigated agriculture will generate other economic activities and employment opportunity in the reservoir area, such as trade, crafts, transport, etc.

During the field survey, there was general consensus over the fact that farmers' participation in the irrigation scheme conception and their contribution works in free hand labour and cost sharing in the initial investment costs. However, the farmers should be able to pay for the recurrent costs, including seasonal direct production costs (agro-chemicals, seeds and casual labour) and the costs for operation and maintenance. The obligation and acceptance of having to pay for all recurrent costs is one essential condition for farmers to feel fully responsible for their scheme.

Small-scale irrigation resources are limited in terms of manpower and development funds. This means that besides scheme subsidisation by the Government, the available resources should be utilised efficiently. The time lag between scheme initiation and implementation is usually considerable (2 to 3 years). It is something that should be avoided at any rate because it directly affect the viability of the scheme. This could be minimised through

- decentralisation of decision-making;
- shortening of physical planning studies;
- greater use or more active involvement of the extension officers.

10.4.4 Scheme Selection Criteria

Guidelines on selection of irrigation schemes are well-documented (Kortenhorst 1983). Guidelines provided below for scheme selection criteria are not exhaustive but shed light on what could contribute to the success of small-scale irrigation scheme in the reservoir area.

- The farmers community should be interested in water development. The best indications of real interest are farmers' own initiative to have some form of water control and request by themselves for assistance. They must be willing to provide free labour wherever necessary. Despite the limited potential land, the local communities in the reservoir area have expressed interest in irrigation schemes to boost their agricultural production. This is considered to be one of the benefits that would emanate from the Mutonga/Grand Falls Hydropower Project.
- Experience in Kenya and elsewhere in the World show that the best scheme is the one with the lowest recurrent cost prospects, no imposed management from outsiders, and minimal dependence on outside institutions, facilities and supplies.
- The irrigation development scheme should fit in the existing farming systems, especially with regard to labour availability. And it should be compatible with the risk-spreading range of the different subsistence activities in the reservoir area.
- The scheme should be compatible with current and expected future water requirements of downstream and upstream communities. This implies an understanding of water rights for equal development opportunities in the region.
- Irrigation scheme should minimise conflicts between competing resource users in the reservoir area.
- The quality of natural resources of the scheme should be suitable for irrigation development.
- Topography, soils and hydrography should be such that water supply by gravity and basin irrigation is feasible at low cost. This condition is not possible in the reservoir area where the terrain cannot allow gravity irrigation due to lack of suitable land below the dam.
- The soliciting farmers from one ethnic group should accept *a priori* that farmers from other ethnic groups are free to join the scheme. However, we recommend a homogeneous cultural trait for the scheme in order to alleviate current frictions between different communities.
- Any land tenure problems in the reservoir area should be resolved within the clan and between the segments of the population concerned, and endorsed by the official land authorities, prior to the final scheme acceptance.
- The scheme should be based on full partnership and participation of the rural communities concerned because scheme success depends primarily on the active involvement of farmers themselves in all stages of scheme development.

10.4.5 Experience from Kibirigwi and Kangocho Irrigation Schemes

The Kibirigwi Irrigation Scheme has been selected to give insight on the management and organisational issues, which are to be expected in planning and implementation of a new small-scale irrigation scheme in the reservoir area.

Kibirigwi scheme was initiated in 1975 by the Tana River Development Authority (TRDA). It was implemented in 1977 by the small-scale irrigation unit of the Ministry of Agriculture with the joint funding of the Kenya and Netherlands governments. The scheme is located on the red soils of the hilly Upper Tana Catchment with an average rainfall of about 1280 mm per annum (i.e. significantly greater rainfall than in the project area).

The principal objective of setting up the scheme was to study the possibilities of increasing farm-incomes in high potential areas of the Tana River Basin by using methods and inputs which are within the farmers' means. Before initiation of the scheme, Kibirigwi had been a settled area for quite a long period and those settlers were practising peasant agriculture. However, they were influenced by the colonial and post-colonial policies which increased their skills and orientated them towards commercial agriculture.

The scheme beneficiaries were farmers who already owned the land. About 250 farms are situated within the scheme perimeter. The average land size is 1.8 ha, but the total scheme area is approximately 482 ha of which 94 ha are vegetable plots under irrigation and 52 ha are available for rotation purposes

This scheme uses irrigation water supply from the Rugati River. The water is gravity fed to a pressure pipeline which is reticulated by distributary channels to the farms designed in small parcels called laterals. Each farmer is supposed to irrigate about half of the irrigible land during any growing season.

Upon completion, the scheme was handed over to Kibirigwi Farmers Co-operation Society (KIFCO), while the scheme management was put under the Ministry of Agriculture in 1983. All the farmers are expected to be members of KIFCO and by agreement are obliged to deliver all horticultural produce to the society. KIFCO performs the marketing of the produce on behalf of two farmers and from the proceeds recover the costs of inputs and irrigation, which are given to the farmers on credit.

The farmers on the scheme grow crops like coffee, maize, bananas, and English potatoes on non-irrigated part of the farm, and horticultural crops, particularly tomatoes, onions, cauliflower, lettuce, cucumber, courgette, capsicum under the regular guidance of extension staff. However, the project was conceived and implemented without involvement or participation of the farmers concerned. They do not therefore consider the scheme or KIFCO as theirs. Kortenhorst observes that this may partly explain the existence of large percentage of marginal and poor performers to whom the project's extension workers have difficult access.

Farmers are discontented with KIFCO handling their produce because their prices are frequently lower than the prevailing market prices. As a result farmers have now resorted to selling their produce at night to middlemen, which is illegal and likely to create friction between KIFCO and farmers.

There are also some institutional conflicts between KIFCO and the Ministry of Agriculture caused by lack of defined roles. The officials of KIFCO are also accused of not having enough skills to run the irrigation scheme on a co-operative basis.

Despite the shortcomings in management, the irrigation scheme has significantly increased farm income from an average KShs.7750 per annum in 1979 to KShs.17,900 in 1983 (Makanda 1990). This increase has been attributed to the fact that irrigation has facilitated agricultural diversification, including horticultural produce which is high paying. Moreover, the scheme has tremendously increased employment opportunities besides contributing for food security of the farm households.

Kibirigwi has some advantages for irrigation-cum-horticultural production which are worth mentioning. These are:

- Situation in an area with adequate water supply, relatively high rainfall, well-drained terrain and fertile soils;
- Financially attractive, effective and reliable transport network for marketing; and
- Presence of farmers who are skilled and well-orientated to commercial farming.

The overview on Kibirigwi Irrigation brings to focus the following lessons, which are important for the successful planning and implementation of small-scale irrigation scheme.

- Proper site identification and involvement of skilled farmers with commercially orientated attitudes is crucial for the cost effective establishment of irrigated agriculture.
- It is important to incorporate farmers in the initiation, planning and implementation stages of irrigation to promote effective management.
- A well-developed and effective transport system is essential for the realisation of the full-benefits of irrigated agriculture.
- The institutional involvement in the schemes should be limited to the provision of technical advisory services and training. These must be spelt out clearly to minimise conflicts, which usually hinder the effective management of the irrigation scheme.
- Marketing through co-operatives has proved to be unprofitable to farmers in the irrigation scheme. This, therefore, makes it mandatory for alternative marketing strategies to be developed in order to enable the farmers get

maximum returns from their produce and simultaneously ensure that the water undertaker is paid for providing water and other inputs, which could have been supplied on credit to the farmers.

Although Kangocho Irrigation Scheme is located in the same geographical region as Kibirigwi, it is different in many ways from the later scheme.

- Unlike Kibirigwi which was initiated and funded by the Government, Kangocho was initiated and managed by the local farmers.
- Kangocho represents an exceptional case of how farmers can join hands and run a small-scale irrigation scheme with minimal costs.
- The farmers formed a self-help group whose membership is procured with payment of a nominal membership of fee of KShs.100 used in the maintenance of the water conveyance system.
- The farmers individually market their produce to the Karatina Wholesale market.
- The most striking aspect of the Kangocho farmers is their ability to organise themselves and improve their farming systems with minimum Government intervention.

The above lessons are relevant to irrigation scheme in the reservoir area. Previous mistakes should be avoided in order to realise the irrigation scheme benefits. With increasing population pressure on land resources, agricultural intensification is the only option to increasing food production and the carry capacity of the reservoir area.

10.5 ESTIMATION OF COSTS

The costs of implementing the proposed irrigation schemes cannot be determined in detail as no designs are available. However, the cost of implementing the existing irrigation schemes have been collected from the Ministry of Agriculture and the National Irrigation Board.

National Irrigation Board estimated an average figure of about Kshs 90,000 (2,000 US dollars) in 1987 per ha as the cost of developing one hectare of irrigible land including the required infrastructure for irrigation. On the basis of this figure, the proposed irrigation scheme of 520 ha would cost approximately Kshs 46.8 million (1.04 million US dollars).

Recent FAO studies give investment costs for preparing the field at 1975 prices as follows:

- Controlled flooding irrigation 3,000 US dollars
- Sprinkler irrigation 70,000 US dollars

On the basis of the evaluation of the types of irrigation technology currently used in Kenya, it is apparent that optimisation of investment on the irrigation scheme is not an easy task as the final decision depends on costs and availability of water, capital and manpower as well as the added value and market value respectively of the product.

The above figures, nevertheless, may underestimate the current costs of irrigation scheme since the economy has undergone significant changes from the time of the estimation and it will only be realistic to revise the figures to reflect the present inflationary trends. Therefore the foregoing estimates will only serve as a guide to the expected cost but the actual costs will have to be determined by the design, area and perimeter and other site specific factors.

The costs of the irrigation scheme implementation should take into account the following.

- Topographic and soil survey;
- Detailed design of irrigation scheme;
- Construction of water intake, conveyance and distribution system;
- Operational and maintenance costs;
- Manpower costs;
- Farmer training and technical support costs;
- Monitoring and evaluation costs; and
- The cost of mitigating anticipated impacts.

Considering the above items for irrigation implementation and maintenance, costs have been worked out in some cases as a percentage of the investment component. These percentages are figures based on experience gained from other schemes outside Kenya; but are indicative of what can happen to the proposed irrigation scheme. The estimates include:

- 1.5 - 3.5% for canals and structures;
- 10% for the canals and structures for irrigation alternatives;
- 7.5% for main and block roads; and
- 10% for unit roads.

Despite the lack of data to carry out Cost-Benefit Analysis, it is likely that the proposed irrigation scheme could be relatively expensive if land is not acquired freely, because of the choice of irrigation technology in an arid environment and if the farmers are not involved in the planning and management of the scheme.

Irrigation is not only a technical and investment process, but involves changes of attitude, knowledge and social behaviour. Several case studies have cited the absolute and/or relative failure of irrigation schemes because the human factor was ignored. Schliephake (1987) noted that small-scale irrigation schemes of 100 - 1,000 ha have good agricultural performance where there is the initiative for well-supported farmers. Instead of capital-intensive schemes with low participation from the actual water users, manpower-intensive schemes with a well-developed extension should be promoted. In light of these observations and experiences, the proposed scheme should be in the range of 100 to 1000 ha. We have suggested an ideal situation, approximately 520 ha.

10.6 ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

10.6.1 Environmental Impacts

Irrigated agriculture is associated with significant changes in the ecological and socio-economic environments (Nippon Koei 1995). These changes have potential adverse effects on the local communities and at times even threaten the very existence of irrigation schemes. The negative impacts are outlined below.

- Smallholder irrigation schemes have often triggered changes in the local ecosystem (Jewsbury 1984) which favour the breeding of disease vectors and proliferation of other water related diseases. The large expanses of stagnant or slow moving water encourage breeding of mosquitoes and snails, which transmit malaria and schistosomiasis (bilharzia). Helminthic infections, hepatitis, poliomyelitis and gastroenteritic diseases, such as amoebiasis, cholera, typhoid, dysentery may be directly transmitted from infected areas through water (Schliephake 1987).
- Increases in soil salinity and sodicity are associated with irrigation (Onyango-Ogembo 1982, Obara 1984, Nippon Koei, Co. 1993, Hungwe 1984). These are due to the accumulation of high amounts of the salts in the soil and more specifically, sodium salts in the case of sodicity. These affect crop performance. Sodic soils have unfavourable structural and drainage properties which tend to cause severe water-logging raising groundwater levels which exacerbates the salinity problems.
- Irrigation of relatively light textured soils of low cation exchange capacity with water of low salinity causes leaching of nutrients resulting in the gradual acidification of soils. This makes the soils less productive (Hungwe 1984).
- Irrigation return flow (waste water) is a repository for all the excess or waste pesticides, herbicides and fertilisers. This is a serious source of water pollution. The release of such chemicals contaminate ground water supplies with serious implications, on human health and through effects such as eutrophication cause severe perturbation of the aquatic systems.
- Serious problems of malnutrition have been experienced in irrigation schemes where there is a strict requirement for farmers to grow only the so-called designated crops to the exclusion of the critical food needs. This emphasis on specific crops has also resulted in the decline of agricultural diversification which has made farmers vulnerable to uncertainties.

- Through changes in the ecological and social environments irrigation may disrupt the lifestyle of communities and cause displacement of wildlife. Such disruptions may increase resource use conflicts between pastoralists, farmers and wildlife (Nippon Koei, 1993).
- Irrigation often involves the concentration of population within a small area from where they all derive their livelihood from limited land. The resulting overgrazing, cutting trees and soil erosion lead to land degradation and exposes such areas to the process of desertification.

Despite the above difficulties, irrigation schemes have several positive impacts which would not only benefit the communities inhabiting the proposed reservoir area but also the entire nation.

- Settlement of unemployed, underemployed and/or landless rural families who would otherwise probably drift to the towns and aggravate the urban problems.
- Improvement of the social welfare and economic status of the farmers through self-employment.
- Boosting agricultural production for foreign exchange earnings.
- Creating direct employment through the scheme employment system.
- Utilising the existing potential land by extending agricultural production to under-utilised land.
- Reclamation of unproductive marginal land.
- Facilitate balance in regional development.

10.6.2 Mitigation Measures

The following mitigation measures have been proposed to alleviate the impacts expected from irrigation scheme, which would lead to health improvement.

- Efficient water management which entails canal clearance to remove weeds would reduce the potential breeding sites for mosquitoes and snails.
- Regular changes in water level may also have a control on snail and mosquito populations. Alternatively, periodic desiccation to destroy these vectors may be necessary.
- Use of molluscicides to control snails if no alternative methods are available.
- Provision of sufficient alternative portable water supplies.
- Effective sanitation to reduce the prevalence of schistosomiasis and gastroenteritic infections transmitted by faecal oral routes.
- Correct situation of villages at least 2 km has been shown to be effective in reducing malaria.

- Social services and health education by public institutions.
- Health and epidemiological surveys and immunisation campaigns.

The management alternative required to alleviate problems of soil salinity are:

- Leaching excess salts from the soil profile with fresh water. But this must be carried out cautiously in order to avoid other side-effects.
- Addition of ameliorative substances to the soil to assist the washing out of salts, e.g. gypsum, to suppress capillary rise and the evaporation of soil solution.
- Frequent irrigation to maintain a more adequate soil water supply to the crop.
- Improvement of the uniformity of slope or level of land to allow for more uniform water application.
- Establishment of artificial drainage if water tables are a problem.

Problems of land degradation should be solved through encouraging agroforestry, intercropping, crop rotation, and good stock management through zero grazing.

The problems associated with water pollution may be addressed by:

- blending the return flow and re-using it in the field since it is highly enriched with nutrients.
- the adoption of cultural methods, such as use of high quality seed and disease resistant varieties to minimise the application of agrochemicals.
- use of composts to reduce fertiliser levels.

10.7 CONCLUSIONS AND RECOMMENDATIONS

The local communities in the reservoir area have become increasingly aware of the necessity of irrigation. This, together with TARDA's development plans for the Tana River Basin prompted an investigation of possible irrigation scheme sites close to the proposed reservoir. The identified sites in both Tharaka Nithi and Mwingi Districts are located downstream of the reservoir.

Irrigation schemes can provide some solutions to the food and income problems of the reservoir area. Experiences from elsewhere show that the success of irrigation is greater if the scheme is small, manageable and responsive to the needs and potentials of the indigenous people. The sites identified are large enough to accommodate irrigation schemes of 100 - 1000ha.

Preliminary assessment of the natural and human resources suggest that the environs of the proposed reservoir have moderate irrigation potential which when exploited properly would probably benefit the communities currently located in and around the proposed reservoir.

Experiences from small scale irrigation in Kenya and elsewhere in Africa reveal that:

- Proper site identification and design is essential for the success of small scale irrigation;
- The involvement of farmers in the initiation, planning and implementation is important in the organization of small scale irrigation projects;
- Farmer skills and favorable attitudes are required for the cost-effective management of such projects;
- Provision of adequate infrastructure such as water supply, transport, health and education is an integral component of small scale irrigation;
- Institutional involvement should be minimized as much as possible in the management of small scale irrigation and where necessary, it should be restricted only to the provision of technical advisory services.
- A marketing structure that maximizes farmer returns is also an important requirement.

On the basis of the above experiences we recommend the following:

- Before carrying out Cost-Benefit Analysis, detailed topographical and soil survey and design of irrigation scheme should be done.
- The communities impacted by the proposed reservoirs should be involved in the design and organization of the proposed scheme so as to avoid repeating previous mistakes.
- Farmers need to be trained to acquire the requisite skills and knowledge required for their effective participation in the management of the proposed project.
- The proposed irrigation should be based on cropping patterns compatible with market demands and this should be based on mixed cropping or mixed farming patterns.
- Monitoring and evaluation is an important management function which will be required as an integral part of the proposed schemes.