社会開発調査部報告書

No. 102

REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

# THE STUDY

ON

# REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

# THE STUDY

# ON

# THE NATIONAL WATER MASTER PLAN



# SECTORAL REPORT
# (E)

# AGRICULTURE AND IRRIGATION

JULY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

# LIST OF REPORTS

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# PREFACE

## Interpretation of Report

The original objective of this NWMP Study is to propose a nationwide framework for orderly planning and development of water resources in the country. The Study also deals with the formulation of individual development schemes. However, it should be noted that the plans formulated in this Study remain at a national level and do not provide complete details at local level. Further details should be examined in subsequent studies on each river basin, district, and project basis which are separately recommended in this Study.

## Administrative Division of Districts

In this Study, the original 41 districts were considered and various statistical data, particularly socio-economic information, were collected for these districts. During the progress of the Study, six districts were detached from the original ones and established as new districts. In the report, the data on these new districts are grouped together with the corresponding original districts as shown below.

| | Original Districts | New Districts | Data included in: |
|---|---|---|---|
| 1. | Machakos | Makueni | Machakos/Makueni |
| 2. | Kisii | Nyamira | Kisii/Nyamira |
| 3. | Kakamega | Vihiga | Kakamega/Vihiga |
| 4. | Meru | Tharaka-Nithi | Meru/Tharaka-Nithi |
| 5. | Kericho | Bomet | Kericho/Bomet |
| 6. | South Nyanza | Migori | South Nyanza/Migori |

(Note: The last three Districts were established very recently.
The report refers only to the names of the original 41 districts.)

The administrative boundary map used in this Study is the latest complete map set covering the whole country (41 Districts, 233 Divisions and 976 Locations), prepared in 1986 by the Survey of Kenya, Ministry of Land, Housing and Physical Planning.

## Data and Information

The data and information contained in the report represent those collected in the 1990-1991 period from various documents and reports made available mostly from central government offices in Nairobi and/or those analyzed in this Study based on the collected data. Some of them may be different from those kept in files at some agencies and regional offices. Such discrepancies if any should be collated and adjusted as required in further detailed studies of the relevant development projects.

## Development Cost

The cost and benefit estimate was based on the 1991 price level, and expressed in US$ equivalent according to the exchange rate of US$1 = KShs25.2 prevailing at that time. The same exchange rate was used in calculating the development cost in K£/KShs currency.

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# E1. AGRICULTURE

## 1.1 Introduction

Agriculture is still the mainstay of Kenya's growing economy. As shown in Table E1.1, the agricultural sector accounts for about 30% of Kenya's total Gross Domestic Product (GDP). Besides, agricultural products earned about K£ 475 million of foreign exchange in 1987 as shown in Table E1.2. The other agriculture sector's contribution to the Kenya's economy is to provide employment for 3 to 4.5 million people; i.e. almost a half of the labour is engaged in agriculture either directly or indirectly.

## 1.2 Land Resources

### 1.2.1 Landform

The Republic of Kenya covers an area of 592,262* $km^2$ of which 581,012 $km^2$ (98%) is Land Area and 11,250** $km^2$ (2%) is Water Area. The land is roughly divided into 23 physiographic regions and are further divided into total 41 physiographic regions. As presented in Table E1.3 sedimentary plains (44%) is the largest physiographic region and followed by uplands (11%), mountains & hills (10%), and plateau (9%).

Two kind of land form maps were produced, one is 1:1,000,000 scale map covering the whole country and another is a quarter million scale maps covering medium to high potential areas. Sectoral Report R presents further detailed description.

### 1.2.2 Soil

The condition of soil in Kenya has been studied and reported by the Kenya Soil Survey (KSS) during the past few decades. Among those studies and reports only the Exploratory Soil Map with scale of 1 to 1,000,000 covers the whole of Kenya. This soil map provides important information on soil characteristics for crop production such as, drainage condition, effective soil depth, colour, consistence, texture, salinity, sodicity, rockiness, stoniness, and texture.

According to this soil map, 26 soil classification units in FAO legend 1974, only 22 soil units are found in Kenya, e.g. Acrisols, Cambisols, Ferrasols, Greysols, Phaeozems, Fluvisols, Luvisols, Nitosols, Arenosols, Regosols, Solonetz, Vertisols, Planosols, and Solonchaks. Figure E1.1 shows their distribution patterns in Kenya and Table E1.4 shows their shares of area in Kenya. As given in this table, Solonetz soil is dominant in Kenya occupying 15% and followed by Luvisols (12%), and Cambisols (10%).

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* official figure of 582,646 $km^2$ plus 9,616 km2 which increased by correction of national boundary, measured by planimeter on a 1:1,000,000 map

** official figure of 11,230 $km^2$ plus 20 $km^2$ (Nyandarua District), information from DWE,Nyandarua.

### 1.2.3 Agricultural land

In view of agricultural production, rainfall amount is the most important factor. Thus, the Ministry of Agriculture (MOA) classified the land into four zones by means of annual rainfall amount. These four categories are;

- High Potential land : which receives an annual rainfall of 857.5 mm or more (over 980 mm in Coast Province)
- Medium potential land : which receives an annual rainfall of between 735 mm to 857.5 mm (735 mm - 980 mm in Coast Province and 612.5 mm - 357.5 mm in Eastern Province)
- Low potential land : which receives an annual rainfall of less than 612.5 mm

Table below shows acreage by categories in each Province and Table E1.5 shows acreage by District.

Agricultural Land

Unit: 1000ha

| Province | High | Medium | Low | Other | Total |
|---|---|---|---|---|---|
| Nairobi | 16 | 0 | 38 | 14 | 68 |
| Central | 909 | 15 | 41 | 353 | 1,318 |
| Coast | 373 | 796 | 5,663 | 1,472 | 8,304 |
| Eastern | 503 | 2,183 | 11,453 | 1,431 | 15,570 |
| North-Eastern | 0 | 0 | 12,690 | 0 | 12,690 |
| Nyanza | 1,218 | 34 | 0 | 0 | 1,252 |
| Rift Valley | 3,025 | 123 | 12,220 | 1,515 | 16,883 |
| Western | 741 | 0 | 0 | 82 | 823 |
| Total | 6,785 | 3,151 | 42,105 | 4,867 | 56,908 |
| (%) | (11.9) | (5.5) | (74.0) | (8.6) | (100.0) |

### 1.2.4 Agro-ecological zone

In 1982, MOA introduced another method to delineate agricultural potentiality of the land in more detail, i.e. a concept of agro-ecological zoning which were established by FAO in 1978. Table E1.6 describes characteristics of each agro-ecological zone.

Since available agro-ecological zone map does not cover the whole country, the Study team made agro-ecological zone map over Kenya by using available information. Annual rainfall data is collected from 212 stations as attached in the Hydrological Databook (DB.1). Potential evaporation is calculated on the basis of mean air temperature, mean relative humidity, mean daily sunshine hours and mean daily windrun according to modified penman method (MOA, 1988). The above data for calculation of potential evaporation and temperature data is collected from the following sources

- Climatological data of 90 stations (see Figure E1.2)
- Evapotranspiration in Kenya (MOWD, 1988)

The combination diagram of temperature belts and moisture availability zones is presented as agro-ecological zone in Figure E1.3. In the Figure, the name of potentially leading crops were used to indicate the zones. The other crops can also be grown in some other zones, but they are normally less profitable.

### 1.2.5 Land use

Present use in the land area was estimated by using information of Landsat image, Socioeconomic surveys under this Study and Publications.

Landsat Image

A total of 31 scenes of Landsat images were used to analyze present land use conditions of the whole country. All images were the latest (at 1989) and good quality (less cloud cover) data and were shot during the dry season in 1987. Based on these Landsat images and available topographic maps, a vegetation/landuse map was made as shown in Figure E1.4. Table E1.7 present the district-wise land use pattern based on Figure E1.4

Socioeconomic survey

A socioeconomic survey was carried out under this Study to collect the district level information of socioeconomy and infrastructure conditions in each District. The results of this survey are shown in Table E1.8

Publication

The Central Bureau of the Ministry of Planning and National Development released various publication of statistical information. Statistical Abstract, one of CBS's publication shows the land categories in each District as shown in Table E1.9

Present Land Use

Present land use condition of each District was grouped into six categories, forest & park, swamp, township, barrenland, agriculture land, and the other land.

Forest & Park : As presented in Table E1.10, a larger area between the data of Statistical Abstract and Landsat image was adopted for forest & park area in each District.

Swamp : Data interpreted from Landsat Image was used

Township : An area in the Statistical Abstract was adopted for township area in each District.

Barrenland : Data interpreted from Landsat Image was used

Agriculture land : Socioeconomic Survey results were applied

Other land : remaining area after reduction of above five categories from land area

Table E1.11 shows the estimated present land use in each District and summarized below.

Present Land use in Kenya

Unit : 1000 km$^2$

| Forest/Park | Swamp | Waters | Town ship | Barren land | Agricultural land | Other land | Total land |
|---|---|---|---|---|---|---|---|
| 65.7 | 6.7 | 11.3 | 4.5 | 75.2 | 46.6 | 382.3 | 592.3 |

## 1.2.6 Assessment of agricultural land potential

Objectives

The objectives of land assessment in the Study are;

(1) to determine the extent of agricultural potential land for assessing future agricultural production potential in the country, and
(2) to estimate irrigation potential by utilizing both surface and groundwater for each District and river basin.

These analyses were required to assess in a broad term whether the land in Kenya can support the agriculture productions required in the year 2010. It is not the study's attempt to prepare a land suitability map itself for physical agricultural/irrigation planning in each region.

In carrying out this assessment study, the Study Team received comments from the KSS that the Study should assess in detail the following nine parametres relevant to land qualities:

- availability of nutrients,
- hazard of sodicity,
- hazard of salinity,
- availability of foothold,
- availability of oxygen,
- availability of moisture,
- soil workability,
- erosion hazard, and
- potential for mechanization

Most of these information are location specific and it was considered to be almost beyond the scope of this nation-wide study to look into these details. The Study had neither sufficient time nor resources affording specific surveys and studies for

collecting these detailed information. Therefore, the Study had to adopt a macroscopic approach basically following the principles proposed in "A Framework for Land Evaluation (FAO/ILRI)". In this context, the method applied in this Study is simplified as compared with the KSS's current practices.

The results of land assessment study are presented in this report as a by-product of this Study. It is noted that the outcomes from this study are of preliminary nature and are to be further upgraded in the subsequent detailed surveys by KSS.

Method of Land Assessment

Potential agricultural land was estimated by the following two steps:

(i) evaluate land condition of soil, climate and topography
(ii) select suitable land for each crop

As shown in Figure E1.5, the land was assessed by selecting suitable conditions for the crop. The factors considered for assessment are soil, climate, topography and land reserve for forests and parks. The procedure of land assessment is as follows.

(i) Preparation of the following thematic maps
    Slope Classification Map*1
    Soil Map
    Agro-ecological Zone Map*2
    Land Use Control Map (Forests and parks)

(ii) Preparation of the assessment criteria for slope, soil (fertility, salinity, sodicity, drainage, effective soil depth, texture) and agro-ecological zone in order to assess land quality with various aspects

(iii) Preparation of land quality requirement for soil, slope, and AEZ in order to select the suitable area for crops

(iv) Selection of suitable area for the crop, applying above requirements to the land quality for the three thematic maps, namely, slope classification map, soil map and agro-ecological zone map

(v) Overlaying these three thematic maps

(vi) Extraction of forests and parks from selected land suitable area map.

The above procedure takes a different approach comparing with KSS's land evaluation method or sequence, however as explained in Appendix E1, basic

*1 The map was prepared by using 1:250,000 scale topographic map obtained from the SOK.

*2 Areas not covered by the Farm Management Handbook were produced under this Study.

methodology and concept of land assessment are identical with KSS's way.

The land potential maps for major crops were prepared using the available secondary data from the Farm Management Handbook. Soil data in the Farm Management Handbook were extracted from the Exploratory Soil Map of Kenya.

Assessment Criteria

The criteria for applying to this study was set up as follows

i) Soil

Soil is one of the important characteristics for assessing suitability of agricultural land. KSS uses a land assessment system modified from FAO Criteria to allow for the Kenyan condition. The proposed criteria for soil suitability classification is set forth based on availability of water, chemical soil fertility, salinity, sodicity, and erosion, possibilities of mechanization, (KSS, 1977 and 1987).

For this study, this modified assessment system is more simplified for general soil information from the exploratory soil map of Kenya. The simplified assessment system for suitability of major crops is based on soil texture, soil fertility, salinity, sodicity, drainage, and effective soil depth. Classification of each soil assessment category is described in following page. The suitability class table for soil mapping unit is shown Table E1.12.

In order to classify the land suitability for the major crop production, the appraisal was categorized into four suitability classes for maize, wheat, rice sorghum/millet, beans, potatoes, coffee, tea, cotton sugarcane, pyrethrum, sisal, horticultural crop and fodder crop from information in the Farm Management Handbook of Kenya (MOA, 1982) and Fertilizer Use Recommendation Project (MOA, 1988). Four suitability classes for principal crops were designated as follows:

| | |
|---|---|
| Class S1 : Highly suitable | Land has no or minor limitation which will reduce productivity for crops. |
| Class S2 : Moderately suitable | Land has limitation which is moderately severe in the land characteristics. The limitation will reduce productivity for most crops. |
| Class S3 : Marginally suitable | Land has severe land characteristics. The limitation will so reduce productivity for most crops. |
| Class NS : Not suitable | Land has very severe land characteristics and is not suitable for crops. |

Suitability class for principle crops based on the land characteristics are shown in Table E1.13. This table shows land requirements for various crops.

- Soil Fertility

KSS rated soil fertility generally for all major soil units identified in Kenya (Braun 1983). The criteria ranges from high to very low.

The fertility class for this study is based on the KSS conception and modified due to additional information from sub-soil units. This modified criteria of all soil unit is shown in Table E1.14. The fertility criteria is as follows:

Soil Fertility

| Suitability Class | Fertility Class |
|---|---|
| 1 | High |
| 2 | Moderate |
| 3 | Low |
| 4 | Very Low |

- Salinity

Soil salinity is an important characteristic for the assessment of the land suitability. Electrical conductivity (ECe) can indicate the soil salinity classes. Soil salinity is classified as follows:

Salinity

| | | ECe (mmho/cm) | |
|---|---|---|---|
| Suitability Class | Salinity class | 0 - 30 cm* | 30 - 100 cm* |
| 1 | Non-Saline | 0 - 4 | 0 - 8 |
| 2 | Slightly Saline | 4 - 8 | 8 - 15 |
| 3 | Moderately Saline | 8 - 15 | 15 - 30 |
| 4 | Strongly Saline | > 15 | > 30 |

* Soil depth

- Sodicity

Sodicity has an adverse effect on the chemical and physical condition of the soil. Sodicity of soil is expressed into the exchangeable sodium percentage (ESP) absorbed in the soil exchange complex. Soil sodicity is classified as follows:

Sodicity

| | | Exchangeable Sodium Percentage | |
|---|---|---|---|
| Suitability Class | Sodicity Class | 0 - 30 cm* | 30 - 100 cm* |
| 1 | Non-Sodic | 0 - 6 | 0 - 15 |
| 2 | Slightly Sodic | 6 - 15 | 15 - 30 |
| 3 | Moderately Sodic | 15 - 30 | 30 - 50 |
| 4 | Strongly Sodic | > 30 | > 50 |

* Soil depth

- Drainage

Soil drainage refers to the rapidity and extent of the removal of water from the soil especially by surface runoff and by flow through the soil. Availability of oxygen for root growth is directly related to soil drainage. Soil drainage is classified as follows:

Drainability

| Suitability Class | Drainage Class |
|---|---|
| 1 | Excessively to well drained |
| 2 | Moderately well drained |
| 3 | Imperfectly drained |
| 4 | Poorly drained |
| 5 | Very poorly drained |

- Effective Soil Depth

Effective soil depth refers to the extent of the root growth. Quantity of nutrition and water absorbed by plant root is related to the effective soil depth and texture. Effective soil depth is classified as follows:

Effective Soil Depth

| Suitability Class | Effective Soil Depth Class | Depth (cm) |
|---|---|---|
| 1 | Extremely deep | 180 < |
| 2 | Very deep | 120 - 180 |
| 3 | Deep | 80 - 120 |
| 4 | Moderately deep | 50 - 80 |
| 5 | Shallow | 0 - 50 |

- Soil Texture, Stoniness and Rockiness

Soil texture is given by the particle size distribution. The soil permeability and the water holding capacity are directly or indirectly related to soil texture. Soil textural class can be grouped as follows:

Soil Texture

| Code | Soil | Texture | Class |
|---|---|---|---|
| H | Heavy | Fine texture | C, SC and SiC |
| M | Medium | Moderately fine texture | CL, SCL and SiCL |
| | | Medium textured | L, SiL and Si |
| | | Moderately coarse textured | SL |
| L | Light | Coarse textured | S and LS |

* C:Clay S:Sand L:Loam Si:Silt

Stoniness is defined in loose mineral fragment, which is the diameter from 7.5 to 25 cm. Rockiness is defined in outcrops of solid rock at the soil surface. Stoniness and rockiness indicate that land condition is not suitable for crops due to low workability, low fertility and shallow of the effective soil depth.

The code of stoniness and rockiness are expressed as S and R in this report for the assessment.

ii) Agro-ecological Zone

Aforementioned in Section 1.2.4, the agro - ecological zone system has been introduced for the purpose of assessing particular crops and crop varieties suited for specific areas (MOA, 1982 and 1988). The assessment is made on the basis of air temperature (T) and moisture availability (r/Eo)

Temperature zones are defined on the basis of annual mean air temperature and mean maximum temperature as follows:

Temperature Zones

| Name of Belt | Symbol | Annual Mean Temp. | Mean Max. Temp. |
|---|---|---|---|
| Tropical Alpine Belt | TA | 2 - 10 | |
| Upper Highland Belt | UH | 10 - 15 | |
| Lower Highland Belt | LH | 15 - 18 | |
| Upper Midland Belt | UM | 81 - 21 | |
| Lower Midland Belt | LM | 21 - 24 | |
| Lowland | L | | |
| Inner Lowland | IL | > 24 | > 31 |
| Coastal Lowland | CL | > 24 | < 31 |

Moisture availability zones are defined on the basis of the ratio of the annual precipitation / potential evaporation (r/Eo) as follows:

Moisture Availability Zones

| Zone Number | Term used for Zones | Ratio of Annual precipitation/ Potential Evaporation |
|---|---|---|
| 0 | Perhumid | 1.20 < r/Eo |
| 1 | Humid | 0.80 < r/Eo < 1.20 |
| 2 | Sub-humid | 0.65 < r/Eo < 0.79 |
| 3 | Semi-humid | 0.50 < r/Eo < 0.64 |
| 4 | Transitional | 0.40 < r/Eo < 0.49 |
| 5 | Semi-arid | 0.25 < r/Eo < 0.39 |
| 6 | Arid | 0.10 < r/Eo < 0.24 |
| 7 | Per-Arid | r/Eo < 0.10 |

iii) Land Gradient / Slopes

Land gradient is one of the most important land element in view of high erosion susceptibility and low workability. For this study, a slope classification map was made from contour map (1:250,000 scale) by GIS. The following table indicates land slope classification from Class 1 to Class 6 expressed as percent of slope.

Slope Classification

| | Gradient (%) | Class | Land Suitability |
|---|---|---|---|
| Class 1 | 0 - 2 | flat to very gently undulating | Suitable for paddy field |
| Class 2 | 2 - 5 | gently undulating | |
| Class 3 | 5 - 8 | undulating | Suitable for irrigated farming* |
| Class 4 | 8 - 16 | rolling | Suitable for rainfed farming* |
| Class 5 | 16 - 30 | hilly | Marginal for rainfed farming* |
| Class 6 | > 30 | steep | Unsuitable for agriculture |

Note : * exclude rice
Source : Table E1.15 and Table E1.16

The land with less than 16% (class 1 to 4) graded may be regard as suitable land for rainfed farming not including rice, but class 5 (16 - 30%) is marginal and will require soil conservation measures. Class 6 (more than 30%) is not suitable for agriculture Therefore, the land defined on Class 6 is excluded from potential agriculture land.

According to KSS, the land with more than 8% in slope is classified into unsuitable land for irrigation farming of upland crop. And the land with more than 2% in slope is unsuitable land for irrigated and rainfed paddy field. (KSS, 1981, Ref. E22 and Table E1.15 and E1.16).

Land Use Control

The government designates forest reserves and national park areas. Such government land use control shall remain as it is for the purpose of conservation of watershed and wildlife. Therefore, those lands are excluded from the agriculture potential land.

In Kenya, about 21,870 $km^2$ is occupied by forest of which 16,614 $km^2$ is gazetted and 5,256 $km^2$ is ungazetted forest. Table E1.17 shows these gazetted/ungazetted forest name and area, and Figure E1.6 shows their location. National parks in Kenya have about 27,200 $km^2$ as shown in Table E1.18. Figure E1.7 indicates the locations of national parks and game reserves in the country as of September 1990.

Land Potential for Agriculture

Using the above criteria and GIS technology, the land area suitable for major crops were assessed. The size and spacial distribution of potential land use are attached in Appendix E6. Table E1.19 presents district-wise land potential area.

## 1.3 Crop Production and Area

Crop planted in the land is considerably diversified, ranging from staple crops of maize, rice, sorghum and industrial crops for local industries, to major export crops of coffee, tea and pyrethrum. Statistical data of crop production and cropped area of these crops were

obtained from District Agricultural Offices through the Socioeconomic Survey as compiled in Appendix E2 and Figure E1.8.

Appendix E2 shows District base crop production, crop area and unit value for a period of 12 years from 1978 to 1989. Figure E1.8 illustrates the trend of Kenya's production and crop area for each major crop.

Based on the above production and crop area, the unit yield of major crops was calculated and illustrated their trends of last 12 years as shown in Figure E1.9. As seen in this Figure, rice has only descending trend from 4.9 ton/ha in 1978 to 3.2 ton/ha in 1989.

## 1.4 Export and Import

Most of the cash crops like coffee, tea, and pyrethrum are exported. Foreign-exchange earnings of agricultural products accounted for about K£619 million or 62% of total exports in 1989. Especially, coffee and tea shared almost half of total exports as shown in Table E1.2. Import of agriculture products less than 4% of total imports over the past ten years. Imported agricultural products are mainly grains such as wheat and rice maize. Table E1.20 shows imported food during 1978-1989.

## 1.5 Food Demand

To achieve self-sufficiency within the country, the Government set up the major foodstuff production target in the year 1993/2000 as follows.

Food Production Targets

*Unit : 1,000 ton*

| Food | SP1 (2000) | DP (1993) |
|---|---|---|
| Maize | 4,400 | 3,090 |
| Wheat | 400 | 255 |
| Milk | 3,600 | 1,693 |
| Meat | 420 | 181 |

SP1 : Sessional Paper No.1 of 1986
DP : Development Plan 1989-1993

These targets were estimated based on 1979 census and population growth rate of 3.7% per annum. In this Study, food production targets in 2000 and 2010 were reestimated based on the projected population which is derived from the interim data of 1989 census (see Sectoral Report A).

### 1.5.1 Per capita consumption

Official figure of per capita consumption of major foodstuff is available from MOA. The MOA projected per capita consumption in the year 2000 assuming the people's taste of diet in rural area is different from that in urban area but the people's taste of diet in future will not change until the year 2000. In this Study, future per capita consumption was estimated by applying MOA's unit per capita consumption (see table below) and manner.

Unit Per Capita Consumption

(Unit:kg/p/year)

| Foods | Urban | Rural |
|---|---|---|
| Maize | 97.1 | 125.6 |
| Millet | 0.0 | 19.8 |
| Wheat | 24.7 | 10.0 |
| Rice | 13.1 | 1.4 |
| Potatoes | 14.8 | 26.2 |
| Other roots | 3.0 | 30.5 |
| Sugar | 30.0 | 15.0 |
| Pulses | 13.8 | 14.2 |
| Milk | 88.6 | 72.1 |
| Beef | 11.9 | 6.8 |
| Fat | 6.5 | 1.7 |
| Vegetable | 36.9 | 20.4 |
| Fish | 1.9 | 1.7 |

Source: MoA

### 1.5.2 Food demand in 2010

Food demand in the future was estimated by the production of per capita consumption and projected population. The results are presented in Table E1.21 and summarized below together with present production.

Food Demand Projection

Unit: 1000 ton

| | Present Production* | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Population (million) | | 22.749 | 26.389 | 30.712 | 35.209 | 40.305 |
| Maize | 2762 | 2744.3 | 3157.3 | 3631.4 | 4135.2 | 4700.4 |
| Sorghum/Millet | 219 | 371.9 | 413.3 | 451.0 | 497.7 | 546.6 |
| Wheat | 298 | 285.7 | 344.9 | 423.7 | 500.2 | 589.8 |
| Rice | 44 | 78.2 | 101.4 | 135.8 | 167.2 | 204.9 |
| Potatoes | 849 | 550.8 | 628.5 | 714.2 | 807.6 | 911.2 |

* Average production of recent 5 years from 1985 to 1989 (see Table E1.22)

As can be seen in this table, maize, wheat and potato have been exceed in self-sufficiency rate of 100% at present. While, in the year 2010, 4.7 million tons of maize (1.7 times present production), 0.55 million tons of sorghum/millet (1.5 times present production), 0.59 million tons of wheat (2 times present production), 0.20 million tons of rice (4.5 times present production) and 0.91 million tons of potatoes (1.1 times present production) will be required.

## 1.6 Land Use Plan

Agricultural production may generally increase either by expanding crop area or by increasing unit yield. In view of agricultural land for expanding crop areas, there is much enough agricultural potential land as assessed in Subsection 1.2.6. The comparison of present agricultural land and potential agricultural land are summarized below.

Comparison between Present and Potential Crop Lands

Unit: 1000ha

| | Maize | Wheat | Rice | Sorghum/Millet |
|---|---|---|---|---|
| Present | 1,500 | 140 | 15 | 270 |
| Potential | 5,000 | 1,350 | 1,300 | 7,200 |

### 1.6.1 Land requirement

Increasing unit yields on the present condition is also one of the effective way to accelerate agricultural production to feed a growing population. Government/MOA anticipated their unit yields and projected various agricultural production in future. Table E1.23 shows the projected unit yields of irrigated and rainfed crops based on the MoA's information and the assumption that the existing trends continues in future.

Agricultural land requirements are calculated by dividing food demands by projected unit yields as shown below.

Preliminary Land Requirement in 2000 and 2010

| Crop | Present Land (1000ha) | 2000 Food Demand (1000ton) | 2000 Required. Land (1000ha) | 2010 Food Demand (1000ton) | 2010 Required. Land (1000ha) |
|---|---|---|---|---|---|
| Maize | 1,500 | 3,631 | 1,397 | 4,700 | 1,469 |
| Wheat | 140 | 424 | 157 | 590 | 147 |
| Sorghum | 270 | 451 | 410 | 547 | 420 |
| Rice | 15 | 136 | 23 | 205 | 33 |
| Total | 1,925 | | 1,987 | | 2,069 |

This table appears somewhat unrealistic. For example, major crops of maize was assessed to require less area in 2000/2010 comparing with present land area for maize and wheat area also decreases from 157 in 2000 to 147 in 2010. Therefore the unit anticipated yields were estimated form trend projection as shown in Figure E1.9. While, average unit yield was applied for rice because of its negative trend (see Section 1.3). Following table shows applied unit yield and calculated required land in 2000 and 2010 respectively.

Land Requirement in 2000 and 2010

| | 2000 Food Demand (1000ton) | 2000 Target Yield (ton/ha) | 2000 Required Land (1000ha) | 2010 Food Demand (1000ton) | 2010 Target Yield (ton/ha) | 2010 Required Land (1000ha) |
|---|---|---|---|---|---|---|
| Maize | 3,631.4 | 2.4 | 1,513 | 4,700.4 | 2.8 | 1,679 |
| Wheat | 423.7 | 2.8 | 151 | 589.8 | 3.4 | 173 |
| Millet/Sorghum | 451.0 | 1.2 | 376 | 546.6 | 1.5 | 364 |
| Rice | 135.8 | 3.0 | 45 | 204.9 | 3.0 | 68 |
| Total | | | 2,085 | | | 2,284 |

### 1.6.2 Land use plan

(1) Specific condition

National expansion programmes of coffee and tea

In Sessional Paper No.1 of 1986, the national expansion programmes for coffee and tea are presented. These programmes aim to attain the following by 2000:

National Expansion Programme

| Crop | Total area |
|---|---|
| Coffee | 275,000 ha |
| Tea | 124,000 ha |

The above target crop area for both coffee and tea was adopted to the Study.

Crop area requirement

As mentioned in the Subsection 1.6.1, required crop area for major crops in 2010 was estimated at 1.7 million ha for maize, 0.2 million ha for wheat, 68 thousand ha for rice. Crop area for the other crops, which exclude major crops, coffee and tea, was assumed to increase annually with the same trend of maize.

Growth Rate of Crop Area

| Crop | unit | 1990 | 2010 | Annual increasing rate |
|---|---|---|---|---|
| Maize | million ha | 1.5 | 1.68 | 0.6% |
| Other crops | million ha | 1.77 | 1.99 | |

Then the crop land requirements in 2010 for major crops are as follows.

Land Requirement in 2010

Unit: 1000ha

| Crop | Land Requirement |
|---|---|
| Maize | 1,679 |
| Wheat | 173 |
| Millet/Sorghum | 364 |
| Rice | 68 |
| Coffee | 275 |
| Tea | 124 |
| Others | 1,995 |
| Total | 4,678 |

Land use intensity

According to the information from MOA and Socioeconomic Survey of this

Study, total crop area in 1990 was estimated at about 3.9 million ha, while about 4.6 million ha was used for agricultural production. The land use intensity is then calculated at about 80% for the present. Present cropping practice will be intensified in future to raise agricultural production level. In this Study, future cropping intensity was assumed to change from 80% to 90%

Township area

Although the present township area was summarized in Statistical Abstract 1991 (Ref.E.4), there is no available information on the expansion of township area. In the Study, the expansion of township area was broadly estimated referring to the past trend of urban size and population growth in Nairobi. The urban size has been expanded at a half rate of population growth in Nairobi for a period of 16 years from 1963 to 1979.

| | unit | 1963 | 1979 | Annual rate |
|---|---|---|---|---|
| Urban size(*) | sq.km | 428 | 684 | 3% (**) |
| Population | nos. | 342,764 | 805,775 | 6% (***) |

Note , (*) : includes township area, forest, park and agricultural land.
(**) : annual expansion rate
(***) : annual growth rate
Source : Kenya : A Study in Physical and Human Geography (pp178)

Population growth rate in Kenya was estimated at about 3% per annum, then the half of growth rate of 1.5% per annum was adopted for the estimation of future township area. It is noted that the population density which is largely different from town to town was disregarded to the estimation. Thus, the larger town has sometimes less township area due to intensive land use. Table E1.24 shows the estimated township area in 2010 for each District.

(2) Land use plan

Table E1.25 presents the future land use plan by District and Figure E1.10 illustrates the present and future land use plan in the country. Assumptions for preparing these Table and Figure are:

- Forest and National Reserve are not changed
- National Park and Game reserve are not changed
- Barrenland and swamp are not available for agriculture and livestock
- Township area is not available for agriculture and livestock
- Present crop intensity of 80% will increase to 90%

## 1.7 Agriculture Development

### 1.7.1 Government policy

Agricultural development policy in Kenya is formally defined in the sixth Development Plan 1989-1993 (Ref.E.2) and Food Policy paper (Ref.E.33). In those documents, the Government of Kenya has set objectives for agricultural development including;

growth of agricultural GDP
increasing foreign exchange earnings
food security
increasing employment
generation of revenue
regional equity
increasing farm incomes
national resource conservation

To achieve the above objectives, the Government of Kenya has set up many programs and targets such as coffee and tea expansion programs, food and horticultural crop production targets.

### 1.7.2 Agricultural development

In line with the national agricultural development policy and targets, relevant government agencies, MOA and river basin development authorities set up various agricultural development projects. As tabulated in Table E1.26, Districts have various agricultural development plans or programmes such as national extension programme, soil and water conservation, horticulture development, and irrigation development. And many past studies recommended agricultural development programme/projects to meet the objectives of agriculture sector mentioned above focusing on the contribution to regional or basin wide agricultural development.

In this Study, nation-wide programme/projects are recommended to contribute to agricultural development directly or indirectly such as

1) Land Use Survey,
2) Agricultural Potential Survey, and
3) Agricultural Production Survey

Land use survey aims at determining the present land use conditions in Kenya. The results are needed to formulate a future land use plan not only for agriculture but also for the other sectors like forestry, industry, and rural development. Agricultural Potential Survey analyses soil condition and evaluates suitability of agriculture development in more detail than mentioned in this report to plan the future agriculture development at an implementable level. Agricultural Production Survey also determines the present agricultural condition for further agricultural development plan. At present many kinds and amount of agricultural

data is available from various agencies. Despite the availability and amount of data, their quality and reliability need more improvement for further reliable agricultural plans.

Total fund for these surveys was roughly estimated at about US$12.2 million - US$3.8 million for Land Use Survey, US$5.8 million for Agricultural Potential Survey and US$2.6 million for Agricultural Production Survey.

## E2. IRRIGATION

In Kenya three major types of irrigation are practiced - private irrigation, smallholder irrigation, and Government managed irrigation. Total area of irrigation performed by these three types is about 65,000 ha as shown below.

Irrigation in Kenya

| Type | Irrigation area (ha) |
|---|---|
| Private | 25,800 |
| Smallholder | 27,200 |
| Managed by Government | 12,000 |
| Total | 65,000 |

Ref. E.23, 37, 45

As seen in the table, private irrigation takes the largest share of total irrigation area, mainly in coffee plantations. Smallholder and Government managed irrigation areas are planted mainly food crops and vegetables.

Various Government Agencies are involved in irrigation planning and implementation. The Ministries or parastatal agencies concerned are :

Ministry of Water Development (MOWD)
Ministry of Agriculture (MOA)
Ministry of Regional Development (MORD)
Ministry of Planning and National Development
Ministry of Reclamation and Development of Arid, Semi-Arid and Wasteland
Ministry of Research, Science and Technology
Ministry of Energy
Office of the President
National Irrigation Board (NIB)
Tana and Athi River Development Authority (TARDA)
Lake Basin Development Authority (LBDA)
Kerio Valley Development Authority (KVDA).
South Ewaso N'giro River Basin Development Authority
North Ewaso N'giro River Basin Development Authority

Among these Government agencies, MOA, MOWD, MORD and parastatals are the main agencies. MOA supports smallholder irrigation and parastatals operate large scale irrigation schemes as well as small scale irrigation schemes.

Data and/or information are available from those agencies concern but less information is available on the private irrigation scheme.

## 2.1 History of Irrigation in Kenya

Irrigation practices in Kenya existed some centuries ago along the Lower Tana applying flood irrigation or along the escarpment of Rift Valley using furrow irrigation. Thereafter irrigation practices have been continuing up to date overcoming many difficulties and issues. Irrigation history in Kenya can be broadly grouped into the following five periods (Ref.E.19).

| | |
|---|---|
| 1 Slave-labour irrigation | Before abolition of slavery, slave labour was used in constructing irrigation systems and farming operations up to the end of the 19th century. |
| 2 Pre-war Colonial Irrigation | Construction of Kenya-Uganda railway imported many workers from India and those people planted vegetables with irrigation for railway crews. |
| 3 War Time Irrigation | During World War II, irrigation activities were carried out at Naivasha and Taveta for horticulture crops and on the lakeshores of Victoria for rice production. |
| 4 Post-war Colonial Irrigation | Colonial Government achieved a broad agricultural rehabilitation programme to control the land occupation by European Settlers. Such as Mwea, Hola, Perkerra, Ishihara and Yatta schemes were implemented under this programme and labours of prisoner and/or detainees. |
| 5 Post Independence Irrigation | The National Irrigation Board, (NIB) was established in 1966 to develop and improve the national irrigation schemes in Kenya. The three Regional Authorities, TARDA, KVDA and LBDA, were born between 1974 and 1980 to develop the regional economy including the implementation of large scale irrigation schemes. |

At present, irrigation schemes have been implemented and managed by various official agencies with GOK's own fund and/or foreign aid funds and also there are some private large scale and many small scale irrigation schemes in Kenya. Recent major irrigation activities can be tabulated chronologically as follows.

| | |
|---|---|
| 1970's | Construct Ahero, Bunyala, West Kano schemes (Dutch fund) |
| 1977 | Start Small Scale Irrigation Development Project (MoA/Dutch) |
| 1978 | Implement Bura scheme (IBRD,Dutch etc.) |
| 1978 | Yala Swamp F/S (Dutch fund) |
| 1980's | Many kind of donor reports on irrigation in Kenya |
| 1980's | Garissa Integrated Development Project |
| 1980 | National Master Water Plan Stage I |
| 1981 | Smallholder rice rehabilitation programme (SRRP1) |
| 1981 | Lower Tana Village Irrigation Programme (LTVIP) |
| 1983 | Extension of Tana Delta Irrigation Project (Haskonig and Mwenge) |
| 1985 | Pre-F/S on Kano Plain Irrigation Project (Japan fund) |
| 1987 | Outline Plan and Feasibility Study of Irrigation Development along the Shore of |

| | |
|---|---|
| | Lake Victoria |
| 1987 | Inventory and Study of Traditional Irrigation Furrows in Elgeyo Marakwet District |
| 1987 | Master Development Plan - Establishment of PIU - Western |
| 1988 | D/D on Tana Delta Irrigation Project (Japan fund) |
| 1989 | Rehabilitation of Mwea Irrigation Project (Japan fund) |
| 1991 | Tana Delta Irrigation Project (Japan fund) |

## 2.2 Present Conditions

Existing schemes

About 65,000 ha of existing irrigation schemes are organized into 25,800 ha of Private, 27,200 ha of Smallholder and 12,000 ha of GOK managed schemes. Table E2.1 presents acreage of these schemes for each District. The sizes of these schemes ranges from 1 ha to more than 20,000 ha. About 60% of the total number of scheme have an area of less than 100 ha. The name and area of each scheme are given in Appendix E5.

Proposed Irrigation Project

About 160 irrigation schemes with a total area of about 118,000 ha have been proposed by various agencies. Table E2.2 shows the area and numbers of these irrigation schemes in each District. Appendix E5 gives the information of proposed schemes.

## 2.3 Water Demand

### 2.3.1 Water requirements

Monthly irrigation water requirements for both existing and proposed schemes were determined in three modes:

Mode A : For schemes with available documents or information, the data presented in those reports/paper are used.

Mode B : For schemes with no documents, information on water requirements presented in "Water Requirement for Irrigation in Kenya" (Ref. E15) is used.

This document was prepared by MOWD in 1985, for estimating irrigation requirement in Kenya. Calculations were made for 72 locations and two different cropping patterns, one is a green grass cover throughout the year and the other one is a typical pattern. The 72 locations are listed in Table E2.3 and shown in Figure E2.1. Applied monthly water requirements for both cropping patterns are cited from this document and shown in Table E2.4.

Mode C : For private commercial schemes, water abstraction amounts registered at Water Apportionment Board (WAB) are used.

The information of water abstraction for irrigation use was retrieved from the database system in MOWD. Appendix E.3 gives the list of water permit which has information of abstraction point and amount. To estimate monthly water requirement, water permit amount was converted into abstraction amount on monthly basis under the following assumptions

- water permit under normal flow condition (N) was allocated every month.
- water permit under flood flow condition (F) was allocated only for flood flow month.

The flood flow month means was defined as the month which has larger monthly mean discharge than annual mean discharge. Table E2.5 shows an index of flood flow month for each subbasin.

### 2.3.2 Present water demand

i) 'A' mode calculation

Only four NIB schemes have data on irrigation water requirements. Table E2.6 shows monthly irrigation demand for those four schemes.

ii) 'B' Mode calculation

Monthly irrigation demand by subbasin was estimated for about 330 existing schemes.

iii) 'C' Mode calculation

As of October 1990, about 7,800 water permits were registered at WAB for irrigation. Out of 7,800 permits, 940 permits have not enough data to show their abstraction points. Tables E2.7 and E2.8 presents the estimated abstraction amount using the remaining 6,900 permits data under the assumptions on flood and normal flow conditions. From these tables, annual water abstraction amount was calculated at about 28.2 MCM.

Table E2.9 presents an estimate of the total irrigation water demand in 1999 by basin as summarized below :

Water Use by Existing Irrigation Schemes

Unit $m^3$/sec

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23.7 | 26.9 | 45.2 | 53.1 | 57.2 | 48.2 | 39.7 | 40.4 | 50.4 | 54.1 | 57.3 | 54.5 | 45.9 |

### 2.3.3 Future water demand

i) 'A' Mode calculation

In addition to the four NIB's schemes, another 18 proposed schemes have data on irrigation water requirements as shown in the Table E2.10.

ii) 'B' Mode calculation

Water requirements for about 110 proposed schemes and 330 existing schemes were estimated by the 'B' mode calculation.

iii) 'C' Mode calculation

For estimating future water permits, a past trend curve was prepared for each basin as shown in Figure E2.2. As can be seen in this figure, there is no trend in all basins. Then the annual average increasing amount of water permits was employed for estimating newly applicable water permits in future (see Table E2.11).

Monthly water demand by subbasin in 2010 was estimated as given in Table E2.12 and summarized below.

Water Demand in 2010

Unit $m^3$/sec

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 93.4 | 100.4 | 126.1 | 133.9 | 143.9 | 130.4 | 110.2 | 128.6 | 158.6 | 184.3 | 162.5 | 146.4 | 134.9 |

## 2.4 Development of Irrigation Systems

### 2.4.1 National policy

According to the sixth Development Plan 1989-1993, the Government set up irrigation development targets during 1989-1993 period as follows.

Irrigation Target

Unit : ha

| Targets | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|
| Present | 33,000 | 34,380 | 35,760 | 38,440 | 41,880 |
| Increment | 1,380 | 1,380 | 2,680 | 3,440 | 3,670 |
| Total | 34,380 | 35,760 | 38,440 | 41,880 | 45,550 |

The Plan emphasizes a low cost approach in the implementation, and the small scale irrigation projects and utilization of gravity flow are given preference.

### 2.4.2 Irrigation potential

Potential of irrigation development in Kenya has been assessed at about 540,000 ha by NMWP in 1980, while a recent study carried out by Euroconsult in 1987 estimated total potential area for irrigation to be about 244,000 ha. Table below gives a comparison of these two estimates for five river basins. The figures include existing irrigation area.

Estimate Irrigation Potential

(Unit : ha)

| Basin | Existing | Study in 1980 | Study in 1987 |
|---|---|---|---|
| Tana | 19,000 | 205,000 | 90,900 |
| Athi | 15,900 | 40,000 | 49,500 |
| Lake Victoria | 5,600 | 200,000 | 57,400 |
| Kerio Valley | 4,000 | 64,500 | 31,200 |
| Ewaso N'giro(N) | 1,300 | 30,000 | 15,700 |
| Total | 45,800 | 539,500 | 244,000 |

In this Study re-assessment of irrigation potential in Kenya was carried out by comparing water availability with both irrigation water requirements and suitable land area for irrigation development. Groundwater has a higher priority for domestic and livestock water usage, however irrigation potential by groundwater is also examined.

a) Irrigation Potential by surface water

land resources

Information of soil and topography was assessed to estimate the extent of land potentially suitable for irrigated agriculture by applying GIS technology. The GIS procedure is almost same as the method of land assessment by GIS, namely;

select land potential for agricultural production considering;
- land gradient
- soil conditions
- temperature

deduct following area form above agricultural potential land
- major township area
- forest, park and national reserves
- major road assuming 100 m width
- remote area from rivers more than 10 km

Figures E2.3 and E2.4 show the distribution of land suitable for upland crops and lowland crops, respectively. The total area suitable for irrigation in Kenya is about 13 million ha for upland crops or about 11 million ha for paddy if water availability is disregarded.

Crop Land Potential in Kenya

Unit : million ha

| Crop | Basin 1 | Basin 2 | Basin 3 | Basin 4 | Basin 5 | Total |
|---|---|---|---|---|---|---|
| Upland Crops | 2.57 | 1.77 | 2.05 | 3.86 | 2.99 | 13.23 |
| Paddy | 0.74 | 1.68 | 1.46 | 3.25 | 3.64 | 10.77 |

water requirements

As mentioned in Section 2.3.1 irrigation water requirements for two different cropping patterns and 72 different locations covering whole of Kenya (Fig. E2.1) were calculated by MOWD . Based on this information of irrigation requirements for green grass cover, monthly unit irrigation demand by basin was estimated as given in Table E2.13.

water availability

The basin mean and 80% dependable monthly flows were applied for the estimation of irrigation water availability after reduction of domestic and livestock water consumption. The basin mean monthly flow is summarized in Table E2.14

irrigation potential

Estimation of the irrigation potential for each subbasin was derived through matching mean flow/80% dependable monthly flow and irrigation demand and taking account into the following assumptions:

1 Domestic & livestock water usage takes priority over irrigation
2 Return flows are disregarded
3 Surplus water is allocated to downstream requirements following river system as illustrated in Figure E2.5
4 No storage facilities are considered
5 Sub-basin irrigable area is limited within land potential

In case that the basin mean monthly flows were applied to the calculation, about 470,000 ha of land is available for upland crop irrigation and 340,000 ha is available for paddy irrigation. A basin-wise break down of the irrigation potential is indicated below and Table E2.15 shows irrigation potential area of each subbasin.

Irrigation Potential Area by Surface Water

Unit : 1000 ha

| Crop | Basin 1 | Basin 2 | Basin 3 | Basin 4 | Basin 5 | Total |
|---|---|---|---|---|---|---|
| Upland Crops | 214.2 | 84.3 | 22.4 | 132.7 | 16.0 | 469.6 |
| | (178.5) | (52.0) | (21.0) | (89.2) | (9.3) | (350.0) |
| Paddy | 136.6 | 47.9 | 21.9 | 117.3 | 14.6 | 338.3 |
| | (114.7) | (33.1) | (20.3) | (85.0) | (8.5) | (261.6) |

Note : Parenthesized figures show the results for applying 80% dependable monthly flow.

b) Irrigation Potential by Groundwater

Irrigation potential for groundwater is also assessed in the same manner as assessment of surface water potential.

groundwater quality

Water quality is one of the important factors to evaluate irrigation water. The quality of groundwater was evaluated for 1,169 boreholes whose water quality data was available (see Sectoral Report C in detail). Based on FAO's evaluation guideline, the criteria for evaluation was made as shown in Figure E2.6. Out of ten parameters in Figure E2.6, seven parameters of quality data are available. These are pH, Electrical conductivity, Chloride, Flouride, Sodium, Manganese and Iron. Tables E2.16, E2.17, and E2.18 presents the FAO's evaluation guideline. Applying this criteria to available water quality data, about 500 boreholes have unsuitable water for irrigation use. The distribution of these boreholes is as shown in Figure E2.7.

Based on the isoquality map presented in Sectoral Report C and criteria (see Figure E2.6) seven maps were prepared to clarify the extent of good quality groundwater area for irrigation as shown in Figure E.2.8. The overall groundwater quality map for irrigation was derived from overlaying these seven maps. The results are given in Figure E2.9.

land resources

Procedure is almost same as assessment of available surface water. Areas reduced from agricultural potential land include township,forest & park, road and less water quality area.

Figures E2.10 and E2.11 shows the distribution of land suitable for upland crops and lowland crops, respectively. The total area suitable for groundwater irrigation in Kenya is about 9 million ha for upland crops or about 7 million ha for paddy.

Crop Land Potential in Kenya (Groundwater)

Unit : million ha

| Crop | Basin 1 | Basin 2 | Basin 3 | Basin 4 | Basin 5 | Total |
|---|---|---|---|---|---|---|
| Upland Crops | 1.88 | 2.12 | 1.29 | 1.80 | 2.08 | 9.17 |
| Paddy | 0.41 | 2.43 | 0.65 | 1.33 | 1.90 | 6.72 |

water requirements

Water requirements for groundwater irrigation is in the same manner as adopted for surface water irrigation.

groundwater availability

Groundwater availability for each sub-basin was estimated as shown in Table E2.19 and summarized below. Detailed discussion of this groundwater availability is presented in Sectoral Report C.

Groundwater Availability

Unit : $m^3$/sec

| | Basin 1 | Basin 2 | Basin 3 | Basin 4 | Basin 5 | Total |
|---|---|---|---|---|---|---|
| Water availability | 1.408 | 3.668 | 2.604 | 4.985 | 7.939 | 20.604 |

irrigation potential

Irrigation potential for each sub-basin was derived through matching groundwater availability and irrigation water demand and taking into account the following assumptions :

1 Available groundwater is calculated by multiplying land potential area with unit groundwater yield,
2 Return flows are disregarded, and
3 Surplus water can not be allocated to other sub-basin

Calculation of the water balance between water demand and available water, indicates that about 1,500 ha of land is available for upland crop irrigation and 1,000 ha is available for paddy irrigation. A basin-wise breakdown of the irrigation potential is indicated below.

Irrigation Potential Area by Groundwater

Unit : ha

| Crop | Basin 1 | Basin 2 | Basin 3 | Basin 4 | Basin 5 | Total |
|---|---|---|---|---|---|---|
| Upland Crops | 598 | 544 | 372 | 0 | 0 | 1,514 |
| Paddy | 155 | 660 | 210 | 9 | 4 | 1,038 |

c) Comparison of estimated Irrigation Potential

The irrigation potential in Kenya has been estimated by two studies so far, namely, National Master Water Plan Stage I (NMWP-I) in 1980 and Study on Options and Investment Priorities in Irrigation Development in 1986 (SOIPID) . Their estimated figures for each river basin are summarized below together with estimated potential areas calculated by this Study.

Estimated Irrigation Potential

Unit : ha

| | | NMWP-I | SOIPID | this Study | | |
|---|---|---|---|---|---|---|
| | | Surface Water* | Surface Water* | Surface Water* | Surface Water** | Ground Water |
| 1 | Lake Victoria | 200,000 | 57,400 | 214,000 | 178,500 | 900 |
| 2 | Kerio Valley | 64,500 | 31,200 | 84,300 | 52,000 | 500 |
| 3 | Athi River | 40,000 | 49,500 | 22,400 | 21,000 | 650 |
| 4 | Tana River | 205,000 | 90,900 | 132,700 | 89,200 | 250 |
| 5 | Ewaso N'giro (N) | 30,000 | 15,700 | 16,000 | 9,300 | 160 |
| | Total | 539,500 | 244,700 | 469,600 | 350,000 | 2,400 |

Note * monthly mean flow was applied.
** 80% dependable monthly flow was applied.

Assumptions for these calculation greatly differ with each other as tabulated below.

Assumptions of each Study

| Item | NMWP-I | SOIPID | this Study |
|---|---|---|---|
| River water | monthly mean flow | monthly mean flow | monthly mean flow & 80% dependable flow |
| Domestic Water | disregarded | considered | considered |
| Hydrological study | done | none | done |
| Cropping Pattern | seven typical cropping patterns | some typical cropping patterns | green grass cover throughout the year |
| Total number of water requirement pattern | 12 patterns | ? | 72 patterns |
| Land evaluation | covered available soil map, part of Kenya | each project area | whole country |
| Groundwater | disregarded | disregarded | estimated |

Major difference points are water requirement and land evaluation. Two other studies applied specific cropping pattern while this Study employed cropping pattern of green grass cover which represent maximum water use. Then the potential area estimated by this Study is minimum area. Needless to say land resources assessment is indispensable for these estimation. The Study carried out land assessment with the available soil map which covered a part of Kenya. The other study of SOIPID employed past study results of land assessment covering a part of Kenya.

Especially spacial distribution of the irrigation potential was not clear for the other two studies while this Study illustrate the irrigation potential as shown in Figures E2.3, E2.4 and attached drawing.

### 2.4.3 Irrigation development

As mentioned in previous section, Kenya has considerable potential for irrigation. At present, only 17% of potential area is irrigated. To develop these potential areas, the following strategy can be drawn up taking into account the government policy and social &

economic conditions in Kenya.

- small scale irrigation scheme would be given top priority
- irrigation area adjoining densely populated District or Location would be given high priority
- those area where only irrigation is the watering method for agriculture would be given high priority

Under the above strategy, small scale irrigation schemes and some selected large scale irrigation schemes are recommended to attain the agricultural/irrigation development target in the year 2010.

a) Small scale irrigation project

About 140 schemes are proposed and total area of proposed scheme is about 7,000 ha. In line with government policy for irrigation development, these small irrigation developments have top priority in implementation. These small scale schemes would be implemented by farmers themselves with assistance of MOA or other government agencies concerned. The cost for implementation was estimated at about Kshs 287 million applying unit cost of 41,000 Kshs/ha. Unit cost was calculated from available data as shown in Figure E2.12

b) Large scale irrigation project

About 160 irrigation schemes were proposed by various agencies. Among those irrigation schemes, 18 large scale schemes were selected for further analysis to formulate water development plan in Kenya taking into account the following criteria.

1) Area should have more than 500 ha
2) Some report/paper exist
3) Official proposed scheme

List of Irrigation Schemes

| Name | Area (ha) | Name | Area (ha) |
|---|---|---|---|
| Arror | 1340 | Lower Rupingazi | 1800 |
| Kano Plain | 25640 | Mwea Ext. | 2900 |
| Kanzalu | 4055 | Sabaki Ext. | 3000 |
| Kibwezi Ext. | 13200 | Tana Delta | 12000 |
| Kimira | 2000 | Taveta | 3780 |
| Kunati | 1050 | Thanantu | 2520 |
| Lower E.'Ngiro | 10000 | Turkwel | 600 |
| Lower Kuja | 1900 | Upper Nzoia | 7550 |
| Lower Nzoia/Bunyala | 10480 | Yala Swamp | 7540 |

Detailed information of selected projects are described below and compiled in Appendix E4, Irrigation Project Sheets. Figure E2.13 shows location of these schemes.

1) Arror

Project area is located at Kerio valley along the left bank of the Kerio River. The irrigable lands are grouped into four Blocks with a net area of 1,340 ha and require a peak flow of 2.0 $m^3$/sec which will be fed by the tailwaters from the power station. Two pipelines will convey the irrigation water, one is for Blocks 1 and 2, and another is for Blocks 3 and 4. Sprinkler systems are recommended for this area mainly due to the soil and topographic conditions. Proposed crops are cash crops, vegetables, and fruit. These crops will get about 21,000 Kshs/ha/annum.

2) Kano Plain

Project area is located at about 380 km northwest from Nairobi in the central part of Nyanza Province. The area extends southeast of Kisumu town and lies on the flat terrain so called Kano Plain. First development plan of Kano Plain was proposed in the Kenya Nile Basin Water Resources Survey in 1956. Total Project area (73,000 ha) was organized into 13,000 ha of swamp, 50,000 ha of arable/natural vegetation and 10,000 ha of other area. About 25,000 ha of paddy and upland field would be irrigated by transferring the water from Sondu River after power generating of about 60MW by Sondu/Miriu Dam.

The Report on the Feasibility Study for Kano Plain Irrigation Project was issued by JICA in early 1992. This feasibility plan envisages the irrigation of 15,000 ha, out of a total 25,000 ha, as the first approach to the Kano Plain development. Peak irrigation water requirement is estimated at about 19 $m^3$/sec in March. Proposed major crops are maize, sorghum, paddy, cotton, and beans and about Kshs 642 million per annum would be earned by the Project. Further development in the remaining 10,000 ha which is located on the right bank of Nyando River would require the implementation of flood mitigation project prior to agricultural/irrigation development.

3) Kanzalu

The Kanzalu irrigable area is located between Kanzalu Range and Athi River about 60 km east from Nairobi. Among a total potential irrigable area of 12,000 ha, about 5,000 ha was investigated which consists of three irrigable areas:

Block A : covering a net irrigable area of 1,750 ha between Ndithe and Athi Rivers,
Block B : covering a net irrigable area of 2,560 ha situated on the peneplain between Kanzalu Range and Ndithe River; and
The valley bottoms between Blocks A and B.

The water sources for the scheme will be the regulated flow from Athi River. Headworks will be constructed downstream of Fourteen Falls in order to divert the required water of about 1.1 $m^3$/sec into a 21 km long main canal.

Recommended crops for the scheme are maize, beans, onions, robusta coffee and rice. About 23,000 Kshs/ha of benefit is expected and about Kshs 300 million will be required to construct headworks, main canal, and tertiary systems.

4) Kibwezi extension

The Kibwezi scheme is located on the right bank of Athi River between the Yatta Gap and the Mtito Andei River with an area of around 30,000 ha. The area is mainly divided into four Blocks:

| | | |
|---|---|---|
| Block A | : | 1,920 ha |
| Block B | : | 4,050 ha |
| Block C | : | 5,980 ha |
| Block D | : | 8,970 ha |

Headworks would be constructed 8km downstream of Yatta Bridge on Athi River. Diverted irrigation water will be conveyed to the proposed nightstorage reservoir by a 26 km long main canal. The location of the nightstorage reservoir will be within the Masongaleni River Valley. After nightstorage reservoir, lined secondary and tertiary canals will convey the water to each irrigation block and field.

Recommended crops for this area are maize, beans, cotton, groundnut and vegetables. About 13,000 Kshs/ha of benefits is expected at full development stage.

A Pilot Irrigation Project has been undertaken by TARDA at about 20 km east of Kibwezi Town. The Authority intended to expand this Pilot project from 55 ha to 135 ha to evaluate;

- the range of crops that could be successfully grown under irrigation in Kibwezi area
- alternative methods of irrigation that can be adopted in the large Kibwezi Scheme.

5) Kimira

The Kimira scheme is located west of Kendu Bay town in South Nyanza District. This area has very flat topography with an average elevation of 1,140 m. Due to poor drainage condition and low topography level, part of the area is submerged during the rainy season. At present, the area is used as grazing land. Irrigation water of about 2.2 $m^3$/sec will be diverted from the Awach Kibuon River and conveyed through about 3 km unlined canal to the area rice, maize, cotton and groundnut are proposed to earn the benefit of about 26,000 Kshs/ha.

6) Kunati

Kunati scheme is located east of Meru town in Meru District. Proposed major crops are cotton, maize, vegetables, and tobacco. Estimated peak irrigation water requirement is about 0.4 $m^3$/sec and annual mean requirement is 0.33 $m^3$/sec. The Thanantu River is the expected water source.

7) Lower Ewaso Ngiro

The area is located to the west of Lake Magadi. The area is suitable for large scale irrigation development due to favorable topography, soils, and climate. The TARDA planned the following activities for the implementation of this scheme;

- establishment of a pilot irrigation project
- aerial photography and topographical surveys of the project area
- semi detailed soil survey
- irrigation planning

8) Lower Kuja

Project area is located at about 110 km southwest from Kisumu town in South Nyanza District. Stagewise development plan, namely Phase I and Phase II will develop the 1,900 ha of total irrigation potential area. First Phase of 750 ha will produce about 12,000 Kshs/ha of benefit per annum. Proposed crops are maize, groundnuts, pulses, cotton, and vegetables. The irrigation water would be pumped from Kuja River by the six engine pumps into lined canal which will convey the water to the project area. Estimated peak discharge is 1.3 litre/sec/ha.

9) Lower Nzoia/Bunyala Extension

These two irrigation schemes are located along the both side of Nzoia River near the rivermouth at Lake Victoria in Busia and Siaya Districts. The area is about 125 $km^2$ with an average elevation of 1,180 m. This area includes the existing Bunyala irrigation scheme. Two main canals on both banks will convey the irrigation water from intake weir. Experimental farm is proposed to seek high value added crops under irrigated agriculture. Proposed crops are cotton, maize, groundnuts, pulses, rice, and vegetables.

10) Lower Rupingazi

This scheme is located at about 10 km from Embu town. The net area of 1,800 ha extends on both side of Rupingazi River. The land in the project area comprises slopes of less than 5% except along the river channel. Sprinkler irrigation systems are recommended in this area due to soil and social conditions. Proposed crops are cotton, tobacco, maize, pulses and vegetables. The peak water requirement for the project is estimated at about 1.1 $m^3$/sec in November. The Rupingazi River is the source of irrigation water.

11) Mwea extension

Mwea irrigation project is located near Sagana town about 80km northwest from Nairobi in Kirinyaga District with a total area of 16,000 ha. It extends over the flat land on the outskirts of Mt.Kenya with an elevation of 1,100 m. This irrigation project comprises the existing Mwea Irrigation Settlement Scheme of 12,000 ha and

the extension area of 4,000 ha. At present following works are on-going for existing Settlement Scheme:

Rehabilitation of headworks
Rehabilitation of main canal
Rehabilitation of link canal
Construction of a Pilot Farm

Extension area has 2,470 ha of paddy field and 430 ha of horticulture land. Upon completion of the Project, Kshs 85 million of benefit from rice and Kshs 23 million of benefit from horticultural crops are expected. A dam with storage capacity of 18 MCM is proposed on Thiba River for the whole Mwea irrigation project.

12) Sabaki Extension

The Sabaki irrigation area is located on the left bank of Sabaki River on the flood plains of the Dagmra Area. For the purpose of costing , a 150 ha pilot scheme is proposed. Irrigation water for this pilot area will be extracted from the Sabaki River by means of boreholes along the river banks. During two years pilot operation period, following investigation and study are proposed:

- method of water conveyance
- method of water intake
- test drilling
- feasibility study for the full development of this project

Detail design and nine years construction works will follow this pilot scheme. Proposed crops are maize, green gram, groundnuts, cotton and vegetables. About Kshs 35 million per annum is expected as the project benefit at full development stage.

13) Tana Delta

Tana Delta is a vast lowland which lies in the most downstream basin of Tana River with the extent of about 2,000 $km^2$. This project is situated in this Delta at about 9 km east from Garsen town with 12,000 ha, which is comprised of three empoldered areas i.e. Polder-1 (4,500 ha), Polder-2 (3,850 ha) and Polder-3 (3,650 ha). Rice cultivation is proposed to earn the annual benefit of Kshs.590 million at full development stage. The total cost required for the implementation of the whole area is about Kshs.3,830 million. Due to the substantial amount of the investment cost and the managerial capacity required for the implementation of the whole project, Polder-1 was selected as first priority development scheme. At present, this Polder-1 area is now under construction. The TARDA is the executing agency for this project.

14) Taita Taveta

The area is located near Taveta town in Taita Taveta District extending along the

Lumi river. Existing small scale irrigation schemes, in total covering about 550 ha have some physical and organizational problems; namely,

- Some part of the area is underlain by a caliche at shallow depth
- Lack of drainage systems
- saline groundwater
- regular flooding
- adequate extension services and lack of a farmers organisation

The water sources for those irrigation schemes are the Lumi River and springs. A resources survey carried out by TARDA identified about 3,800 ha of irrigation potentials in this area. It is noted that about 70% of the project area is in private land. The following detailed investigations are required for development of the whole area;

- detailed surface and groundwater resources assessment including the present water management system in private land
- aerial photograph and mapping of the project area
- semi detailed soil surveys
- irrigation planning

15) Thanantu

The scheme is located at about 20 km east from Meru town in Meru District. The Thanantu River forms the northern boundary while Kuuru River forms the southern boundary. A sprinkler system has been recommended due to the high permeability of the volcanic soils. Irrigation water will be diverted from the Thanantu River. Proposed crops are cotton, maize, tobacco and citrus. The cost of irrigation system is estimated at 112,500 Kshs/ha including weir, intake, settling tank and distribution system.

16) Turkwel

The area is located at about 50 km downstream of Turkwel Dam. Total area of 600 ha comprises five small cluster of 120 ha each which are scattered on both side of the Turkwel River. The proposed crops for each cluster are cotton, maize, green gram, fruit and vegetables. Gross margin of each cluster was calculated at Kshs 391,000. Several points can be raised concerning this project:

- Existing Turkwel irrigation schemes were reported to have a particularly poor record of production and suffered large cost over-runs,
- Impact on supplying water to downstream users,
- Impact on fuel wood resources, and
- Reliability of water for irrigation after regulating river flow by the Turkwel Dam.

If ecological and institutional problems are disregarded, more than 7,000 ha can be irrigated around this area after completion of Turkwel Dam.

17) Upper Nzoia

The area is located at about 20 km south from Kitale town in Bungoma District.

This area covers a total area of 176 $km^2$ with an elevation of 1,700 m. The landform is hilly with occasional steep slopes. A Pilot scheme is proposed to obtain information on a series of agricultural, economic and social problems and to train an initial nucleus of technicians and farmers. This Pilot scheme will have a 300 ha and will need an investment of Kshs 36 million. Sprinkler irrigation is proposed to irrigate hilly area. To irrigate the whole area of 9,400 ha in gross, a dam having a capacity of 75 MCM is required. The total cost of the irrigation scheme and dam will be Kshs 1,077 million or 114,000 Kshs/ha. Proposed crops for pilot scheme are orange, maize, and vegetables.

18) Yala Swamp

The Yala Swamp is located in the Siaya and Busia Districts of Nyanza and Western Provinces. The swamp itself was formed by the deposition of silt from the Yala River at the point where the river flows into Lake Victoria. In addition to the Yala River, the Hwiro River (seasonal river) also flows into the Yala swamp.

The Swamp has been divided into three areas. The 2,300 ha Area I is the name given to the area which was reclaimed in 1970 and is now being cultivated. The 9,200 ha Area II forms the main body of the swamp and is the area which would be reclaimed by gravity drainage. The 6,000 ha Area III is the swamp which is generally below the level of Lake Victoria and is considered to be only reclaimable by the construction of polders and pumping out of the water.

The reclamation of the Yala Swamp was first proposed in the Kenya Nile Basin Water Resources Study 1956. After this proposal various studies have been undertaken on the reclamation of the Yala Swamp. As early as the 1960's a start was made with the reclamation of the Yala Swamp resulting in the drying out of Area I. Detailed designs and tender documents for Area II were prepared in 1982. Latest proposal is reclamation and development of Area II by extension and expansion of the existing Yala River diversion canal, diverting the Hwiro river and reconstructing the existing dyke

(c) Cost and Benefit

Project cost and benefit of above schemes have been estimated in respective Project Reports or documents published by the government agencies concerned. Based on the these estimated cost and benefit, total irrigation development cost and expected project benefit at 1991 price were calculated as tabulated in Table E2.20.

## 2.5 Development Priority Ranking

The order of development priority for the above 18 large scale irrigation schemes was determined by viability of the following five aspects

1 Water availability
2 Present status

3 Population impacts
4 Environment
5 Economic

### 2.5.1 Water availability

For the irrigation scheme, water availability is the most important factor as a matter of course. In general water availability of river flow is presented by their water reliability expressed by percentage, for example 80% reliability means, a drought year will occur once in five years. Hydrological analysis revealed water availability of those irrigation schemes as follows. Detailed discussions on this matter are presented in Sectoral Report M.

| Name | Water reliability (%) | Order | Score (A) |
|---|---|---|---|
| Arror | 80 | 1 | 1 |
| Kano Plain | 80 | 2 | 1 |
| Kunati | 80 | 3 | 1 |
| Lower Kuja | 80 | 5 | 1 |
| Bunyala Extension | 80 | 4 | 1 |
| Mwea Extension | 80 | 6 | 1 |
| Sabaki Extension | 80 | 7 | 1 |
| Tana Delta | 80 | 8 | 1 |
| Turkwel | 80 | 9 | 1 |
| Thanantu | 37 | 10 | 10 |
| Kanzalu | 23 | 11 | 11 |
| Yala Swamp | 23 | 12 | 11 |
| Kimira | 20 | 13 | 13 |
| Lower Rupingazi | 20 | 14 | 13 |
| Upper Nzoia | 13 | 15 | 15 |
| Kibwezi Extension | 0 | 16 | 16 |
| Lower E.Ngiro | 0 | 17 | 16 |
| Taita Taveta | 0 | 18 | 16 |

### 2.5.2 Present status

Present status of each scheme was assessed by their study level so far completed, for example feasibility level study scheme has a priority over the prefeasibility (Pre F/s) and master plan level schemes. Study level of each scheme is as follows.

| Name | Status | Order | Score (E) |
|---|---|---|---|
| Tana Delta | D/D | 1 | 1 |
| Kano Plain | F/S | 2 | 2 |
| Lower Kuja | F/S | 3 | 2 |
| Mwea Extension | F/S | 4 | 2 |
| Yala Swamp | F/S | 5 | 2 |
| Arror | PreF/S | 6 | 6 |
| Kanzalu | PreF/S | 7 | 6 |
| Kibwezi Extension | PreF/S | 8 | 6 |
| Kimira | PreF/S | 9 | 6 |
| Kunati | PreF/S | 10 | 6 |
| Bunyala Extension | PreF/S | 11 | 6 |
| Lower Rupingazi | PreF/S | 12 | 6 |
| Sabaki Extension | PreF/S | 13 | 6 |
| Thanantu | PreF/S | 14 | 6 |
| Turkwel | PreF/S | 15 | 6 |
| Upper Nzoia | PreF/S | 16 | 6 |
| Lower E.'Ngiro | M/P | 17 | 17 |
| Taita Taveta | M/P | 18 | 18 |

### 2.5.3 Population impacts

If the scheme's location is remote from densely populated areas, a severe problem of transmigration of farmer may occur. And the construction cost in remote area is expensive in general. The following table shows the number of people in the scheme area who will benefited by those schemes.

| Name | People (nos) | Order | Ranking (C) |
|---|---|---|---|
| Kano Plain | 68200 | 1 | 1 |
| Mwea Extension | 42900 | 2 | 2 |
| Bunyala Extension | 30500 | 3 | 3 |
| Upper Nzoia | 15300 | 4 | 4 |
| Yala Swamp | 13500 | 5 | 5 |
| Kanzalu | 9600 | 6 | 6 |
| Kimira | 8400 | 7 | 7 |
| Kibwezi Extension | 8400 | 8 | 7 |
| Thanantu | 4800 | 9 | 9 |
| Kunati | 3300 | 10 | 10 |
| Taita Taveta | 3200 | 11 | 11 |
| Lower Kuja | 3100 | 12 | 12 |
| Sabaki Extension | 2900 | 13 | 13 |
| Lower Rupingazi | 1800 | 14 | 14 |
| Lower E.'Ngiro | 1400 | 15 | 15 |
| Tana Delta | 500 | 16 | 16 |
| Arror | 70 | 17 | 17 |
| Turkwel | 30 | 18 | 18 |

### 2.5.4 Environment

As discussed in Sector Report N, environmental impacts of selected irrigation schemes are assessed as shown in Table E2.21. This table was made from Table N.11.3 giving score of "1" point for probably no impact, "-1" point for possible impact and "-2" point for probable impact respectively. Total score of these point is given in following table. Average score of 3 was given as the total score for the schemes of Kunati, Thanantu and Upper Nzoia where the impact assessment is absent.

| Name | Total Score | Order | Score (D) |
|---|---|---|---|
| Lower Rupingazi | -3 | 1 | 1 |
| Arror | 0 | 2 | 2 |
| Kimira | 0 | 3 | 2 |
| Lower Nzoia/Bunyala | 0 | 4 | 2 |
| Kano Plain | 2 | 5 | 5 |
| Yala Swamp | 2 | 6 | 5 |
| Kanzalu | 3 | 7 | 7 |
| Kibwezi Ext. | 3 | 8 | 7 |
| Kunati | 3 | 9 | 7 |
| Lower Kuja | 3 | 10 | 7 |
| Mwea Ext. | 3 | 11 | 7 |
| Sabaki Ext. | 3 | 12 | 7 |
| Thanantu | 3 | 13 | 7 |
| Upper Nzoia | 3 | 14 | 7 |
| Taita Taveta | 5 | 15 | 15 |
| Tana Delta | 7 | 16 | 16 |
| Turkwel | 8 | 17 | 17 |
| Lower E.'Ngiro | 10 | 18 | 18 |

### 2.5.5 Economic

For economic comparison, internal rate of return (IRR) was calculated for each scheme after adjusting cost and benefit. If no data/information is available IRR is calculated by the estimated cost and benefit and assumed flow of cost/benefit.

Among 18 schemes nine schemes have no information of IRR, then those scheme's IRR was calculated under the following assumption:

- Project life of scheme would be 50 years
- Construction works would complete within five years and each year would have 20% progress.
- O & M cost would be estimated at Kshs 10,000 for each one hector (see Fig. E2.14)
- Replacement cost of facility would be 10% of construction cost (see Fig. E2.14) and would be needed every five years
- The benefits would be derived after completion of facility i.e. from sixth year. The build-up period would take five years. During this build-up period, the benefits would increase linearly; 20% of full benefits in the sixth year, 40% in seventh year, 60% in eighth year and 80% in ninth year.

These assumptions for the calculation of IRR are illustrated in Figure E2.15 schematically.

Calculation results of IRR and net present value are summarized in the following table together with IRR figures cited from respective reports.

Summary of Calculation Results

Unit : Kshs million

| Project | Net Present Value (10%) Cost | Benefit | B-C | B/C | IRR | |
|---|---|---|---|---|---|---|
| Arror | 198.79 | 180.55 | -18.2 | 0.91 | 3.0% | |
| Kano Plain | 2859.51 | 4112.97 | 1253.5 | 1.44 | 16.3% | |
| Kanzalu | 818.55 | 1161.15 | 342.6 | 1.42 | 12.1% | |
| Kibwezi extension | 2363.39 | 3779.90 | 1416.5 | 1.60 | 12.6% | |
| Kimira | 476.17 | 438.01 | -38.2 | 0.92 | 9.1% | * |
| Kunati | 125.66 | 300.70 | 175.0 | 2.39 | 23.4% | * |
| Lower Ewaso 'Ngiro | 1685.90 | 1756.93 | 71.0 | 1.04 | 10.5% | * |
| Lower Kuja | 106.38 | 183.08 | 76.7 | 1.72 | 18.4% | |
| Bunyala Ext. | 790.22 | 1407.42 | 617.2 | 1.78 | 23.2% | * |
| Lower Rupingazi | 215.44 | 515.44 | 300.0 | 2.39 | 23.4% | * |
| Mwea extension | 1388.73 | 3483.69 | 2095.0 | 2.51 | 15.5% | |
| Sabaki Extension | 562.19 | 859.07 | 296.9 | 1.53 | 4.7% | |
| Tana Delta | 2999.30 | 1942.62 | -1056.7 | 0.65 | 14.0% | |
| Taita Taveta | 438.48 | 664.09 | 225.6 | 1.51 | 16.3% | * |
| Thanantu | 485.94 | 442.75 | -43.2 | 0.91 | 8.9% | * |
| Turkwel | 43.25 | 29.95 | -13.3 | 0.69 | 6.4% | * |
| Upper Nzoia | 2201.21 | 1013.93 | -1187.3 | 0.46 | 2.3% | * |
| Yala Swamp | 872.26 | 167.74 | -704.5 | 0.19 | -2.9% | |

* : Estimated by Study Team

Above cost and benefit has been adjusted by applying escalation rate which estimated based on the cost index table (Ref.E4) as shown in Table E2.22.

From above table, the following economic ranking table was made.

| Name | IRR | Order | Score (E) |
|---|---|---|---|
| Kunati | 23.4 | 1 | 1 |
| Lower Rupingazi | 23.4 | 2 | 1 |
| Bunyala Ext. | 23.2 | 3 | 3 |
| Lower Kuja | 18.4 | 4 | 4 |
| Tana Delta | 16.3 | 5 | 5 |
| Kano Plain | 16.3 | 6 | 5 |
| Mwea Ext. | 15.5 | 7 | 7 |
| Taita Taveta | 14 | 8 | 8 |
| Kanzalu | 11.7 | 9 | 9 |
| Lower E.'Ngiro | 10.5 | 10 | 10 |
| Kimira | 9.1 | 11 | 11 |
| Thanantu | 8.9 | 12 | 12 |
| Kibwezi Ext. | 6.7 | 13 | 13 |
| Turkwel | 6.4 | 14 | 14 |
| Sabaki Ext. | 4.7 | 15 | 15 |
| Arror | 3 | 16 | 16 |
| Upper Nzoia | 2.3 | 17 | 17 |
| Yala Swamp | -2.9 | 18 | 18 |

### 2.5.6 Priority ranking

Priority ranking of selected irrigation schemes are so determined as less total score scheme has priority over bigger score schemes. Total score of each scheme and its priority ranking are given in following table.

| Name | Score (A) | (B) | (C) | (D) | (E) | Total | Priority Ranking |
|---|---|---|---|---|---|---|---|
| Kano Plain | 1 | 2 | 1 | 5 | 5 | 14 | 1 |
| Bunyala Extension | 1 | 6 | 3 | 2 | 3 | 15 | 2 |
| Mwea Extension | 1 | 2 | 2 | 7 | 7 | 19 | 3 |
| Kunati | 1 | 6 | 10 | 7 | 1 | 25 | 4 |
| Lower Kuja | 1 | 2 | 12 | 7 | 4 | 26 | 5 |
| Lower Rupingazi | 13 | 6 | 14 | 1 | 1 | 35 | 6 |
| Kanzalu | 11 | 6 | 6 | 7 | 9 | 39 | 7 |
| Kimira | 13 | 6 | 7 | 2 | 11 | 39 | 7 |
| Tana Delta | 1 | 1 | 16 | 16 | 5 | 39 | 7 |
| Yala Swamp | 11 | 2 | 5 | 5 | 18 | 41 | 10 |
| Arror | 1 | 6 | 17 | 2 | 16 | 42 | 11 |
| Sabaki Extension | 1 | 6 | 13 | 7 | 15 | 42 | 11 |
| Thanantu | 10 | 6 | 9 | 7 | 12 | 44 | 13 |
| Kibwezi Extension | 16 | 6 | 7 | 7 | 13 | 49 | 14 |
| Upper Nzoia | 15 | 6 | 4 | 7 | 17 | 49 | 14 |
| Turkwel | 1 | 6 | 18 | 17 | 14 | 56 | 16 |
| Taita Taveta | 16 | 18 | 11 | 15 | 8 | 68 | 17 |
| Lower E.'Ngiro | 16 | 17 | 15 | 18 | 10 | 76 | 18 |

## 2.6 Recommendations

Out of 18 schemes, construction of Tana Delta schemes has commenced and implementation of Mwea Extension scheme was pledged by the GOJ in 1991. These two schemes will produce mainly paddy of about 45,000 ton per annum. In view of rice production, existing schemes and these two schemes will provide enough rice production till the year of 2005 as shown in Figure E2.16. To ensure the food security, generating employment and contribution of Kenya's economy, all small scale irrigation schemes and some large scale irrigation schemes are recommended to be implemented within the next two decades. The implementation schedule for the irrigation development is shown in Figure E2.17. The total capital expenditure on this irrigation development would be about Kshs. 25,900 million (K£ 1.295 billion). The following table shows annual estimated expenditures.

Estimated Annual Expenditures

Unit : Kshs. million

| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|
| Amount | 273.6 | 823.2 | 854.4 | 248.2 | 386.9 | 1119.2 | 573.9 | 410.6 | 626.0 | 872.1 |

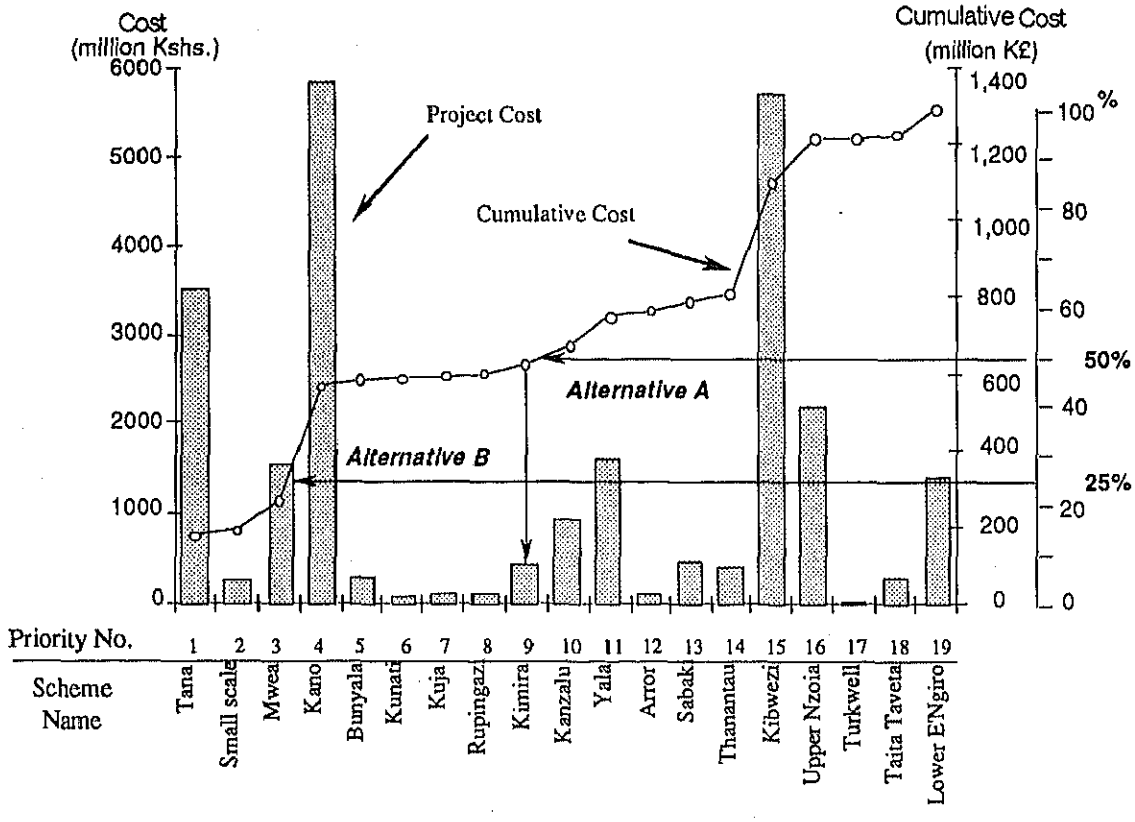
| Year | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | after 2010 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount | 913.2 | 1254.1 | 1275.7 | 2696.4 | 3543.8 | 3075.3 | 2609.3 | 2011.2 | 395.1 | 1920.0 | 25,882 |

## Alternative development plan

As estimated in Section 8.2 of Sectoral Report A, the total cumulated public expenditures for development projects related to water resources development from 1992 to 2010 will be K£6.8 billion (see Table A8.1). Out of K£6.8 billion, K£2.5 billion will be expended by MOWD and about 18% of the remaining will be allocated to irrigation development. Namely, about K£ 0.8 billion of capital is expected to invest for irrigation development projects. Considering this financial constraints on this irrigation sector, following two alternative development plan were examined.

Alternative - A : K£ 650 million (50% of total requirement) would be available
Alternative - B : K£ 325 million (25% of total requirement) would be available

Based on the recommended priority for development order and current irrigation development conditions, following budget requirement graph were prepared for selecting irrigation schemes so as not to exceed anticipated cumulated public expenditure for irrigation development projects.




As can be seen in above illustration, following irrigation schemes would be implemented under the Alternative -A and B.

Alternative - A : Tana Delta , Small Scale, Mwea Ext., Kano Plain, Bunyala Ext., Kunati, Lower Kuja, Lower Rupingazi,
Alternative - B : Tana Delta , Small Scale, Mwea Ext.

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# *TABLES*

Table E1.1 Gross Domestic Product,1981 - 1988

Percentage of Total GDP at Constant (1982)Prices (%)

| Item | 1981 | 1882 | 1983 | 1984 |
|---|---|---|---|---|
| A. Traditional Economy | 5.55 | 5.49 | 5.56 | 5.71 |
| B. Monetary Economy | | | | |
| 1. Enterprises and Non-Profit Institutions: | | | | |
| Agriculture | 30.15 | 32.15 | 31.92 | 30.44 |
| Manufacturing | 12.66 | 12.42 | 12.68 | 13.13 |
| Wholesale,Retail Trade, Restaurants and Hotels etc. | 11.21 | 10.00 | 10.03 | 10.51 |
| Others | 24.58 | 24.13 | 23.66 | 23.71 |
| Total | 78.60 | 78.70 | 78.29 | 77.79 |
| 2. Private Householdes | 1.07 | 1.09 | 1.13 | 1.20 |
| 3. Governnment Services | 14.78 | 14.72 | 14.99 | 15.30 |
| TOTAL GDP | 100.00 | 100.00 | 100.00 | 100.00 |

| Item | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|
| A. Traditional Economy | 6.05 | 5.65 | 5.41 | 5.32 |
| B. Monetary Economy | | | | |
| 1. Enterprises and Non-Profit Institutions: | | | | |
| Agriculture | 30.11 | 29.95 | 29.11 | 28.90 |
| Manufacturing | 13.10 | 13.13 | 13.00 | 13.10 |
| Wholesale,Retail Trade, Restaurants and Hotels etc. | 10.81 | 11.12 | 11.30 | 11.37 |
| Others | 23.35 | 23.38 | 24.69 | 24.68 |
| Total | 77.37 | 77.58 | 78.10 | 78.05 |
| 2. Private Householdes | 1.23 | 1.30 | 1.31 | 1.36 |
| 3. Government Services | 15.35 | 15.47 | 15.18 | 15.27 |
| TOTAL GDP | 100.00 | 100.00 | 100.00 | 100.00 |

Source :Ref. E.38, E,4, E.5

## Table E1.2 Exports of Principal Commodities

Unit:K£'000

| Commodity | 1978 | | 1979 | | 1980 | | 1981 | | 1982 | | 1983 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | | | | | | | | | | | | |
| Meat | | | | | | | 4,216 | 0.8% | 6,247 | 1.1% | 8,060 | 1.3% |
| Dairy products,Eggs | | | | | | | 729 | 0.1% | 1,128 | 0.2% | 1,598 | 0.3% |
| Fish | | | | | | | 1,051 | 0.2% | 1,121 | 0.2% | 1,230 | 0.2% |
| Maize | | | | | | | 68 | 0.0% | 327 | 0.1% | 12,518 | 2.0% |
| Coffee | 124,679 | 33.7% | 110,573 | 28.7% | 108,129 | 22.2% | 109,370 | 21.3% | 144,564 | 26.5% | 160,087 | 25.3% |
| Tea | 63,187 | 17.1% | 62,843 | 16.3% | 58,003 | 11.9% | 61,104 | 11.9% | 77,593 | 14.2% | 123,421 | 19.5% |
| Fruit | 20,128 | 5.4% | 21,552 | 5.6% | 25,232 | 5.2% | 32,206 | 6.3% | 38,429 | 7.0% | 54,940 | 8.7% |
| Other | 10,709 | 2.9% | 20,333 | 5.3% | 20,532 | 4.2% | 25,119 | 4.9% | 9,198 | 1.7% | 9,881 | 1.6% |
| Total | 218,703 | 59.1% | 215,301 | 55.8% | 211,896 | 43.5% | 233,863 | 45.5% | 278,607 | 51.1% | 371,735 | 58.7% |
| Basic Materials | | | | | | | | | | | | |
| Petroleum products | 76,943 | 20.8% | 85,265 | 22.1% | 170,776 | 35.0% | 171,236 | 33.3% | 162,041 | 29.7% | 146,877 | 23.2% |
| Pyrethrum | 4,623 | 1.2% | 5,765 | 1.5% | 9,151 | 1.9% | 6,048 | 1.2% | 9,623 | 1.8% | 8,929 | 1.4% |
| Hides & skins | 9,825 | 2.7% | 13,770 | 3.6% | 9,547 | 2.0% | 9,206 | 1.8% | 7,902 | 1.4% | 6,331 | 1.0% |
| Sisal | 4,038 | 1.1% | 4,808 | 1.2% | 8,847 | 1.8% | 8,756 | 1.7% | 10,845 | 2.0% | 12,091 | 1.9% |
| Cotton | 1,389 | 0.4% | 925 | 0.2% | 2,605 | 0.5% | 1,637 | 0.3% | | 0.0% | 864 | 0.1% |
| Other | 5,852 | 1.6% | 6,358 | 1.6% | 7,304 | 1.5% | 8,413 | 1.6% | 8,828 | 1.6% | 8,417 | 1.3% |
| Total | 102,670 | 27.8% | 116,891 | 30.3% | 208,230 | 42.7% | 205,296 | 40.0% | 199,239 | 36.5% | 183,509 | 29.0% |
| Manufactured Goods | 48,344 | 13.1% | 53,072 | 13.8% | 67,148 | 13.8% | 74,495 | 14.5% | 67,794 | 12.4% | 77,698 | 12.3% |
| Miscellaneous | 247 | 0.1% | 270 | 0.1% | 370 | 0.1% | 209 | 0.0% | 96 | 0.0% | 136 | 0.0% |
| Total | 369964 | 100% | 385,534 | 100% | 487,644 | 100% | 513,863 | 100% | 545,736 | 100% | 633,078 | 100% |

| Commodity | 1984 | | 1985 | | 1986 | | 1987 | | 1988 | | 1989 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | | | | | | | | | | | | |
| Meat | 11,228 | 1.5% | 8,248 | 1.1% | 4,184 | 0.4% | 2,017 | 0.3% | 1,709 | 0.2% | 5,081 | 0.5% |
| Dairy products,Eggs | 738 | 0.1% | 666 | 0.1% | 1,122 | 0.1% | 1,569 | 0.2% | 2,367 | 0.3% | 2,213 | 0.2% |
| Fish | 835 | 0.1% | 1,102 | 0.1% | 2,509 | 0.3% | 5,637 | 0.7% | 8,938 | 1.0% | 14,600 | 1.5% |
| Maize | 5,927 | 0.8% | 1,241 | 0.2% | 14,663 | 1.5% | 19,459 | 2.6% | 21,668 | 2.4% | 15,566 | 1.6% |
| Coffee | 203,623 | 27.0% | 230,623 | 29.4% | 388,486 | 40.6% | 194,569 | 25.8% | 244,547 | 26.6% | 203,813 | 20.4% |
| Tea | 189,478 | 25.1% | 191,657 | 24.4% | 172,789 | 18.0% | 163,366 | 21.7% | 185,263 | 20.2% | 271,899 | 27.2% |
| Fruit | 54,195 | 7.2% | 52,970 | 6.7% | 66,148 | 6.9% | 77,169 | 10.2% | 94,784 | 10.3% | 90,968 | 9.1% |
| Other | 7,494 | 1.0% | 9,768 | 1.2% | 14,836 | 1.5% | 11,203 | 1.5% | 11,603 | 1.3% | 14,718 | 1.5% |
| Total | 473,518 | 62.7% | 496,275 | 63.2% | 664,737 | 69.4% | 474,989 | 63.0% | 570,879 | 62.2% | 618,858 | 61.9% |
| Basic Materials | | | | | | | | | | | | |
| Petroleum products | 155,529 | 20.6% | 141,351 | 18.0% | 125,666 | 13.1% | 124,594 | 16.5% | 148,068 | 16.1% | 150,398 | 15.0% |
| Pyrethrum | 9,727 | 1.3% | 9,515 | 1.2% | 11,568 | 1.2% | 9,758 | 1.3% | 11,551 | 1.3% | 17,039 | 1.7% |
| Hides & skins | 7,122 | 0.9% | 9,989 | 1.3% | 12,611 | 1.3% | 16,874 | 2.2% | 26,102 | 2.8% | 13,583 | 1.4% |
| Sisal | 12,569 | 1.7% | 14,429 | 1.8% | 10,943 | 1.1% | 9,884 | 1.3% | 11,922 | 1.3% | 16,255 | 1.6% |
| Cotton | 148 | 0.0% | 1,975 | 0.3% | 548 | 0.1% | 50 | 0.0% | 1 | 0.0% | | 0.0% |
| Other | 9,893 | 1.3% | 7,900 | 1.0% | 6,710 | 0.7% | 7,735 | 1.0% | 12,980 | 1.4% | 14,337 | 1.4% |
| Total | 194,988 | 25.8% | 185,159 | 23.6% | 168,046 | 17.5% | 168,895 | 22.4% | 210,624 | 23.0% | 211,612 | 21.2% |
| Manufactured Goods | 85,746 | 11.4% | 103,360 | 13.2% | 114,284 | 11.9% | 108,967 | 14.5% | 136,015 | 14.8% | 169,292 | 16.9% |
| Miscellaneous | 561 | 0.1% | 303 | 0.0% | 10,904 | 1.1% | 599 | 0.1% | 202 | 0.0% | 79 | 0.0% |
| Total | 754,813 | 100% | 785,097 | 100% | 957,971 | 100% | 753,450 | 100% | 917,719 | 100% | 999,842 | 100% |

Source : Ref. E.4, E.5

Table E1.3 Land Form Classification in Kenya

| | | Area (km2) | | Percent |
|---|---|---|---|---|
| M | MOUNTAINS AND MAJOR SCARPS | 22,662 | | 3.9% |
| H | HILLS | 35,707 | | 6.1% |
| | Hl Hills and minor scarps | | 30,139 | |
| | Hs Step-faulted scarps of the Rift Valley | | 5,568 | |
| L | PLATEAU | 52,962 | | 9.1% |
| | Li Plateaus and high-level structural plains | | 41,159 | |
| | Ls Step-faulted floor of the Rift Valley | | 8,879 | |
| | Lc Coastal Plateaus | | 1,922 | |
| | Lu Plateau/upper-level upland transitions | | 1,002 | |
| R | VOLCANIC FOOTRIDGES | 30,978 | | 5.3% |
| F | FOOTSLOPES | 25,896 | | 4.5% |
| | Footslopes | | 20,989 | |
| | Footslopes and piedmont plains undifferentiated | | 4,907 | |
| Y | PIEDMONT PLAINS | 24,684 | | 4.2% |
| U | UPLANDS | 65,324 | | 11.2% |
| | Uu Upper-level uplands | | 1,193 | |
| | Uh Upper middle level uplands | | 7,868 | |
| | Um Lower middle level uplands | | 20,587 | |
| | Ul Lower level uplands | | 12,305 | |
| | Ux Uplands undifferentiated levels | | 17,046 | |
| | Uc Coastal uplands | | 6,325 | |
| Pe | UPLANDS/HIGH-LEVEL PLAIN TRANSITIONAL LANDS | 89,086 | | 15.3% |
| | Pn Erosional Plains | | 65,650 | |
| | Up Non-dissected erosional plains | | 3,578 | |
| | Pd Dissected erosional plains | | 19,858 | |
| Ps | SEDIMENTARY PLAINS | 139,747 | | 24.1% |
| | Psh High-level sedimentary plains | | 40,006 | |
| | Psm Middle-level sedimentary plains | | 54,586 | |
| | Psl Lower-level sedimentary plains | | 33,090 | |
| | Psx Sedimentary plains of undifferentiated levels | | 2,049 | |
| | Pv Volcanic Plains | | 10,016 | |
| Pc | COASTAL PLAINS | 11,727 | | 2.0% |
| | Pch Higher-level coastal plains | | 4,529 | |
| | Pcl Lower-level coastal plains | | 6,655 | |
| | Pcr Reef coastal plains | | 543 | |
| Pl | LACUSIRINE PLAINS | 7,633 | | 1.3% |
| Pt | SEDIMENTARY PLAINS OF UPPER RIVER TERRACES | 2,560 | | 0.4% |
| Pf | SEDIMENTARY PLAINS OF LARGE ALLUVIAL FANS | 6,025 | | 1.0% |
| | Pf1 Older fans | | 2,587 | |
| | Pf2 Younger fans | | 3,438 | |
| A | FLOODPLAINS | 28,625 | | 4.9% |
| B | B OTTOMLAND S | 6,352 | | 1.1% |
| D | DUNES OR DUNE LAND | 2,308 | | 0.4% |
| La | LAVA FLOWS | 11,144 | | 1.9% |
| S | SWAMPS | 645 | | 0.1% |
| T | MANGROVE SWAMPS | 69 | | 0.0% |
| V | MINOR VALLEYS | 1,148 | | 0.2% |
| W | BADLANDS | 14,822 | | 2.6% |
| Z | COASTAL OR LAKE-SIDE BEACH RIDGES | 908 | | 0.2% |
| | Total | 581,012 | | 100.0% |

Source : Sectoral Report R

Table E1.4 Soil Compostion in Kenya (1/4)

Unit km2

| District Code | Name | Soil Type ACRISOLS | ANDOSOLS | ARENOSOLS | CAMBISOLS | CHERNOZEMS | FERRALSOLS | FLUVISOLS |
|---|---|---|---|---|---|---|---|---|
| 110 | Nairobi | | | | 43.269 | | | |
| 210 | Kiambu | | 157.781 | | 40.133 | | 53.516 | |
| 220 | Kirinyaga | | 291.384 | | 14.037 | | 153.951 | |
| 230 | Muranga | | 379.367 | 84.075 | 54.221 | | 348.817 | |
| 240 | Nyandarua | 153.27 | 656.105 | | 3.977 | | | |
| 250 | Nyeri | | 904.014 | | 84.245 | | | |
| 310 | Kilifi | 25.272 | | 1553.972 | 1771.367 | | 1753.381 | 173.856 |
| 320 | Kwale | 100.954 | | 512.636 | 2037.819 | | 1299.488 | 22.104 |
| 330 | Lamu | | | 29.805 | | | 360.662 | 11.587 |
| 340 | Monbasa | | | 36.476 | 22.935 | | 6.946 | |
| 350 | Taita Taveta | 35.977 | 189.596 | | 2075.729 | | 10239.799 | 217.795 |
| 360 | Tana River | 2791.51 | | 168.452 | 1268.951 | | 962.932 | 1768.53 |
| 410 | Embu | 83.445 | 158.646 | 75.973 | 840.195 | | 806.891 | |
| 420 | Isiolo | 268.028 | | 138.807 | 6170.244 | 372.227 | | 1232.388 |
| 430 | Kitui | 6080.083 | | 170.977 | 2528.517 | | 15761.26 | 517.063 |
| 440 | Machakos | 4698.632 | 353.832 | 451.462 | 1783.387 | | 1544.176 | |
| 450 | Marsabit | | 109.726 | 1255.766 | 4041.845 | | | 3248.175 |
| 460 | Meru | 25.954 | 1137.498 | 24.253 | 2143.698 | 187.166 | 913.784 | 19.496 |
| 510 | Garissa | 4985.219 | | 2473.367 | 457.835 | | 219.482 | 48.46 |
| 520 | Mandera | | | 5117.613 | 5278.296 | | 418.124 | 94.412 |
| 530 | Wajir | | | 11344.091 | 29.083 | | | 799.946 |
| 610 | Kisii | 53.02 | | | 47.022 | | 231.825 | |
| 620 | Kisumu | 0.382 | | 124.23 | 16.928 | | 242.796 | 63.239 |
| 630 | Siaya | 37.541 | | | 8.164 | | 1036.536 | |
| 640 | South Nyanza | 622.729 | | 23.935 | 231.475 | | 469.615 | |
| 710 | Kajiado | 197.409 | 528.596 | 104.164 | 5175.197 | | 15.075 | 1173.924 |
| 720 | Kericho | 44.68 | 427.053 | | 304.114 | | 11.75 | 24.069 |
| 730 | Laikipia | | | | 375.961 | | | |
| 740 | Nakuru | | 3006.257 | | 402.848 | | | |
| 750 | Narok | 930.629 | 3423.294 | | 99.115 | | 21.8 | 227.423 |
| 760 | Trans Nzoia | 162.528 | | | 68.961 | 67.61 | 1198.164 | 2.361 |
| 770 | Uasin Gishu | 107.171 | | | 77.126 | | 1939.55 | |
| 810 | Baringo | | 222.626 | | 4355.277 | | | 160.958 |
| 820 | Elg. Marakwet | 228.695 | | | 1289.41 | | 0.363 | 145.769 |
| 830 | Nandi | 251.042 | | 68.794 | 721.128 | | 445.201 | 0.098 |
| 840 | Samburu | | | | 8444.218 | 4.754 | | 218.526 |
| 850 | Turkana | | | 1871.004 | 285.726 | | | 7834.515 |
| 860 | West Pokot | 1253.939 | | | 3342.489 | | 2.929 | 288.042 |
| 910 | Bungoma | 162.133 | 11.512 | | 175.415 | | 1415.874 | |
| 920 | Busia | 70.795 | | | 0.487 | | 762.597 | |
| 930 | Kakamega | 1788.572 | | 37.172 | 343.133 | | 1048.102 | |
| | Total | 25159.609 | 11957.287 | 25667.024 | 56453.977 | 631.757 | 43685.386 | 18292.736 |

Source : Ref.B.36

Table E1.4 Soil Compostion in Kenya (2/4)

Unit km2

| District Code | Name | Soil Type GLEYSOLS | GREYZEMS | HISTOSOLS | IRONSTONE | LAVA | LITHOSOLS | LUVISOLS |
|---|---|---|---|---|---|---|---|---|
| 110 | Nairobi | | | | 240.159 | | | |
| 210 | Kiambu | | | | 207.079 | | 76.065 | |
| 220 | Kirinyaga | | | 36.754 | | | | |
| 230 | Muranga | | | 0.278 | 20.136 | | | |
| 240 | Nyandarua | | | 185.581 | | | 265.709 | 310.805 |
| 250 | Nyeri | | | 255.567 | | | | 151.952 |
| 310 | Kilifi | | | | | | 35.623 | 3309.991 |
| 320 | Kwale | | | | | | 64.714 | 2538.237 |
| 330 | Lamu | 10.199 | | | | | | 3860.457 |
| 340 | Monbasa | | | | | | 5.596 | |
| 350 | Taita Taveta | | | | | 194.218 | | 3149.403 |
| 360 | Tana River | 199.621 | | | | | | 986.163 |
| 410 | Embu | | | 3.065 | | | 21.426 | 2.111 |
| 420 | Isiolo | 2667.541 | | | | 1165.292 | 51.203 | 2817.755 |
| 430 | Kitui | 178.255 | | | | | 40.764 | 3264.175 |
| 440 | Machakos | | | | | 715.41 | | 1932.007 |
| 450 | Marsabit | 230.607 | | | | 6778.572 | 14857.748 | 1546.051 |
| 460 | Meru | | | 326.537 | 77.017 | | 401.695 | 947.684 |
| 510 | Garissa | 1821.543 | | | | | 48.176 | 1751.346 |
| 520 | Mandera | 260.715 | | | | | 3285.068 | 8437.172 |
| 530 | Wajir | 1988.031 | | | | 443.172 | 473.785 | 13251.505 |
| 610 | Kisii | 7.097 | | | | | | |
| 620 | Kisumu | 108.779 | | | 196.502 | | | 68.369 |
| 630 | Siaya | 85.828 | | | 28.863 | | | 158.469 |
| 640 | South Nyanza | 70.93 | 2.274 | | 0.308 | | | 430.835 |
| 710 | Kajiado | | | | 13.188 | 169.048 | 115.491 | 8078.108 |
| 720 | Kericho | 29.98 | 166.583 | | 54.254 | | | 110.018 |
| 730 | Laikipia | | | | | | 277.461 | 1612.75 |
| 740 | Nakuru | | | | | 101.059 | 675.587 | 243.535 |
| 750 | Narok | 24.833 | 1030.984 | | | | 141.263 | 16.696 |
| 760 | Trans Nzoia | 126.623 | | 1.452 | | | | 236.789 |
| 770 | Uasin Gishu | 268.091 | | | | | | 0.345 |
| 810 | Baringo | | | | | 479.873 | 2298.312 | 163.456 |
| 820 | Elg. Marakwet | | | | | | | 480.847 |
| 830 | Nandi | 142.765 | | | | | | 53.324 |
| 840 | Samburu | | | | | 614.71 | 2017.584 | 6192.028 |
| 850 | Turkana | | | | | 621.379 | 10019.958 | 3583.134 |
| 860 | West Pokot | | | | | | 8.787 | 1536.575 |
| 910 | Bungoma | 111.595 | | 100.53 | | | | |
| 920 | Busia | 99.009 | | | | | | |
| 930 | Kakamega | 27.389 | | | | | | |
| | Total | 8459.431 | 1199.841 | 909.764 | 837.506 | 11282.733 | 35182.015 | 71222.092 |

Source : Ref.E.36

Table E1.4 Soil Compostion in Kenya (3/4)

Unit km2

| District Code | Name | Soil Type NITISOLS | PHAEOZEMS | PLANOSOLS | RANKERS | REGOSOLS | RENDZINAS | SOLOCHAKS |
|---|---|---|---|---|---|---|---|---|
| 110 | Nairobi | 92.581 | 0.815 | | | | | |
| 210 | Kiambu | 1616.242 | 52.892 | | | | | |
| 220 | Kirinyaga | 820.272 | | | | 3.501 | | |
| 230 | Muranga | 1494.994 | | | | 128.285 | | |
| 240 | Nyandarua | 532.76 | 808.805 | 343.508 | | | | 21.904 |
| 250 | Nyeri | 1430.246 | 269.792 | 12.111 | | | | |
| 310 | Kilifi | 64.371 | 207.345 | 1286.454 | | 47.664 | 121.869 | 14.796 |
| 320 | Kwale | | 267.146 | 359.567 | | 114.64 | 269.472 | |
| 330 | Lamu | | 77.103 | 1296.511 | | | | 55.635 |
| 340 | Monbasa | | | | | | | |
| 350 | Taita Taveta | | | | | 250.161 | 627.839 | 37.287 |
| 360 | Tana River | | | 5397.58 | | 6.225 | | |
| 410 | Embu | 422.132 | | | | 178.703 | | |
| 420 | Isiolo | | 29.242 | 3502.01 | | 168.879 | | 1088.44 |
| 430 | Kitui | | | 509.792 | | 382.145 | | |
| 440 | Machakos | 343.861 | 20.079 | 14.972 | | 869.184 | | |
| 450 | Marsabit | 385.051 | 1091.563 | 103.828 | | 865.224 | | 5274.897 |
| 460 | Meru | 2413.531 | 668.674 | | | 140.582 | | |
| 510 | Garissa | | 173.47 | 9235.013 | | | | |
| 520 | Mandera | | | | | 32.562 | | 412.048 |
| 530 | Wajir | | | 1484.198 | | 627.185 | 249.26 | 262.435 |
| 610 | Kisii | 1397.543 | 192.566 | 122.68 | 127.357 | | | |
| 620 | Kisumu | 62.702 | 67.789 | 413.722 | | 189.529 | | |
| 630 | Siaya | 164.556 | 652.972 | 135.252 | 2.263 | | | |
| 640 | South Nyanza | 135.591 | 1992.833 | 727.549 | 21.967 | 555.484 | | |
| 710 | Kajiado | 582.196 | 302.68 | 62.351 | | 1187.786 | 124.029 | 710.58 |
| 720 | Kericho | 2427.055 | 616.897 | 731.306 | 54.158 | | | |
| 730 | Laikipia | 466.085 | 3796.499 | 328.87 | | 704.28 | | 24.681 |
| 740 | Nakuru | 315.982 | 343.914 | 87.91 | | 1177.285 | | |
| 750 | Narok | 392.873 | 4281.203 | 4564.816 | 1368.519 | 787.085 | | 29.54 |
| 760 | Trans Nzoia | 522.805 | | | | 22.219 | | |
| 770 | Uasin Gishu | 1293.811 | | | | 54.051 | | |
| 810 | Baringo | 727.95 | | | | 666.88 | | 1294.602 |
| 820 | Elg. Marakwet | 331.445 | | | 250.181 | 90.17 | | 8.151 |
| 830 | Nandi | 979.579 | | 2.174 | | 118.698 | | |
| 840 | Samburu | 190.008 | 713.782 | | 87.088 | 1312.874 | | 138.892 |
| 850 | Turkana | | | | | 13954.236 | | 14656.968 |
| 860 | West Pokot | | | | 155.635 | 2164.76 | | |
| 910 | Bungoma | 768.419 | | 233.449 | | | | |
| 920 | Busia | 308.419 | | 327.363 | 51.414 | 21.064 | | |
| 930 | Kakamega | 212.44 | | 140.047 | | 26.505 | | |
| | Total | 20895.5 | 16628.061 | 31423.033 | 2118.582 | 26847.846 | 1392.469 | 24030.856 |

Source : Ref.E.36

Table E1.4 Soil Compostion in Kenya (4/4)

Unit km2

| District Code | Name | Soil Type SOLONETZ | VERTISOLS | XEROSOLS | WATER | UNKNOWN |
|---|---|---|---|---|---|---|
| 110 | Nairobi | | 317.262 | | 0 | 27.725 |
| 210 | Kiambu | | 208.234 | | 3 | 150.366 |
| 220 | Kirinyaga | | 199.758 | | 0 | |
| 230 | Muranga | | 50.85 | | 0 | |
| 240 | Nyandarua | | 16.482 | | 20 | 11.864 |
| 250 | Nyeri | | 115.202 | | 0 | 113.24 |
| 310 | Kilifi | 1988.301 | 135.92 | | 109 | |
| 320 | Kwale | 161.004 | 350.428 | | 65 | |
| 330 | Lamu | 258.638 | 42.85 | | 308 | |
| 340 | Monbasa | | | | 65 | |
| 350 | Taita Taveta | 84.684 | 230.268 | | 16 | |
| 360 | Tana River | 22688.183 | 2868.454 | 210.391 | 0 | |
| 410 | Embu | | 144.175 | | 0 | |
| 420 | Isiolo | 5397.038 | 248.587 | 171.248 | 0 | |
| 430 | Kitui | 672.22 | 659.087 | | 0 | |
| 440 | Machakos | | 1350.772 | | 5 | 95.792 |
| 450 | Marsabit | 6413.351 | 3697.802 | 21182.33 | 4,126 | |
| 460 | Meru | | 148.947 | | 0 | |
| 510 | Garissa | 19174.526 | 2915.079 | 639.056 | 0 | |
| 520 | Mandera | | | 2755.93 | 0 | |
| 530 | Wajir | 22989.353 | 1880.463 | 1108.627 | 0 | |
| 610 | Kisii | | | | 0 | |
| 620 | Kisumu | | 508.536 | | 567 | 17.419 |
| 630 | Siaya | | 36.278 | | 1,005 | 92.809 |
| 640 | South Nyanza | 228.912 | 107.465 | | 2,064 | |
| 710 | Kajiado | 133.092 | 3040.998 | 39.527 | 142 | 150.884 |
| 720 | Kericho | | 17.271 | | 0 | |
| 730 | Laikipia | | 1692.467 | | 0 | 502.411 |
| 740 | Nakuru | 211.468 | 724.639 | | 176 | |
| 750 | Narok | 87.701 | 675.988 | | 0 | |
| 760 | Trans Nzoia | | 91.885 | | 0 | |
| 770 | Uasin Gishu | | | | 0 | |
| 810 | Baringo | | 96.385 | 173.188 | 163 | |
| 820 | Elg. Marakwet | | | 28.554 | 0 | |
| 830 | Nandi | | | | 0 | |
| 840 | Samburu | 137.194 | 25.848 | 1132.737 | 0 | |
| 850 | Turkana | 5523.587 | | 8891.016 | 2,279 | |
| 860 | West Pokot | 205.362 | | 224.774 | 0 | |
| 910 | Bungoma | | 7.088 | | 0 | |
| 920 | Busia | | 54.539 | | 137 | |
| 930 | Kakamega | | | | 0 | |
| | Total | 86354.614 | 22660.007 | 36557.378 | 11250 | 1162.51 |

Source : Ref.E.36

## Table E1.5 Categories of Agricultural Land

'000 Hectare

| | High Potential | Medium Potential | Low Potential | Total | All Other Land | Total Land Area |
|---|---|---|---|---|---|---|
| Central Province | | | | | | |
| Murang'a | | | | | | |
| Kiambu | 386 | 5 | 24 | 415 | 78 | 493 |
| Kirinyaga | 98 | 10 | — | 108 | 35 | 143 |
| Nyandarua | 265 | — | 5 | 270 | 83 | 353 |
| Nyeri | 160 | — | 12 | 172 | 157 | 329 |
| Total | 909 | 15 | 41 | 965 | 353 | 1,318 |
| Coast Province | | | | | | |
| Kilifi | 104 | 247 | 851 | 1,202 | 39 | 1,241 |
| Kwale | 126 | 162 | 508 | 796 | 30 | 826 |
| Lamu | 7 | 319 | 321 | 647 | 4 | 651 |
| Mombasa | 21 | — | — | 21 | — | 21 |
| Taita | 42 | 10 | 590 | 642 | 1,054 | 1,696 |
| Tana River | 73 | 58 | 3,393 | 3,524 | 345 | 3,869 |
| Total | 373 | 796 | 5,663 | 6,832 | 1,472 | 8,304 |
| Eastern Province | | | | | | |
| Embu | 66 | 186 | — | 252 | 19 | 271 |
| Isiolo | — | — | 2,561 | 2,561 | — | 2,561 |
| Kitui | 67 | 1,137 | 1,078 | 2,282 | 657 | 2,939 |
| Machakos | 125 | 771 | 454 | 1,350 | 68 | 1,418 |
| Marsabit | 4 | — | 7,045 | 7,049 | 346 | 7,395 |
| Meru | 241 | 95 | 315 | 651 | 341 | 992 |
| Total | 503 | 2,189 | 11,453 | 14,145 | 1,431 | 15,576 |
| Nairobi Total | 16 | — | 38 | 54 | 14 | 68 |
| North-Eastern Province | | | | | | |
| Garissa | — | — | 4,393 | 4,393 | — | 4,393 |
| Mandera | — | — | 2,647 | 2,647 | — | 2,647 |
| Wajir | — | — | 5,650 | 5,650 | — | 5,650 |
| | — | — | 12,690 | 12,690 | — | 12,690 |
| Nyanza Province | | | | | | |
| Kisumu | 432 | 29 | — | 461 | — | 461 |
| Siaya | | | | | | |
| Kisii | 220 | — | — | 220 | — | 220 |
| South Nyanza | 566 | 5 | — | 571 | — | 571 |
| Total | 1,218 | 34 | — | 1,252 | — | 1,252 |
| Rift Valley Province | | | | | | |
| Baringo | 166 | 84 | 751 | 1,001 | 62 | 1,063 |
| Elgeyo-Marakct | 104 | — | 92 | 196 | 77 | 273 |
| Kajiado | 22 | — | 1,760 | 1,782 | 314 | 2,096 |
| Kericho | 380 | — | — | 380 | 109 | 489 |
| Laikipia | 130 | — | 768 | 898 | 74 | 972 |
| Nakuru | 291 | 39 | 231 | 561 | 141 | 702 |
| Nandi | 234 | — | — | 234 | 40 | 274 |
| Narok | 908 | — | 704 | 1,612 | 240 | 1,852 |
| Samburu | 140 | — | 1,612 | 1,752 | 329 | 2,081 |
| Trans Nzoia | 208 | — | — | 208 | 39 | 247 |
| Turkana | 12 | — | 5,937 | 5,949 | — | 5,949 |
| Uasin Gishu | 327 | — | — | 327 | 51 | 378 |
| West Pokot | 103 | — | 365 | 468 | 39 | 507 |
| Total | 3,025 | 123 | 12,220 | 15,368 | 1,515 | 16,883 |
| Western Province | | | | | | |
| Bungoma | 253 | — | — | 253 | 55 | 308 |
| Busia | 163 | — | — | 163 | — | 163 |
| Kakamega | 325 | — | — | 325 | 27 | 352 |
| Total | 741 | — | — | 741 | 82 | 823 |
| Total | 6,785 | 3,157 | 42,105 | 52,047 | 4,867 | 56,914 |

Source: Ref. E.4

Table E1.6 Characteristics of Main Agro-ecological Zones Map for Kenya (1/2)

| Symbol | Name of Zone | Characteristic of Zone | Approximate Altitudes and Climate Characteristic |
|---|---|---|---|
| TA | TROPICAL-ALPINE ZONES | Temperature conditions not suitable for trees or crops | 3,000/3,200 to 4,400 m. Cold, annual mean temp. 2-10C; mean daily max. below 13C; night frosts common |
| TA I | TROPICAL-ALPINE CATTLE AND SHEEP ZONE | Climatic and soil conditions provide grazing for cattle, complete nature protection on slopes advisable (Nat. Park) | Moderately cold and humid to semi-humid; annual average precipitation at least more than 50 % of the potential evaporation (Eo) |
| TA II | TROPICAL-ALPINE SHEEP ZONE | Grazing not suitable for cattle; complete nature protection on slopes advisable (Nat. Park) | Very cold and humid to arid; annual av. precip. less than 50% of the pot. evaporation or more in higher altitudes |
| UH | UPPER HIGHLAND ZONES | Temperature conditions suitable for frost-resistant crops, or for others between the frost periods | 2,200/2,400 to 3,000/3,200 m. Cool,annual mean temp. 10-15C, mean nightly min. below,8C; night frosts occasionally in cold seasons |
| UH 1 | SHEEP AND DAIRY ZONE OR FOREST RESERVE | Climatic conditions not well suited for grain crops except oats, bur favourable for artificial pastures, if not forest is on slopes ecologically more advisable | Cool and humid; annual average precipitation more than 80% of the potential evaporation. Dry seasons negligible |
| UH 2 | PYRETHRUM-WHEAT ZONE | Climatic conditions good1) for pyrethrum and fair2) for wheat | Cool and sub-humid; annual average precip. 65-80% of the pot ev.(or more to store enough soil moisture for dry seasons affecting pyrethrum) |
| UH 3 | WHEAT-BARLEY ZONE | Climatic conditions good for wheat and barley, fair to poor3) for pyrethrum | Cool and sub-humid; annual av.precip. 50-65% of the pot. ev.; and growing periods must have at least 130 days in 6 out of 10 years |
| UH 4 | UPPER HIGHLAND RANCHING ZONE | Only marginal or not suitable for rainfed crops or dairy. Natural pasture for upgraded cattle and sheep, low density garazing | Cool and transitional; annual av. precip. 40-50% of the pot. ev.; 60% probability of growing periods less than 130 days |
| UH5 | UPPER HIGHLAND NOMADISM ZONE | Not in Kenya | Cool and semi-arid to arid |
| LH | LOWER HIGHLAND ZONES | Temperature conditions very suitable for high quality tea and cold enough for pyrethrum | 1,800/1,900 to 2,200/2,400 m. Moderately cool, annual mean temp. 15-18C. Frost very rare and only limited to basins valleys or holes |
| LH 1 | TEA-DAIRY ZONE OR FOREST RESERVE | Climatic conditions good for tea, dairy pastures, potatoes and vegetables, fair for maize | Moderately cool and humid; annual av. precip. at least 80 % of the pot. ev.(or more to store enough soil moisture for dry seasons affecting tea) |
| LH 2 | WHEAT/MAIZE-PYRETHRUM ZONE | Climatic conditions fair-good for pyrethrum and wheat, fair for maize | Moderately cool and sub-humid; annual av. precip. at least 65-80 % of the pot. ev.(or more to store enough soil moisture for dry seasons affecting pyrethrum) |
| LH 3 | WHEAT/(MAIZE)-BARLEY ZONE 4) | Climatic conditions good for wheat and barley, fair-marginal for maize | Moderately cool and semi-humid; ann. av. precip. 50-65 % of the pot. ev.; growing periods must be well developed and at least 115 days in 6 out of 10 years |
| LH 4 | CATTLE-SHEEP BARLEY ZONE | Climatic conditions fair for barley and wheat. Natural pasture for medium density grazing | Moderately cool and transitional; annual av.precip. 40-50 % of the pot. ev. and growing periods must be at least 105 days in 6 out of 10 years |
| LH 5 | LOWER HIGHLAND RANCHING ZONE | Except of very early maturing barley not suited for rainfed crops or dairy. Nat. pasture for low density grazing | Moderately cool and semi-arid; annual av. precip. 25-40 % of the pot.ev.; 60 % probability of growing periods less than 105 days |
| LH 6 | LOWER HIGHLAND NOMADISM ZONE | Not in Kenya | Mod. cool and arid; annual av. precip. less than 25 % of the pot. evaporation |
| UM | UPPER MIDLLAND ZONES | Temperature conditions very suitable for arabica coffee | 1,300/1,500 to 1,800/1,900 m. Temperate, annual mean temp. 18-21C. Absolutely no frost |
| UM 1 | COFFEE-TEA ZONE | Climatic conditions good to fair for Arabica coffee and tea, the same for maize | Temperature and humid; annual av. precip. at least 80 % of the pot. ev.(or more to store enough soil moisture for dry seasons affecting tea) |
| UM 2 | MAIN COFFEE ZONE | Climatic conditions good for Arabica coffee and maize | Temperate and sub-humid; annual av. precip. 65-80 % of the pot. ev.(or more to store enough soil moisture for dry seasons affecting coffee) |
| UM 3 | MARGINAL COFFEE ZONE | Moisture conditions fair to poor for coffee, then irrigation profitable; fair for maize | Temperature and semi-humid; annual av. precipitation 50-65 % of the pot. ev.(or more to store enough soil moisture for survival of coffee in dry seasons) |

Table E1.6 Characteristics of Main Agro-ecological Zones Map for Kenya (2/2)

| Symbol | Name of Zone | Characteristic of Zone | Approximate Altitudes and Climate Characteristic |
|---|---|---|---|
| UM 4 | SUNFLOWER-MAIZE ZONE OR UPPER SISAL ZONE | With unimodel rainfall good for sunflower and maize, with bimodel rainfall mainly fair; sisal good(large scale) | Temperature and transitional; annual av. precipitation 40-50 % of the pot. evaporation |
| UM 5 | LIVESTOCK-SORGHUM ZONE OR UPPER MARGINAL SISAL ZONE | Climatic conditions fair for sorghum, poor for maize. Natural pasture for low density grazing. Sisal fair to poor | Temperate and semi-arid; annual av. precip. 25-40% of the pot. ev.;growing periods must be at least 65 days in 6 out of 10 years |
| UM 6 | UPPER MIDLAND RANCHING ZONE | Only marginally or not suitable for rainfed crops or dairy. Natural pasture for low to very low density grazing | Temperate and arid; annual av. precip. 15-25 % of the pot. evaporation |
| LM | LOWER MIDLAND ZONES | Temp. conditions suitable for cotton (nearly like lowland temperatures) | 800 to about 1,300 m in Eastern Kenya and 1,500 m in Western. Warm, annual mean temp. 21-24C, mean min.> 14C |
| LM 1 | LOWER MIDLAND SUGAR CANE ZONE | Climatic conditions good for sugarcane, too wet for cotton, fair for maize | Warm and humid; annual av. precip. at least 80 % of the pot ev.(or more to store enough soil moisture for dry season affecting sugar cane) |
| LM 2 | LOWER MIDLAND MARGINAL SUGAR CANE ZONE | Climatic conditions fair to marginal for sugar cane, good for maize | Warm and sub-humid; annual av. precip. 65-80 % of pot. ev.(or more to store enough soil moisture for dry seasons affecting sugar cane) |
| LM 3 | COTTON ZONE | Climatic conditions good to fair for cotton, fair for maize | Warm and semi humid; annual av. precip. 50-65 % of pot. ev.(or more to store enough soil moisture for dry seasons affecting cotton) |
| LM 4 | MARGINAL COTTON ZONE OR MIDDLE SISAL ZONE | Climatic conditions fair to poor for cotton and maize fair for pigeon peas, good for sisal | Warm and transitional; annual av. precip. 40-50 % of pot. ev.(or more in bimodal rainfall areas for survival of cotton in dry season) |
| LM 5 | LOWER MIDLAND LIVESTOCK-MILLET ZONE OR MARGINAL MIDDLE SISAL ZONE | Climatic conditions fair to poor for millets, cowpeas and grams or sisal. Natural pasture for low density grazing | Warm and semi-arid; annual av. precip. 25-40 % of pot. ev., or less or more because growing periods must be at least 45 days in 6 out of 10 days |
| LM 6 | LOWER MIDLAND RANCHING ZONE | Not suitable for rainfed crops. Natural pasture for low to very low density grazing | Warm, semi-arid in areas with intermediate rainfall, arid in other areas |
| L | LOWLAND ZONES | Temp. conditions very suitable for coconuts and cashewnuts | 0-800 m, in Rift Valley 1,000 m. Hot, annual mean temp. more than 24C |
| L 1 | COCOA ZONE | Not in Kenya | Hot and humid |
| L 2 | LOWLAND SUGAR CANE ZONE | Climatic conditions good to poor for sugar cane, good for coconuts, cassava and maize | Hot and sub-humid; annual av. precip. 65-80 % of pot. ev.(or more to store enough soil moisture for dry seasons affecting sugar cane) |
| L 3 | COCONUT-CASSAVA ZONE | Climatic conditions good to fair for coconuts and cassava, cotton fair (danger of rainfall in open bolls) maize fair | Hot and semi-humid; annual av. precip. 50-65 % of pot. ev.(or more to store enough soil moisture for coconuts and cassava) |
| L 4 | CASHEWNUT-CASSAVA ZONE OR LOWER SISAL ZONE | Climatic conditions good to fair for cashewnuts; and cassava, good for sisal, marginal for coconuts; cotton in subzones with suitable growing periods | Hot and transitional; annual av. precip. 40-50 % of pot. ev.(or more to store enough soil moisture for cashewnuts and cassava) |
| L 5 | LOWLAND LIVESTOCK-MILLET ZONE OR MARGINAL LOWER SISAL ZONE | Climatic conditions fair to marginal for millets, cowpeas and garms or sisal. Natural pasture for low density grazing | Hot amd semi-arid; annual av. precip. 25-40 % of pot. ev.,or less or more because growing periods must be at least 40 days in 6 out of 10 years |
| L 6 | LOWLAND RANCHING ZONE | Not suitable for rainfed crops. Natural pasture for low to very low density grazing | Hot, semi-arid in areas with intermediate rainfall, and in other areas |
| L 7 | LOWLALND NOMADISM ZONE | Natural pasture for periodic low density grazing only | Hot and very arid(peradic), annual av. precip. < 15 % of pot. evaporation |

Source : Ref.E.17

Note : 1) Good = Average yield more than 60% of the optimum on suitable soils
2) Fair = Average yield 40 to 60% of the optimum on suitable soils
3) Poor = Average yield 20 to 40% of the optimum on suitable soils.
4) Maize = Normally less suitable, therefore in brackets.