

*Draft*

**NORTHERN KENYA LAND RESOURCES REPORT**

**R. W. Borden**

**1990**

**Cargill Technical Services  
Thame, Oxon  
UK**

# NORTHERN KENYA LAND RESOURCES REPORT

## 1.0 INTRODUCTION

The following is a report on the land resources of Northern Kenya and result from a reconnaissance trip undertaken by the Consultant during August of 1990. The objective of the trip was to identify areas with potential for large scale commercial crop production in the northern areas where agriculture (other than livestock rearing) does not have a strong tradition. While the emphasis of the investigation is on land resources - soil suitability and availability of land not otherwise under intensive use - mean rainfall data (Appendix A) was also collected as an indicator of which crops may most likely have potential. The areas investigated are discussed below; conclusions and recommendations complete the report.

## 2.0 METHODOLOGY

Before departing on the reconnaissance trip, basic information on the target areas (Figure 1) was collected (see References in Appendix A). This included known soils data, topographic maps, satellite imagery, etc. On arrival in target areas, contact was made with the local officials (DC, DO and/or Chief). In consultation with them, field trips were planned and - in the company of local officials locations where land was thought suitable and which could be made available were visited. Along the journey, soil investigations made and soil samples taken for analysis at the National Agricultural Laboratory in Nairobi (*now awaiting analysis*), and notes were made of general environment.

## 3.0 MARSABIT DISTRICT

General: The area inspected included most of the land on Marsabit Mountain above 850 meters elevation. Until recently all of this area was included in the Marsabit National Park, but in 1984 the Council recommended that 54,000 ha on the south and east be re-allocated for agricultural use. There are currently agricultural settlements at Karare, Kituruni, Songa, Badasa, Gombo and northeast of Marsabit town.

Soils: Well drained, moderately to very deep, dusky red to dark reddish brown friable clay soils and very friable clay loams with humic top soil have developed on the upper moister slopes of Mount Marsabit. The dryer middle and lower slopes have deep, well drained, shallow dark reddish brown, friable rocky and stony clay loams with inclusions of lava vents and rock outcrops. All have developed on olivine basalt and ashes of major volcanoes. In some places moderately deep, stony, cracking clay soils have also developed. These soils are described more fully in Appendix A and C, and their spatial distribution is shown on Figure 2.

Soils of the top slopes (Map Unit A) on the sites of higher rainfall (notably on the eastern and southern slopes) have a soil profile which is deeply (3+ m) weathered while those on the lower rainfall (western and northern slopes) sites are weathered to a little over 1 m depth. These soils have formed on basalt lava and volcanic ash, and have a macro topography which is flat to generally undulating (0-2%) and no significant micro-relief. The soils usually have a top layer of dark reddish brown clay, which varies between 30 and 50 cm in thickness. This overlies a dark reddish brown to dark red clay subsoil. The soil reaction is strongly to moderately acid; base saturation averages about 50 percent. In general, soil fertility (both chemical and physical)

can be rated as good to very good, based on cation exchange capacity of the topsoil, organic matter content, carbon/nitrogen ratio, and the availability of phosphorus and potassium. Infiltration rate is rapid. Hydraulic conductivity is also likely to be high. Sites with shallow and very shallow soils, and areas outcropping bedrock are found, particularly along stream channels and steps in the lava flow. Where soils are deep they are well suited for cultivation, but the special status of the area (i.e. National Park) forbids any kind of crop production activities.

Soils of the upper slopes (Mapping Units B through E) usually have profiles weathered to 2 m depth. On the small lava flow ridges and along the slopes of the deeply incised gullies and to the lower edges of the unit the soil depth is 1 m or less, and bedrock may outcrop. These soils have also developed on basalt lava and volcanic ash. Topography is very gently to gently undulating with deeply incised gullies between the lava flows. The humic horizon varies from 10 to 50 cm depending on the slope (in general the layer decreases in thickness down the slope). The topsoil consists of dark reddish brown clay overlying dark reddish brown to dark red clay subsoil, and may be underlain by stone lines or basalt bedrock at a depth of about 70 cm. The soil reaction is moderately acid with a base saturation ranging from 37 to 56 percent (increasing from upper to lower areas) depending on the rainfall pattern. Fertility of the top 50 cm is lower than that of the Top Slope soils. The amount of organic matter varies considerably in accordance with the vegetation growth (2.2 percent on the upper areas, 0.9 percent on the lower areas). The cation exchange capacity is rated as good. The portion of available phosphorus is very low, but potassium levels are high. Infiltration rates vary considerably with location - two tests gave 110 and 260 cm/hr dry and 7 and 18 cm/hr wet respectively. These soils are well suited for any cultivation, and currently some 3000 ha is being cultivated. Besides small scale irrigation farming, dairy ranching as well as larger scale rainfed arable farming might be considered.

Soil Chemical Analysis: 11 soil profiles have been analyzed (Table C-2 Figure 2). While there is some variation in profile characteristics, in general the soils are deep, highly weathered and well drained. Soil reaction tends to be in the neutral range (pH 6.6 to 7.2) but profiles in the slightly higher rainfall areas tend towards acidity, while those of the drier areas tend to be slightly alkaline. All profiles are non-saline and non-sodic. Texture is almost uniformly well structure, friable (firm) clay. Cation exchange capacity is, with one exception, medium to high, as is base saturation, indicating generally fertile soils. Organic matter content, and thus nitrogen levels, is in all cases low. Exchangeable calcium tends to be low to moderate in all horizons while magnesium is often high. The resulting low calcium:magnesium ratios indicate that calcium levels may be below plant requirements and available phosphorus, may be inhibited. Potassium levels are, as a rule, high. Commercial crop production is likely to require moderate to high levels of nitrogen and potassium provided through a calcium based fertiliser; response to potassium fertiliser is not expected.

Climate: Marsabit Mountain above the 1200 meter contour lies within agro-climatic zones III and IV (Humid to Semi-humid) based on elevation. Average annual rainfall ranges between 600 and 1400 mm; potential evaporation is 1450 to 2200 mm; thus the ratio of rainfall to potential evaporation ( $r/E_o$ ) of 40 to 65 percent. Risk of failure of a maize crop is low (rated at 5 to 25 percent). The Western (due to rain shadow effect) and lower slopes fall within agro-climatic zone V (Semi-arid). Average annual rainfall ranges between 450 and 900 mm; potential evaporation is 1650 to 2300 mm; thus the ratio of rainfall to potential evaporation ( $r/E_o$ ) of 25 to 40 percent. Risk of failure of a maize crop here is fairly high (rated at 25 to 75 percent).

The annual rainfall is clearly bimodal. The main rainy season (long rains) normally start in March/April and last until May; the short rains start in October and last about 2 months. The higher parts of Mt. Marsabit receive more than 800 mm per year on average (Table B1, Appendix B). Cloud, mist and fog frequently cover the mountain, and thus are supplementary sources of plant moisture. Lower elevations receive less moisture: 465 mm at Songa and around 250 mm on the lower plains. The average number of rain days increases from less than 35 to greater than 80 with increasing elevation.

Deviation from the mean is very high (57%). Monthly variables reach coefficients of variation of 70 (in the normally wettest months) to over 350 (in the dry season). The coefficient of variation on the mean annual rainfall of 875 mm is 32 percent. Thus it is highly uncertain how much rain will fall in the next wet season.

Rainfall probabilities (based on 53 years of data) and return periods have been calculated for Marsabit (Bake, 1983). The probability of a monthly rainfall of 50 mm, the minimum necessary for minimal plant growth, is low and thus the risks to crop production are high.

Mount Marsabit has an estimated evapotranspiration rate of 1200 mm per year (Table B2). Only 4 months (April, May, October and November) receive more rainfall than the crop water requirement.

The rainfall is generally concentrated into two seasons, the southeast monsoon during March-May and the northeast monsoon during October-December. The proportion of the southeast monsoon in relation to annual rainfall is 48 percent, while that of the northeast monsoon is 38 percent. The climatic water deficiency (rainfall minus potential evaporation) is about 1100 mm on the mountain, increasing to over 2600 mm on the plain.

Water Resources: Considerable quantities of water flow off the mountain during the rainy season, but few of the channels have any surface flow, nor potential to develop storage reservoirs to contain this surface water due to the very permeable volcanic and underlying sedimentary rock. Where there is stream flow, it is usually fed by one of the several springs which flow year round. Most of the settlements tap these springs for water supplies.

Badasa, Songa and Gof Bongole are the three main spring areas. Badasa and Songa have pipelines and tank fittings and the water pressure at the termination of the pipeline lower down at Songa is high enough to connect it with a sprinkler irrigation system. This pipeline supplies 0.6 l/sec. Water resources at Badasa are restricted and not sufficient for irrigation purposes. A dam might be constructed at Gof Bongole below the spring - flow is apparently 3.8 l/sec at Karsa Gudas 18 km downstream.

There is some known groundwater potential and the mountain serves as the source of water for the sedimentary aquifer extending to the south east. A full investigation should be undertaken to identify possible sources and dam sites as part of project development.

### **Present Agricultural Areas:**

Gof Chopa/Kupierase Baji Hill Area lies some 15 km north and east of Marsabit town, and in-between the land is extensively farmed. Maize is the predominant crop and is said to produce

well. This is a nearly level plateau (1000 to 1400 meters elevation) on the north side of mountain with generally shallow and rocky soils with inclusions of deeper friable to firm dark brown relatively stone free soil (Sample 11, Table C-2, Appendix C). One farmer said he harvested 25 bags (2250 kg) off about half a hectare of this soil.

Gombo Area, south of the above and to the east of Marsabit town is the oldest farming settlement. The land appears to be very suitable but yields are said to be indifferent. The area is cut by a deep ravine (Laga Saganti).

Badasa Area is some 10 km southeast of Marsabit just outside the forest reserve (900 to 1000 meters elevation). The land is gently sloping but cut by deeply incised stream channels which flow out onto the plain on east side of mountain. Soils tend to be deep and stone free (Sample sites 9 and 10, Appendix C) on ridges but shallow adjacent to the drainage channels. The local MP farms about 100 ha here and these past rains got 130 bags (11,700 kg) of an unknown area (Sample site 9, Tables C2 and C2b, Appendix C).

Songa Area is some 13 km south of Marsabit town, again just below the forest. This area was settled in the early 1970s. The MOA established a Forest Nursery in 1979. This has subsequently essentially become an agricultural sub-station with a very good selection of excellent fruit trees including lemon, papaw, avocado, cashew, etc. as well as Napier grass, Grevillea and Leucaena. The soils are dark red, stone free and very hard with abundant large cracks when dry.

Kituruni/Karare Area: Kituruni is another 3 km further south but is otherwise similar to Songa (Sample site 8, Tables C2 and C2c, Appendix C). Karare lies some 10 km west of Kituruni (or 22 km south of Marsabit town along the main highway). Both have been settled in the past decade.

Except for Karare and Gof Chopa areas where the topography is gentler, the majority of this area slopes gently to the southeast on long crests between deeply cut stream channels. Nowhere does the current cultivation drop below 900 meters elevation, and most of it stays close to the forest which is protected above (roughly) the 1200 meter contour.

#### **Potential for Further Development:**

While the better (i.e. higher rainfall) areas are substantially allocated, there are still a number of high ridges, and most of the lower slopes available, though these are currently used for dry season grazing. Mapping Unit E has been released for agricultural development and is the area with the most reliable agricultural potential. Of the total area of the Unit, some 20,000 ha lies above the 800 m contour, and of this an estimated 6,000 is suitable and not yet allocated for cultivation. It is also possible that some of Mapping Unit D might be available for development.

## **4.0 MOYALE REGION**

This area is part of three Districts (Sololo, Moyale and Bute), but for ease of presentation and because conditions are similar, they have been grouped as one unit. Within this district are three sub-units: Sololo to Moyale; Moyale to Bute; and Bute to Gurar. Common features of the

district are discussed below, while specific aspects of each subunit are discussed under appropriate headings.

Geology: The predominant geological material underlying the Ethiopian border area is undifferentiated basement system rocks (mainly gneisses). Hills of basic igneous rocks (serpentines, basalts, nepheline phonolites, older basic tuffs, etc.) occur as outliers in the plain.

Land Resources: At the base of the escarpment which, generally, forms the border with Ethiopia, is a nearly level, non-dissected peneplain of late tertiary age on Pre-Cambrian crystalline rock. The pattern of soils is dusky red to yellowish red, non-calcareous well drained profiles with textures varying at short distances from sandy loams to sand clay, interspersed, at sites of poor drainage, with bands and pockets of dark grey to black cracking clays, often saline and/or sodic Vertisols. Because these soils are highly variable, it is not easy to give an all embracing suitability rating, but based on soil/slope criteria, some parts will be moderately to well suited for crop production. Rainfall may, however, limit the scope for development. Areas which could be made available are described below. Gross and net areas are estimated in Table 1. Net areas are considerably less than gross due to soil variability and present land use.

Soil Mapping Unit A: Soils adjacent to the hills that form the Ethiopian border and which jut out into the plain are well drained, very deep yellowish red to dark reddish brown, loose loamy coarse sand to friable sandy clay loam. These soils have developed on undifferentiated basement system rocks and these frequently lie near the surface and/or outcrop. These soils are highly variable, but some areas are moderately to well suited to crop production (i.e. the broad valley between Bute and Gurar and on the east facing slopes south and east of Gurar).

Soil Mapping Unit B: At lower elevations away from the hills the soils tend to be well drained, deep to very deep dark red to dusky red friable sandy loam and sandy clay loams developed on sheetwash and aeolian deposits. These soils are highly variable, but some parts are well suited to crop production.

Soil Mapping Unit C: In the lower lying topographic sequence, imperfectly drained, deep, very dark grey to black, very firm, moderately calcareous, moderately to strongly sodic, cracking clays, developed on basic igneous rock. These soils are moderately suited to cultivation.

Soil Mapping Unit D: Soils along the Ethiopian border and of the hills that jut out into the plain are predominantly excessively drained, shallow reddish brown, friable, rocky or stony sandy clay loams. These soils have developed on undifferentiated basement system rocks and these frequently lie near the surface and/or outcrop. Except for small locations, these soils have little or no potential for mechanised cultivation.

Soil Mapping Unit E: The soils of the outlying igneous hills are well drained, shallow to moderately deep, very dark brown, firm stony or rocky clay loam on the higher parts. Except for small locations, these soils have little or no potential for mechanised cultivation.

Soil Mapping Unit F: The soils of the lower slopes of the igneous hills are well drained, deep to very deep, dark brown, firm moderately calcareous clays. This soil unit is generally well suited to mechanized cultivation.

Soil Mapping Unit G: In the slightly raised areas of the flood plains and adjacent to stream channels, soils tend to be moderately well to imperfectly drained, dark brown to dark reddish brown, very firm, moderately calcareous, slightly saline, slightly to moderately sodic, sand clay loams.

Soil Mapping Unit H: In the similar locations to Soil Unit G, but moderately well, deep, yellowish red, slightly firm, slightly calcareous, slightly saline, moderately sodic, cracking clays.

Soil Mapping Unit I: On the ridge at Moyale and in two valleys under the escarpment near Sololo the soils are well drained, deep, red sandy loams over firm sandy clay developed on basement system rocks. Though these soils have good agricultural potential, the rough topography makes these areas more suitable for orchard and small holder than for large scale farming.

Soil Chemical Analysis: 12 soil profiles have been analyzed (Table C-2; Figure 3). There is considerable variation in profile characteristics. Soil reaction tends to be neutral to moderately alkaline (pH 6.6 to 7.8) but profiles in the lower rainfall areas tend to be alkaline to strongly alkaline. All profiles are non-saline, but some of the soils have sodic subsoils (particularly Soil Units C, G and H). Texture ranges from loose loamy coarse sand to very hard clay. Cation exchange capacity ranges from low to very high, while base saturation is also extremely variable, giving a broad range to soil fertile status. Organic matter content, and thus nitrogen levels, is in most cases low. Exchangeable calcium tends to be low to medium (generally higher on the flood plain soils), while levels of magnesium are medium. Calcium: magnesium ratios vary considerably and thus in some soils calcium levels may be below plant requirements and available phosphorus may be inhibited. Potassium levels are, as a rule, high. Commercial crop production is likely to require moderate to high levels of nitrogen and potassium provided through a calcium based fertiliser; response to potassium fertiliser is not generally expected.

Climate: This area lies within agro-climatic zone V (Semi-arid). Average annual rainfall ranges between 450 and 900 mm (Tables B1 and B2, Appendix B); potential evaporation is 1650 to 2300 mm; thus the ratio of rainfall to potential evaporation ( $r/E_o$ ) of 25 to 40 percent. Risk of failure of a maize crop is fairly high (rated at 25 to 75 percent). The number of rain days (average) per year is ranges widely. Higher elevations nearer the Ethiopian escarpment have slightly lower temperatures and more reliable rainfall and thus the risk of crop failure is considerably reduced. The long rains are said to be the most reliable (approximately 60 percent of total annual rainfall).

Water Resources: Considerable quantities of water flow south from Ethiopia during the rainy season, but there is only limited potential to develop (contain in ponds, reservoirs etc.) this surface water due to the low relief and lack of storage sites which do not pond the water back into Ethiopia nor flood prime agricultural land. There appear (from 1:100,000 Scale topographic maps) to be only a few potential storage sites along the Ethiopian Escarpment. Subsurface outflow seepage from Ethiopia may indirectly contribute soil moisture (through subsurface seepage) to crops grown on land near the border. Groundwater potential is largely unknown, but the basement geology and rainfall suggest that reasonable quantities should be found throughout the area. This will need to be more fully investigated as part of project development.

## 4.1 BUTE-GURAR

Land Resources: East of Bute (Block I, Figure 3), along the Ethiopian border and the hills that jut out into the plain the soils are predominantly Soil Mapping Unit D. To the east of the Godana Oda ridge (south and east of Gurar) there is what appears to be a substantial area (Soil Unit A, 15,000 ha gross and Soil Unit B, 10,000 ha gross) of suitable agricultural land. This area was not visited during the survey, but was seen from the air. These soils are highly variable, but bush cover is heavy indicating the parts of these areas would be moderately to well suited to crop production, provide rainfall is adequate.

One area identified with good agricultural potential is the Adadijole Cooperative block (estimated 4,000 ha) in the broad valley between Bute and Gurar (Block II, Figure 3). Two soil profiles were described in this area. Sample Site 12 - deep, moderately well drained, friable, yellowish brown very fine sandy clay loam over strong brown sandy loam developed from colluvial material (Soil Mapping Unit A). The land is nearly level, and anthills (of remnants of anthills) are common. Sample Site 13 - deep, imperfectly drained, dark grey to black very firm, (moderately calcareous, slightly moderately sodic), cracking clay (Soil Mapping Unit C). Site 12 is said to represent most of the soils within the block; Site 13 soils to represent only a small portion along the southern boundary, but are said to be best for rainfed sorghum. There are occasional shallow soils and rock outcrops in the area.

Water Resources: There appear (from 1:100,000 Scale topographic maps) to be two potential storage sites north of Bute and one southeast of Gurar. It seems that there is fair groundwater potential.

## 4.2 MOYALE-BUTE

Land Resources: Around Moyale and east to Bute along the Ethiopian border (Block III, Figure 3) and in places extending a considerable distance into the plain - estimated 30,000 ha gross. These soils are highly variable, but some areas would be moderately to well suited to crop production, (notably Mapping Units A and F), provide rainfall is adequate.

Five representative soil profiles were sampled in this block (Table C1). These are:

Sample Site 14 - well drained, deep, friable, yellowish red sandy loam over dark reddish brown loam (Soil Unit A). Locally said to be moderately suitable soil for crops.

Sample Site 15 - well drained, deep, red to dusky red, friable clay; wide surface cracks (Soil Unit F). This soil, examined in a maize field near Nana, is said by locals to be the best soil in the Moyale area.

Sample Site 16 - very hard, dark grey clay, strongly vertic and calcareous, slightly saline at 50 cm (Soil Unit C).

Sample Site 17 (taken near Godoma village) - dark reddish brown sandy loam over dark red sandy loam/sandy clay loam (Soil Unit A). These are similar to Sample Site 12 (Block II) and are said not to be the best soil in the Godoma area (The Chief classed these as Nana No. 1 and Godoma No. 2 soils).

Sample Site My 18 - Yellowish red sandy loam over dark red sandy clay loam (Soil Unit A).

Water Resources: Potential storage sites may be found just east of Moyale (near Masili) and at Godoma. Several small storage ponds are scattered across the area. These are used mainly for cattle watering and rarely contain water for the entire dry season. Groundwater potential is fair to good. Nana had a well drilled in 1973 and redug again in 1987, but is not functioning. It is said to be less than 50 foot deep, has a good supply of salty water. There is said to be good water across the border in Ethiopia. Godoma village has a well, said to be 300 meters (feet??) deep providing lots of good water. Bute also has a good borehole.

### **4.3 MOYALE-SOLOLO**

Land Resources: West of Moyale to Dambala Faschana (Block IV, Figure 3) there are some 13,000 ha (gross) of Soil Unit B out of a total estimated land area of 35,000 ha (Table 1). The Soil Unit B area is immediately west of a high ridge and thus could be in a rain-shadow (this will need checking), though vegetation/bush cover is heavy.

Six representative soil profiles were sampled in this block (Table C1). These include:

Sample Site 20 - Dark red to dusky red sandy clay loam over clay (Soil Mapping Unit B but much finer texture)

Sample Site 22 (taken at Biro) - Yellowish red to dark reddish brown loamy sand-sandy loam (Soil Unit A). Locals say this soil is not good as it is subject to drought.

Sample Site My 24 - Very dark greyish brown over dark brown clay (Soil Mapping Unit H). Said not to be very good soil by locals.

Sample Site 25 (taken are Dadacha Obo) - Dark brown to dark reddish brown clay loam over clay (Soil Mapping Unit F). This soil said to be very good by locals.

Water Resources: Potential storage sites may be found near Bori and Sololo. Several small storage ponds are scattered across the area. These are used mainly for cattle watering and rarely contain water for the entire dry season. Groundwater potential is fair to good. Sololo has a borehole.

### **4.4 SOLOLO**

Land Resources: East and west of Sololo (Block V, Figure 3), under the escarpment, are two valleys of about 1000 ha each. These are Soil Mapping Unit I (Table C1). Though these soils have good agricultural potential, the rough topography makes these areas more suitable for orchard and small holder than for large scale farming. The rest of the area is predominantly Soil Unit A. At Golole, 8 km northwest of Sololo town the local agriculturalist reported farmers averaging 10 to 15 bags (900 to 1300 kg) per hectare of maize.

Water Resources: Both valleys are well watered in the rainy season but may have potential storage sites. Groundwater potential is fair to good. Sololo and Golole both have boreholes.

## **5.0 SOLOLO-HURI HILLS**

Land Resources: West of Sololo there are 6 locations (Figure 1) ranging in size from 500 to 5000 ha (gross). The soils tend to be Soil Unit A and D (with rock outcrops). These soils offer some potential for large scale farming but are of limited area.

The old lava plains of the Walde area have a mainly semi-arid climate (250-500 mm rainfall). Topography is flat to very gently undulating and the drainage is seasonal. The soils are predominantly Soil Mapping Unit C, and profiles are mostly saline and sodic (Sample Site 26, Table C1). These lands are not suitable for arable crop production due to low rainfall and soil salinity.

Climate: This area lies within agro-climatic zone VI (Arid). Average annual rainfall ranges between 300 and 550 mm; potential evaporation is 1900 to 2400 mm; thus the ratio of rainfall to potential evaporation (r/Eo) of 15 to 25 percent. Risk of failure of a maize crop is very high (rated at 75 to 95 percent).

Water Resources: There is virtually no potential storage sites in this area. Groundwater potential is unknown, though it is known that groundwater tends to be saline.

## **6.0 HURI HILLS**

Land Resources: On the crest of the Huri Hills (Figure 1) the soils are somewhat similar to those of Marsabit. Above the 1200 meter contour the soils are well drained, very deep, dusky red to dark reddish brown friable clay developed on Olivine Basalts and ash from older volcanoes. The lower slopes are predominantly well drained, shallow, dark reddish brown, friable, rocky and stony clay loams with bedrock and lava vent inclusions.

Climate: This area lies within agro-climatic zone VI (Arid). Average annual rainfall ranges between 300 and 550 mm; potential evaporation is 1900 to 2400 mm; thus the ratio of rainfall to potential evaporation (r/Eo) of 15 to 25 percent. Risk of failure of a maize crop is very high (rated at 75 to 95 percent). Annual rainfall recorded since 1975 has been less than 450 mm (average 350 mm) except for 1976 when it was 750 mm.

Water Resources: Considerable investigations have been undertaken since 1975 and the conclusion is that there is very little potential to develop surface water storage nor find adequate groundwater.

## **7.0 MOUNT KULAL**

Land Resources: Mount Kulal (Figure 1) soils are again somewhat similar to those of Marsabit. On the crest of the mountain (above the 1200 meter contour), the soils are predominantly well drained, shallow, dark reddish brown, friable very rocky and stony clays. On the more level areas, these soils tend to have a deep well developed profile. The lower slopes are predominantly well drained, shallow, dark reddish brown, friable, rocky and stony clay loams

with bedrock and lava vent inclusions. All soils have developed on Olivine Basalts and ash from older volcanoes.

Climate: The crest (above 1200 meters) of Mount Kulal lies within agro-climatic zones III and IV (Humid to Semi-humid). Average annual rainfall ranges between 800 and 1600 mm; potential evaporation is between 1450 and 2200 mm; thus the ratio of rainfall to potential evaporation (r/Eo) of 40 to 65 percent. Risk of failure of a maize crop is low (rated at 5 to 25 percent). The lower slopes fall within agro-climatic zone V (semi-arid). Average annual rainfall ranges between 450 and 9000 mm; potential evaporation is 1650 to 2300 mm; thus the ratio of rainfall to potential evaporation (r/Eo) of 25 to 40 percent. Risk of failure of a maize crop is fairly high (rated at 25 to 75 percent).

## **8.0 BANISSA**

Land Resource: From Banissa north to the Ethiopian Border (Figure 1) there is a large peneplain some 35,000 ha in extent. Core area of well drained, deep, dark red, friable clay over petro-plinthite developed on Tertiary claystones (Banissa beds). Surrounding the above is a well drained, shallow to moderately deep, dark reddish brown, firm, moderately calcareous clay over petrocalcic material on Jurassic oolitic limestone. These soils appear to have moderate to good agricultural potential but rainfall is too low and unreliable to grow crops.

Climate: This area lies predominantly within agro-climatic zone VII (Very arid). Average annual rainfall is less than 350 mm and potential evaporation 2100 to 2500 mm; thus the ratio of rainfall to potential evaporation (r/Eo) of less than 15. Risk of failure of a maize crop is rated at 95 to 100 percent.

Water Resources: Seems little potential to develop surface water (i.e. ponds, reservoirs). Groundwater potential unknown.

## **9.0 SOCIAL IMPLICATIONS/IMPACT**

While the land in the areas investigated appear to be highly under-utilised, it must be borne in mind that all are, at one time or the other during the year, traditional grazing lands for the local livestock owners. Any increased cultivation intensity will need to take this into consideration and recognise such traditional rights as trek routes and access to water.

## **10.0 POTENTIAL CROPS AND THEIR REQUIREMENTS**

The low and highly variable total rainfall, and the bimodal pattern, significantly reduces the crop options for commercial large scale mechanised crop production. For the purposes of this study, a brief assessment has been made of preferred crops and those which are possible alternatives. These are:

### **Cereals:**

Maize: requires 600 to 900 mm of well distributed rain over the 90 to 150 day growing season. Optimum average daily temperature is about 20-25°C. Long season rains in general are not sufficient to meet crop requirements (at Marsabit only 4 of the last 10 years had rainfall greater

than minimum). Maize is not drought tolerant, and thus, even though the crop is grown, cannot be expected to give commercial yields under the existing rainfall regime.

Sorghum: requires 450 to 650 mm of well distributed rain over the 90 to 150 day growing season and has good drought tolerance, and thus would be more suited to the area than maize. Full mechanisation possible and there are no major problems with pests. However, market may be limited as the majority prefers maize to sorghum.

Sorghum and Millet: requires 250 plus mm rainfall, has good drought tolerance, and thus should produce well in the area. As with sorghum, markets may be limited.

Wheat: requires 450 to 650 mm of well distributed rain, but temperatures are higher than optimum. Some wheat is grown at Marsabit and there may be new short season varieties which would be commercially attractive at the higher altitudes.

Teff: is not generally grown outside the highlands of Ethiopia, and thus its suitability for this area and under commercial management needs to be confirmed.

### **Fibres:**

Cotton: requires at least 450 mm of rain spread over the growing season. Optimum average daily temperature is about 30°C. While drought tolerant, the distinct bimodal rainfall pattern is not conducive to commercial production. Limitations would be sufficient labour as it is not possible to mechanise harvesting at present time in Kenya.

Kenaf: in theory this could be grown in the area, but requirement for high quantities of water for retting would restrict consideration at this time. Possibly some market in Kenya for manufacturing to maize bags, etc.

### **Oilseeds:**

Castor: is a very drought tolerant oilseed with a good market as an industrial oil. New hybrids can be grown as annuals. Very little inputs needed by way of pest control etc., but a dedicated oil refinery is required.

Sesame: has a very short growing season (8 to 10 weeks), but as pods tend to shatter easily, there is limited potential for mechanise. A fairly specialised oil mill is required. Market in Kenya/abroad for confectionary.

Sunflower: has rather high rainfall (minimum 600 mm) requirement, but is drought tolerant. New short season high oil content hybrids would be needed. Very easy to fully mechanise and harvesting particularly easy. The market for oil is very good.

Soya: requires 450 to 700 mm rainfall, is not particularly drought tolerant, and thus very limited potential.

Groundnut: required 500 plus mm of well spread rain and is not sufficiently drought tolerant, so has limited potential.

Safflower: is widely grown in Asia on 300 mm rain and is very drought tolerant, thus appears to be well suited to the area. Difficult to handle at harvest due to spines on flowers unless fully mechanised, and it is not recommended year after year due to soil diseases.

Jojoba: Has been tried in Kenya but has not caught on as a viable crop.

### **Fruits/Vegetables:**

There is limited potential for most of these on a small scale and at specific locations.

In conclusion, the easiest to grow and mechanise are sunflower and sorghum. A check on research data available for the area, or similar environments, is required. By far the best oilseed for rainfall of the area is safflower and it can be mechanised but the market would need to be identified.

## **11.0 POTENTIAL MARKETS**

There is a limited market for production within the area, particularly food crops such as maize, and this is expected to expand in the long term. Improving infrastructure will increase ease of transport around the region and away from it.

Outside the area, the best market for food crops, at least in the short term, will be north of the border in Ethiopia, as possibly also in Sudan. Tapping this market would have advantages in bringing in foreign exchange but sale would most likely be by triangular agreements with money provided by foreign donors to purchasing governments. Such marketing will need to be aware of general barriers to inter-regional trade (i.e. Kenya does not allow export of wheat) and local versus world commodity prices.

The EC estimates that 1.3 million tonnes of cereal and 0.05 million tonnes of vegetable oil food aid will be required in the region in the current year. Triangular agreements are typically for quantities of 10 to 15,000 tonnes per order and purchase is on tender basis, not an assured market for a commercial venture.

More investigation will be necessary to ascertain the potential cross border food requirements for the foreseeable future and to plan the strategy for obtaining a reasonable portion of that market.

## **12.0 SUMMARY AND CONCLUSIONS**

Approximately 6,000 ha of land at Marsabit and 35,000 ha in Moyale Region have little or no restriction to commercial crop production (Figures 2 and 3 - Table 4.1). The remainder of the area investigated is either used, not suitable, or otherwise restricted.

Marsabit: The best land and highest rainfall area is from Karare Gate around to Badasa on the eastern side of the mountain above the 800 meter contour (Soil Mapping Unit E, Figure 2). There is also some good land north and west of Badasa and west of Karare but this has (or appears to have) lower rainfall, and some of it lies within the part boundary. Aerial view shows

that 25-30 percent of the potential area is occupied, and approximately 50 percent would not be suitable (shallow soils, steep slopes, etc.). Two large ridges between Songa and Kituruni are not occupied.

Sololo-Moyale-Bute: Within the demarcated areas, there will be inclusions of land with is unsuitable for one reason or another for commercial production of one or more of the suggested crops. Limitations include salinity, topography, coarse texture and shallow profiles.

Climatic data collected at the various recording stations in the area show that the rainfall is marginal for cotton and decidedly risky for maize primarily because the annual rainfall is bimodal, falling in two distinct seasons. Only the long rains offer a possibility for cereal production, but even so only two years in the last ten have had adequate rainfall to produce a commercial yield. Factors other than rain contribute to obtaining yields where rainfall is short - these are altitude, mists and cloud cover which reduce potential evaporation and increase rainfall effectiveness.

Bute-Gurar: This area looks good (has good tree cover) but soils are variable and a more thorough investigation is needed to delineate soil types, and to document the rainfall of the area. The Council at Bute has demarcated an area at Adadijole which has an estimated gross area of 4000 ha (Block II, Figure 3). To the east of the ridge containing Godana Oda (south and east of Gurar) there is what appears to be a good area of land. The estimated gross area is 25,000 ha.

Huri Hills: Considerable pasture, afforestation and crop production research has been done since 1975. Some limited success has been obtained with crop production during the long rains. In a 5 year cycle, in 2 years the yields will be greater than 20 kg/kg seed sown, in 2 years the yield will be less than 20 kg/kg seed sown and one year will be a total failure. By comparison, a commercial farming venture would expect to see a return in the order of 100 times this (i.e. 2000 kg per kg sown, or more).

Kalacha: Considerable success with irrigation of vegetables from springs at the edge of the Chalbi Desert, but this on small scale and there seems to be no potential for any large scale production.

Mount Kulal: Very small areas suitable for farming, even on relatively small scale, due to steep slopes. Best area is around Gatab and this is largely occupied.

### **13.0 RECOMMENDATIONS**

One: The priority area for acquiring land for cultivation in northern Kenya should be as follows:

Priority 1: Marsabit - Mapping Unit E - all unallocated land above approximately 800 meters and the forest reserve. Any additional land outside the park and not allocated in Soil Mapping Unit D.

Priority 2: Bute - Block II - Adadijole Cooperative Block (Chachana's land).

Priority 3: Bute East - Block 1 (East and South of Gurar), Soil Mapping Units A and B. This might be linked with Priority 2.

Priority 4: Moyale West - Block IV, Soil Mapping Unit B. You might add Soil Mapping Units A and F.

Priority 5: Moyale East - Block III, Soil Units A and F where not allocated.

Priority 6: Sololo - Block V, Soil Mapping Unit A, where not allocated. Doubtful if much land is available, but may be some potential to rent.

Two: Once land areas have been selected, further soil investigations should be undertaken to differentiate suitable from non-suitable soils. At this time a detailed investigation of surface and groundwater development potential should be commissioned.

Three: Potential crops suggested in section 10 of the report need to be considered in more detail once the land has been selected as micro-climatic variations may be important. Markets also need to be firmed up (i.e. at the moment, Djibouti is a demand area for sorghum, but not Ethiopia).

Two further points:

1. At Marsabit the land is good land but MP Falana says farmers are not interested therefore yields indifferent. If this is true there may be a possibility of renting allocated land and thus increasing production in the better areas.
2. The D.O at Bute is new and when I was there was insisting that all investment be cleared through the D.C. and D.D.C. at Wajir (but he emphasised that any investment should be direct??). As a result he was unwilling to give me free access and I was only permitted to see land (not take soil samples) that was part of the Adadijole Cooperative east of Bute.

## APPENDICES

### APPENDIX A: SOIL PROFILE DESCRIPTIONS

#### Mapping Unit A

Location: On the top of Mount Marsabit above 1400 m.

Agro-climatic Zone: Zones III and IV.

Parent Material: Basalts, tuffs and possibly also weathered. (Tertiary/Quaternary volcanics).

Relief: Mountainous; very irregular, undulating parts occur as well as very steep slopes (slopes from 8 to over 30%).

Erosion: Under natural forests hardly any erosion occurs; where the land is used for agriculture, moderate splash and rill wash to heavy gully erosion takes place.

Vegetation: Mist montane forest.

Land Use: Mainly forest reserve (wildlife); outside the reserve heavy grazing by domestic animals takes place as well as arable farming.

Surface Stoniness: None to fairly stony (basalt stones).

Soils: The soils are dark reddish brown, well drained, deep to very deep, clay with a clear ABC profile development (Profile Description No 1).

The surface horizon is well supplied with available Ca and Mg but K and P are low. The organic carbon content (4%) CEC (30me/100g) and base saturation are high. Soil reaction is strongly acid (pH-H<sub>2</sub>O = 5; pH-KCl = 4.5). These values tend to decrease with profile depth (Tables C1 and C2).

#### Mapping Unit B

Location: Around and to the north east of Marsabit town.

Agro-climatic Zone: Mainly zone V, bordering zone IV.

Parent Material: Basalts and pyroclastics. (Tertiary and Quaternary volcanic rocks).

Relief: Gently sloping, slopes from 2 to 5%, places interrupted by small cinder cones with steep slopes (slope class B).

Erosion: Splash and rill wash to slight gully erosion; cattle tracks cause rill erosion.

Vegetation: Perennial grassland with shrubs; in places cleared for cultivation.

Land use: Mainly extensive grazing; in places cultivated plots.

Surface stoniness: Non to fairly stony (basalts).

Soils: The soils are well drained, deep to very deep, dark reddish brown clay (stony in places) with an ABC profile development (Profile Description 3).

The surface horizon is moderately fertile having a generally lower level of nutrients than the subsoil. Ca levels are particularly low while available P and K are low to moderate. Organic carbon content (ranging from 1.9 to 2.5%) is also low. CEC ranges between 17 and 28 me/100g soil while CEC-clay is around 45 me/100g. Base saturation is around 80%. Soil reaction is neutral (pH-H<sub>2</sub>O = 6.8; pH-KCl = 5.7) (Tables C1 and C2).

Clay mineralogy: X-ray analysis shows the presence of both illite and kaolinite.

#### Mapping Unit C

Location: This unit lies at the northern side of the top of Mt. Marsabit.

Agro-climatic Zone: Zone V.

Parent Material: Various volcanic rocks, basalts, tuff and ashes (Tertiary/Quaternary).  
Relief: Irregular with gentle to steep slopes - 2 to over 16% (slope class BCD). Many pyroclastic hills occur within this unit.  
Erosion: Heavy (splash and rill wash) and slight gully erosion occurs.  
Vegetation: Evergreen to semi-deciduous bushland with perennial grasses as understory.  
Land Use: Heavy grazing with domestic animals is practised.  
Surface Stoniness: Very stony (mainly subangular lava stones).  
Soils: The soils are well drained, shallow to moderately deep, dark reddish brown, moderately to strongly calcareous, very stony and gravelly clay loam to clay which do not show a very well developed ABCR profile (Profile Description 4).  
The surface horizon is moderately well to well supplied with available nutrients. Organic carbon content is 0.5 to 1.4%; CEC is 21me/100g and base saturation of 80-100%. Soil reaction is neutral (pH-H<sub>2</sub>O = 6.6; pH-KC1 = 5.8).  
The subsoil has a significantly higher CEC (28me/100g soil; 75me/ 100g clay); and soil reaction (pH-H<sub>2</sub>O = 7.4; pH-KC1 = 6.5) (Tables C1 and C2).

### **Mapping Unit D**

Location: Southwest of Marsabit, near the top of the mountain.  
Agro-climatic Zone: Zone V and VI.  
Parent Material: Basalts and pyroclastics (Tertiary/Quaternary volcanics).  
Relief: Nearly flat, slopes (0-2%), interrupted by cinder cones with steep slopes (slope class AB).  
Erosion: Slight splash and rill wash erosion; with increasing grazing pressure, erosion will increase.  
Vegetation: Evergreen to semi-deciduous bushland with *Acacia hockii*/*Dichrostachys*/*Harrisonia* as the main species; perennial grasses the understory.  
Land Use: Grazing by pastoralists.  
Surface stoniness: Non to fairly stony (basalts).  
Soils: The soils are well drained, deep to very deep, dark reddish brown, clay (in places very stony) and show a distinct profile development (Profile Description 5).  
The surface horizon is moderately well supplied with available nutrients; only phosphorus is low. Organic C content is about 1%, CEC about 25 me/100g and base saturation high. Soil reaction is neutral (pH-H<sub>2</sub>O = 6.8; pH-KC1 = 5.6).  
In the subsoil, CEC and base saturation are appreciably lower (CEC is about 17 me/100g soil and 30 me/100g clay) with a base saturation of 75%. The pH-H<sub>2</sub>O is 6.6; pH-KC1: 5.9. (Tables C1 and C2).

Clay Mineralogy: Metahalloysite is dominant. Montmorillonite also occurs.

### **Mapping Unit E**

Location: Southeast of Marsabit.  
Agro-climatic Zone: Zone V.  
Parent Material: Basalts mixed with pyroclastic rocks (Tertiary/Quaternary volcanics).

Relief: Crests are undulating with slopes of 5-8%; the valley sides are hilly with slopes over 16% (slope class BE).

Erosion: Severe splash and rill wash, and slight gully erosion.

Vegetation: Evergreen to semi-deciduous bushland with perennial grasses as understory.

Land Use: Seasonal grazing. This land is extensively cultivated at present.

Surface Stoniness: In places stony (subangular basalt).

Soils: The soils are well drained, moderately deep to very deep and dark reddish brown, very bouldery to stony clay loam to clay with a clear ABCR profile development. (Profile Description 6).

The surface horizon is moderately well supplied with available nutrients. Organic carbon content (1%) and CEC (15me/100g soil) is low. Base saturation is 100%. Soil reaction is moderately alkaline (pH-H<sub>2</sub>O = 7.9; pH-KCl = 6.6).

Subsoil CEC is slightly higher at 19 me/100g soil (12 me/100g clay) and soil reaction neutral (Tables C1 and C2).

Clay Mineralogy: Kaolinite is the dominating clay mineral.

### **Profile Description No: 1**

#### General Site Information

Mapping Unit: A

Soil Classification: Luvic Phaeozem

Observation No/Date: 55-1; 12/2/74

Location/Altitude: Marsabit District; 37E57'E, 2E18'; 1400m

Agro-climatic Zone: III

Parent Material: Basalts and tuffs (Tertiary volcanics)

Physiography: Mountain top

Relief: Mountainous; Slope at Site: 25-35%, upper slope

Vegetation: Moist montane forest

Land Use: Game and forest reserve

Erosion: Nil

Surface Stoniness/Rockiness: Locally basalt outcrops

Surface Sealing: Nil

Drainage Class: Well drained

#### Profile Description

Ah 0-20cm Dark brown (7.5 yr 3/2 dry and moist); clay; moderate, coarse, crumbs; slightly hard when dry, very friable when moist, sticky and plastic when wet; common medium and coarse pores; clear and wavy transition to:

Bt3 75-115cm Dusky red (2.5 yr 3/2 dry and moist); clay; weak, fine and medium, sub-angular blocky; slightly hard when dry, very friable when moist, very sticky and very plastic when wet; thin, continuous clay cutans; clear and smooth transition to:

BC 115-130+cm Dark reddish brown (5 yr 3/2 dry and moist); clay

Remarks: The description of the soil below 115 cm depth is based on an augering.

### **Profile Description No: 3**

#### General Site Information

Mapping Unit: B  
Soil Classification: Chromic Cambisol  
Observation No/Date: 55-17; 24/3/82  
Location/Altitude: Marsabit District; 37E58'E, 2E21'N; 1320m  
Agro-climatic Zone: V  
Parent Material: Basalts, possible mixed with some volcanic ashes (Tertiary/Quaternary)  
Physiography: High level uplands  
Relief: Gently sloping; Slope at Site: 4%  
Vegetation: Perennial grassland  
Land Use: Mainly grazing  
Erosion: Slight gully  
Surface: Stoniness/  
Rockiness: None to fairly stony  
Surface Sealing: Nil  
Drainage Class: Well drained

#### Profile Description

- Ah 0-20cm Dark reddish brown (2.5 yr 3/4 dry), reddish brown (5 yr moist); clay; strong, fine to medium, subangular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; common fine and medium, few coarse pores; gradual and smooth transition to:
- Bw1 20-50cm Reddish brown (2.5 yr 4/4 dry), dark reddish brown (2.5 yr 3/4 moist); clay; moderate, coarse, subangular blocky; hard when dry, very friable when moist, sticky and plastic when wet; few fine to coarse pores; gradual and smooth transition to:
- Bw2 50-90cm Dark red (2.5 yr 3/6 dry), dark reddish brown (2.5 yr 3/5 moist); stony clay; weak, coarse prismatic, breaking into moderate, medium and coarse, subangular blocky; hard when dry, very friable when moist, sticky and plastic when wet; few, fine to coarse pores; stones consist of weathered rounded basalt; clear and smooth transition to:
- C 90-140cm Soft, rotten basalt with Fe and Mn mottles; irregular transition to:
- R 140+cm Coherent basalt.

Remarks: Roots are present to a depth of over 100 cm.

### **Profile Description No: 4**

#### General Site Information

Mapping Unit: C  
Soil Classification: Eutric Cambisol, stony and petric phase  
Observation No/Date: 55-14; 27/3/82  
Location/Altitude: Marsabit District; 38E00'E, 2E24'N; 1200m  
Agro-climatic Zone: V

Parent Material: Basalts and pyroclastic materials (Tertiary/Quaternary)  
Physiography: High level uplands  
Relief: Undulating; Slope at Site: 3%  
Vegetation: Evergreen to semi-deciduous shrub land with perennial grasses as understory  
Land Use: Strong splash and rill wash erosion  
Surface Stoniness/Rockiness: Stony to very stony  
Surface Sealing: Nil  
Drainage Class: Well drained

#### Profile Description

Ah 0-20cm Dark reddish brown (5 yr 3/3 dry and 5 yr 3/2 moist); stony and gravelly clay; weak, medium, prismatic, breaking into moderate, fine to medium, subangular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; few, fine to medium pores; stones and gravel consist of lava fragments; clear and smooth transition to:  
Bw 20-60cm Dark reddish brown (5 yr 3/4 dry and 5 yr 3/3 moist); very bouldery and stony clay; weak, fine to medium, subangular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; moderately calcareous; stones and boulders consist of basalt; abrupt and smooth transition to:  
Cmk 60-62cm Platy petrocalcic material: abrupt and smooth transition to:  
CR 62+cm Tuffs

Remarks: Many fine and common roots from 0-60 cm.

#### **Profile Description No: 5**

##### General Site Information

Mapping Unit: D  
Soil Classification: Chromic Luvisol  
Observation No/Date: 55-16; 29/3/82  
Location/Altitude: Marsabit District; 37E53'E, 2E11'N; 1050m  
Agro-climatic Zone: V  
Parent Material: Basalts and pyroclastics (Tertiary/Quaternary volcanics)  
Physiography: Stepped plateau; Slope at Site: 1%  
Vegetation: Scrubland with perennial grasses as understory  
Land Use: Intensive grazing  
Erosion: Splash and slight rill erosion  
Surface Rockiness/Stoniness: None to fairly stony  
Drainage Class: Well drained

#### Profile Description

Ah 0-20cm Dark reddish brown (5 yr 3/4 dry) and (5 yr 3/3 moist); clay loam; strong, fine to medium, subangular to angular blocky; hard when dry, friable when moist, sticky and plastic when wet; few fine to coarse pores; clear and smooth transition to:  
Bt1 20-55cm Red (2.5 yr 4/6 dry), dark reddish brown (2.5 yr 2.5/4 moist); clay; moderate,

coarse, subangular blocky, slightly hard when dry, very friable when moist, sticky and plastic when wet; no cutans observed; common, fine to coarse pores; gradual and smooth transition to:

- Bt2 55-130+cm Dark red (2.5 yr 3/6 dry), dark reddish brown (2.5 yr 3/5 moist); clay; weak, medium to coarse, angular blocky; hard when dry, very friable when moist, sticky and plastic when wet; moderately thick, broken, clay cutans; common fine to coarse pores; very few, medium, basalt fragments.

Remarks: Throughout the profile, common, fine and few, large roots occur.

## **Profile Description No: 6**

### General Site Information

Mapping Unit: E

Soil Classification: Ferralic Cambisol, bouldery and partly petric phase

Observation No/Date: 55-23; 17/1/83

Location/Altitude: Marsabit District; 37E53'E, 2E8'N; 840m

Agro-climatic Zone: V

Parent Material: Basalts and pyroclastics (Tertiary/Quaternary volcanics)

Physiography: Footridges

Relief: Crests are undulating, with steep slopes to the valley sides; Slope at Site: 5%

Vegetation: Evergreen to semi-deciduous bushland with perennial grasses as understory

Land Use: Seasonal grazing

Erosion: Severe sheet wash, slight gully

Surface Rockiness/Stoniness: In places stony

Surface Sealing: Nil

Drainage Class: Well drained

### Profile Description

- A 0-20cm Yellowish red (5 yr 3/5 dry), dark reddish brown (2.5 yr 3/4 moist); stony clay loam; moderate, fine to coarse, subangular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; many fine, few medium and large pores; stones consist of basalt's clear and smooth transition to;
- Bw1 20-40cm Dark reddish brown (2.5 yr 3/4 dry and moist); stony and bouldery clay loam; weak, medium to coarse, angular blocky; very friable when moist, sticky and plastic when wet; many fine, common medium, few large pores; boulders and stones consist of basalt; gradual and smooth transition to:
- Bw2 40-65cm Dark reddish brown (2.5 yr 3/4 dry and moist); very bouldery clay loam; porous massive; weakly coherent; very friable when moist, sticky and plastic when wet; many fine, few medium pores; boulders consist of basalt; gradual transition to:
- BC 65+cm More than 80% basalt boulders

Remarks: The stones and boulders in the profile are rounded and slightly weathered at the outside. Roots are present throughout the profile.

## APPENDIX B: RAINFALL DATA

**Table B1: Rainfall Probabilities and Return Periods at Marsabit (After Bake, 1983)**

(a) Annual rainfall probabilities (median 777 mm/year)

Rainfall (mm)	Probability (%)	Return Period (years)
300- 400	5.7	18
401-500	1.9	53
501-600	16.7	6
601-700	9.3	11
701-800	18.5	5
801-900	9.3	11
901-1000	9.3	11
1001-1100	13.0	8
1101-1200	3.7	25
1201-1300	3.7	25
>1300	39.3	11

(b) Monthly rainfall probabilities at Marsabit

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
<25mm	0.6	0.8	0.3	0.0	0.3	0.9	0.8	0.8	0.8	0.2	0.0	0.3
>50mm	0.3	0.1	0.4	0.9	0.6	0.0	0.0	0.1	0.0	0.7	0.8	0.4
>100mm	0.1	0.1	0.2	0.8	0.4	0.0	0.0	0.0	0.0	0.5	0.5	0.3
>200mm	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.2	0.2	0.1
Median (mm)	17	4	43	209	70	3	7	7	7	103	116	47
Average (mm)	38	19	78	225	98	7	16	18	13	123	154	70

(c) Monthly rainfall probabilities for the lowlands (Marsabit/3, Median 239 mm/yr)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
<25mm	0.9	0.9	0.6	0.1	0.5	1.0	1.0	1.0	1.0	0.4	0.4	0.7
>50mm	0.1	0.0	0.1	0.7	0.3	0.0	0.0	0.0	0.0	0.3	0.4	0.1
>100mm	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
>200mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Median (mm)	6	1	14	70	23	1	2	2	2	34	39	16

**Table B2: Monthly Potential Evaporation (Eo), Evapotranspiration (Et) and Rainfall (r) at Marsabit (mm)**

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Eo	145	145	164	145	145	145	164	164	164	146	127	127	1800
Et	96	96	108	96	96	96	108	108	108	108	84	84	1200
r	38	19	78	225	98	7	16	18	13	123	154	70	859

## APPENDIX E: SOIL PROFILE ANALYSIS

**Table C1a: Summary of fertility status of the topsoil of the different mapping units**

Mapping Unit	Depth (cm)	pH (H <sup>2</sup> O)	CEC (me/100g)	C (%)	N (%)	Ca	Mg	K	Na	Mn	P
						(ppm)					
Marsabit											
1	-	53	30	5.0	-	122	73	0.14	-	-	5.0
2	0-50	6.0	29	2.6	0.2	9.8	5.6	0.92	0.2	0.9	44.0
3	-	6.8	20	1.2	-	12.0	6.4	0.9.	-	-	10.0
4	-	6.6	21	1.1	-	14.0	6.0	2.2.	-	-	14.0
5	-	6.8	25	1.0	-	5.6	4.6	0.9.	-	-	4.0
6	-	7.9	15	1.0	-	9.4	8.4	1.24	-	-	7.0
7	0-50	6.5	21	1.0	0.12	5.0	4.6	0.74	0.08	0.56	7.0
10	0.50	5.8	24	2.1	0.15	4.2	3.2	0.94	0.05	0.52	7.0
Sololo											
19	0-10	6.4	14	-	-	-	-	0.5	-	-	32.0
21	0-10	6.5	6	-	-	-	-	0.7	-	-	4.0
23	0.30	7.0	34	-	-	-	-	0.3	-	-	20.0
26	0-40	8.5	66	0.7	0.05	29.5	8.9	0.04	1.70	0.02	8.0

Source: KSS Reports P22 and R12.

**Table C1b: Summary of fertility status of the topsoil of the different mapping units**

Mapping Unit	Available Nutrients							Remarks
	K	Ca	Mg	P	C	CEC	pH	
	(me/100g)			(ppm)		(me/100g)	(H <sup>2</sup> O)	
MV1	0.14	12.2	7.3	5	4.0	30	5.3	
U1V2	0.90	12.0	6.4	10	1.1	21	6.8	
U1V3P	1.10	14.0	6.0	10	1.1	21	6.6	
LsV2	0.9.	5.6	4.6	4	1.0	25	6.8	
RVp	1.24	9.4	8.4	7	1.0	15	7.9	

**TABLE C2: LABORATORY DATA FOR SOIL PROFILE DESCRIPTIONS**

Profile	Depth (cm)	pH (H <sub>2</sub> O) (1:2.5)	pH KCL (1:2.5)	EC (1:2.5) ms/cm	C %	N %	CEC (me/100g) pH 8.2	Exchangeable Cations (me/100g)				Sum of Cations	Base Sat	ESP	Texture-Limited Pre-treatment			
								Ca	Mg	K	Na				Sand %	Silt %	Clay %	Texture
1	0-20	5.0	4.5	0.50	3.80	0.51	33.00	12.40	10.20	0.50	0.30	23.40	<1	71	16	36	48	C
	20-40	4.9	4.2	0.13			30.00	9.8	7.50	0.30	0.30	17.90	1	60	14	22	64	C
	40-75	4.8	3.8	0.09			27.00	7.20	7.60	0.40	0.20	15.40	<1	57	12	24	64	C
	75-115	4.8	3.6	0.06			27.00	6.00	6.70	0.30	0.20	13.20	<1	48	10	26	64	C
	115-300	4.6	3.6	0.13			27.00	6.00	6.60	0.50	0.20	13.90	<1	51	12	36	52	C
2	0-50	6.0	4.9	0.21	2.59	0.20	28.80	7.80	3.83	1.70	0.36	13.69	48	1.25	19	14	67	C
	150-200	5.5	5.2	0.06			21.60	2.80	2.60	0.55	0.24	6.20	29	1.11	11	46	43	
	210-300	6.4	5.5	0.06			35.20	2.00	2.95	2.10	0.57	7.60	22	1.62	11	10	79	
3	0-20	6.6	5.6	0.08	1.90	0.19	23.30	3.20	5.30	0.80	0.20	12.50	49	<1	14	24	62	
	20-50	6.4	5.4	0.09	0.80		23.10	10.30	6.90	1.90	0.20	19.60	85	<1	14	24	62	
	50-90	6.7	5.4	0.09	0.70		21.40	3.70	6.20	1.00	0.20	14.10	66	<1	14	28	58	
4	0-20	6.6	5.8	0.10	1.40	0.14	20.70	8.60	6.20	2.60	0.20	17.60	85	<1	22	30	48	
	20-6	7.4	6.5	0.06	0.40		28.30	17.50	10.70	0.40	0.40	29.00	100	1	40	26	34	
5	0-20	7.3	6.4	0.11	0.88	0.14	27.10	24.20	9.20	1.60	0.80	35.80	100	3	42	26	32	
	20-50	6.5	5.8	0.24	0.33		17.70	7.40	5.30	0.70	0.20	13.60	77	1	18	22	60	
	50-90	6.7	6.0	0.19	0.29		15.30	5.60	5.40	0.50	0.20	11.70	76	1	16	30	54	
6	0-20	7.9	6.6	0.14	1.02		14.60	10.10	5.40	1.70	0.60	17.80	100	4	26	46	28	
	20-40	7.2	6.2	0.10	0.74		18.90	8.80	6.20	1.50	0.50	17.00	90	3	16	38	46	
	40-60	7.2	6.0	0.10	0.56		14.30	8.00	5.30	1.10	0.50	14.90	100	3	20	32	48	
7	0-50	6.5	5.3	0.08	0.96	0.12	21.00	6.40	3.90	1.31	0.26	11.87	57	1.24	10	30	60	
	150-200	6.9	5.7	0.05			19.20	1.20	4.90	0.35	0.36	6.80	35	1.88	30	10	60	
	260-300	7.2	5.7	0.10			27.00	4.00	9.20	0.85	1.85	15.90	59	6.85	20	28	52	
8	0-20	6.6	5.7	0.27	1.70	0.23	23.20	1.20	2.32	0.93	0.65	5.10	22	2.80	10	30	60	C
	90-100	6.7	5.7	0.09	0.09	0.08	29.70	13.40	3.05	0.90	0.79	18.10	61	2.60	6	22	72	C
9	0-20	6.6	6.1	0.45	2.56	0.33	23.60	0.50	2.98	0.10	0.07	3.60	15	0.30	12	36	52	C
	90-100	6.7	5.5	0.15	0.69	0.08	24.40	1.20	2.40	0.96	0.61	5.20	21	2.50	10	20	70	C
10	0-50	5.8	5.2	0.40	2.12	0.15	23.60	4.00	3.00	1.60	0.20	8.80	37	0.85	13	20	67	C
	150-200	6.4	6.0	0.03			22.40	0.80	2.80	0.60	0.20	4.7	21	0.89	13	8	79	C
	260-300	5.8	5.0	0.05			26.00	1.00	3.00	0.70	0.50	5.20	20	1.92	27	12	61	C
11	0-20	6.7	5.5	0.19	0.18	0.04	33.00	1.30	2.25	0.22	0.20	4.00	12	0.60	12	32	56	C
	90-100	6.9	5.5	0.10	0.63	0.07	40.20	1.50	2.54	1.07	0.74	5.85	15	1.80	10	28	62	C
13	0-10	6.7	5.3	0.14	0.57	0.07	15.60	0.80	0.28	0.42	0.20	1.70	11	1.20	18	24	58	C
14	0-20	6.6	5.9	0.28	0.60	0.09	11.20	1.20	0.06	0.56	0.29	2.10	19	2.50	56	24	20	C
	90-100	7.0	5.7	0.12	0.23	0.04	12.50	2.20	0.43	0.51	0.29	3.40	27	2.30	52	28	20	C
15	0-20	6.7	5.9	0.16	1.22	0.21	25.50	2.60	0.79	0.15	0.16	3.70	14	0.60	24			C
	90-100	6.9	5.4	0.12	0.51	0.05	21.70	3.50	0.85	0.37	0.79	5.50	25	3.60	26			SiCL
16	0-20	7.3	6.1	0.40	0.73	0.11	45.00	21.50	5.83	0.11	3.08	30.50	68	6.80	32			C
	50-60	8.5	6.5	0.50	0.65	0.07	45.20	26.00	5.40	0.13	3.26	34.80	77	7.20	32			C
17	0-20	8.1	6.0	0.09	0.10	0.01	4.70	0.60	0.50	0.11	0.15	1.40	29	3.20	82			C
	90-100	7.3	5.9	0.11	0.40	0.05	5.30	0.80	0.28	0.45	0.25	1.80	34	4.70	74			C
18	0-20	7.1	5.9	0.16	0.50	0.09	8.2	1.30	0.13	1.15	0.61	3.20	39	7.4	72			C
	90-100	7.7	6.5	0.35	0.22	0.05	15.60	3.50	0.1	2.75	1.42	7.90	51	9.10	66			C
19	0-10	6.4	-	0.30	-	-	13.5	-	-	-	-	-	-	-	-			CL
	10-20	6.4	-	0.40	-	-	12.5	-	-	-	-	-	-	-	-			C
	20-40	7.0	-	0.80	-	-	17.0	-	-	-	-	-	-	-	-			C
	40-80+	7.0	-	1.50	-	-	16.0	-	-	-	-	-	-	-	-			CL
20	0-20	7.1	6.1	0.18	0.51	0.08	10.00	0.60	1.16	0.18	0.15	2.10	21	1.50	64			C
	90-100	7.0	5.1	0.06	0.14	0.04	15.40	0.90	1.64	0.14	0.15	2.80	18	1.00	44			C
21	6.5	-	-	-	-	6.0	-	-	-	-	-	-	-	-				
	6.6	-	-	-	-	6.0	-	-	-	-	-	-	-	-				
	6.2	-	-	-	-	7.5	-	-	-	-	-	-	-	-				
	5.7	-	-	-	-	7.0	-	-	-	-	-	-	-	-				

**Table C2: Laboratory Data for Soil Profile Descriptions (Continued)**

Profile	Depth (cm)	pH (H <sub>2</sub> O) (1:2.5)	pH KCL (1:2.5)	EC (1:2.5) ms/cm	C %	N %	CEC (me/100g) pH 8.2	Exchangeable Cations (me/100g)				Sum of Cations	Base Sat	ESP	Texture-Limited Pre-treatment			
								Ca	Mg	K	Na				Sand %	Silt %	Clay %	Texture
23	0-30	7.0	-	0.3	-	-	34.0	-	-	-	-	-	-	5				C
	30-90	7.7	-	3.0	-	-	33.0	-	-	-	-	-	-	12				C
	90-150	7.7	-	3.0	-	-	25.0	-	-	-	-	-	-	19				C
	150-180	7.7	-	3.0	-	-	20.0	-	-	-	-	-	-	22				C
24	0-20	7.0	5.7	0.14	0.93	0.09	14.00	0.70	1.52	0.18	0.11	2.50	18	0.80	62	12	26	
	90-100	6.9	5.4	0.10	0.50	0.05	9.60	0.50	1.56	0.08	0.15	2.30	24	1.50	58	10	32	
25	0-20	7.5	6.0	0.25	0.23	0.03	12.40	1.10	2.00	0.14	0.22	3.50	28	1.70	58	14	28	
	100-110	7.3	6.4	0.45	0.60	0.10	11.50	1.30	1.64	0.24	0.23	3.40	30	2.00	60	16	24	
26	0-40	8.6	6.8	0.54	0.73	0.05	65.00	15.60	8.40	0.40	5.15	29.55	45	7.85	48	12	40	
	100-150	8.5	7.1	1.75			33.60	14.40	9.80	0.50	17.10	41.80	100	50.89	36	12	52	
	200-250	8.2	6.6	2.25			35.20	8.40	8.40	0.25	14.50	31.55	90	41.19	54	6	40	

Source: Kenya Soil Survey Reports and analysis of samples taken during this study

**Table C2a: Laboratory Data of Profile Description No: 2 (Mapping unit: MV1)**

Ref	Depth (cm)	pH (H <sub>2</sub> O) (1:2.5)	pH KCL (1:2.5)	EC (1:2.5) ms/cm	C %	N %	CEC (me/100g) pH 8.2	Exchangeable Cations (me/100g)				Sum of Cations	Base Sat	ESP	Texture-Limited Pre-treatment			
								Ca	Mg	K	Na				Sand %	Silt %	Clay %	Texture
Ah	0-20	5.0	4.5	0.50	3.8	0.51		12.4	10.2	0.5	0.3	23.4		<1				
Bt1	20-40	4.9	4.2	0.13				9.8	7.5	0.3	0.3	17.9		1	14	22	64	C
Bt2	40-75	4.8	3.8	0.09				7.2	7.6	0.4	0.2	15.4		<1	12	24	64	C
Bt3	75-115	3.6	3.6	0.06				6.0	6.7	0.3	0.2	13.2		<1	10	26	64	C
BC	115-130	3.6	3.6	0.13				6.6	6.6	0.5	0.2	13.9		<1	12	36	52	C

**Table C2b: Laboratory Data of Profile Description No: 8 (Mapping unit: U1V2)**

Ref	Depth (cm)	pH (H <sub>2</sub> O) (1:2.5)	pH KCL (1:2.5)	EC (1:2.5) ms/cm	C %	N %	CEC (me/100g) pH 8.2	Exchangeable Cations (me/100g)				Sum of Cations	Base Sat	ESP	Texture-Limited Pre-treatment			
								Ca	Mg	K	Na				Sand %	Silt %	Clay %	Texture
Ah	0-20	6.6	5.6	0.08	1.9	0.19	23.9	32	5.3	0.8	0.2	12.5	49	<1	14	24	62	C
Bw1	20-50	6.4	5.4	0.09	0.8		23.1	10.6	6.9	1.9	0.2	19.6	85	<1	14	24	62	C
58Bw2	50-90	6.7	5.4	0.09	0.7		21.4	6.7	6.2	1.0	0.2	14.1	66	<1	14	28	58	C

**Table C2c: Laboratory Data of Profile Description No: 9 (Mapping unit: U1V3P)**

Ref	Depth (cm)	pH (H <sub>2</sub> O) (1:2.5)	pH KCL (1:2.5)	EC (1:2.5) ms/cm	C %	N %	CEC (me/100g) pH 8.2	Exchangeable Cations (me/100g)				Sum of Cations	Base Sat	ESP	Texture-Limited Pre-treatment			
								Ca	Mg	K	Na				Sand %	Silt %	Clay %	Texture
Ah	0-20	6.6	5.8	0.10	1.4	0.14	20.7	8.6	6.2	2.6	0.2	17.6	85	<1	22	30	48	C
Bw	20-50	7.4	6.5	0.06	0.4		28.3	17.5	10.7	0.4	0.4	29.0	100	1	40	26	34	C

**Table C2d: Laboratory Data of Profile Description No: 13 (Mapping unit: LsV2)**

Ref	Depth (cm)	pH (H <sub>2</sub> O) (1:2.5)	pH KCL (1:2.5)	EC (1:2.5) ms/cm	C %	N %	CEC (me/100g) pH 8.2	Exchangeable Cations (me/100g)				Sum of Cations	Base Sat	ESP	Texture-Limited Pre-treatment			
								Ca	Mg	K	Na				Sand %	Silt %	Clay %	Texture
Ah	0-20	7.3	6.4	0.11	0.88	0.14	27.1	24.2	9.2	1.6	0.8	35.8	100	3	42	26	32	CL
Bt1	20-50	6.5	5.8	0.24	0.33		17.7	7.4	5.3	0.7	0.2	13.6	77	1	18	22	60	C
Bt2	50-90	6.7	6.0	0.19	0.29		15.3	5.6	5.4	0.5	0.2	11.7	76	1	16	30	54	C

**Table C2e: Laboratory Data Of Profile Description No: 22 (Mapping unit: RVp)**

Ref	Depth (cm)	pH (H <sub>2</sub> O) (1:2.5)	pH KCL (1:2.5)	EC (1:2.5) ms/cm	C %	N %	CEC (me/100g) pH 8.2	Exchangeable Cations (me/100g)				Sum of Cations	Base Sat	ESP	Texture-Limited Pre-treatment			
								Ca	Mg	K	Na				Sand %	Silt %	Clay %	Texture
Ah	0-20	7.9	6.6	0.14	1.02		14.6	10.1	5.4	1.7	0.6	17.8	100	4	26	49	28	CL
Bw1	20-40	7.2	6.2	0.10	0.74		18.9	8.8	6.2	1.5	0.5	17.0	90	3	16	38	46	C
Bw2	40-60	7.2	6.0	0.10	0.56		14.3	8.0	5.3	1.1	0.5	14.9	100	3	20	32	48	C

## **APPENDIX D: MAPS AND FIGURES**

**Figure 1 – Map of Northern Kenya**

**Figure 2 – Marsabit Soil Distribution**

**Figure 3 - Bute and Gurar (Block II)**

**Map 1 - Mapping Unit A to I**

## **APPENDIX E: REFERENCES**

- Bake, G., 1983, An analysis of climatological data from Marsabit District of northern Kenya, Technical Report No. B3, UNESCO-IPAL, Nairobi.
- Bonarius, H., 1975, Preliminary Assessment of Irrigation Development in the Marsabit Area. Kenya Soil Survey Site Evaluation Report P 22.
- Kekem, A.J. van, 1986, Soils of the Mount Kulal, Marsabit Area. Kenya Soil Survey Reconnaissance Soil Survey Report No. R 12. [WOSSAC ID 41298 & 42102s & 42111]
- Sombroek, W.G., Braun, H.M.H. and Pouw, van der B.J.A., 1982, Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, 1980, Scale 1:1,000,000. Kenya Soil Survey Exploratory Soil Survey Report No E 1. [WOSSAC ID 170s & 24250 & 42112]
- Sombroek, W.G., Mbuvi, J.P. and Okwaro, H.W., 1976, Soils of the Semi-Arid Zone of North-Eastern Kenya. Kenya Soil Survey Miscellaneous Soil Paper No M 2. [WOSSAC ID 41299]
- Woodhead, T., 1968, Studies of potential evaporation in Kenya, E. Afr. Agric. For. Res. Org., Nairobi.

## **APPENDIX F: LOCAL OFFICIALS MET**

J.J. Falana, MP for Marsabit Constituency  
John Ngeno, District Commissioner, Marsabit  
Ibrahim (Abdilli) Mohamed, Clerk to County Council, Marsabit  
Dr. Godana Bonaya, MP for North Horr Constituency  
N. Hongo, District Officer, Moyale  
Oteno Koech (?), District Officer, Bute  
Abdi S'Ibrahim, Chief, Bute  
Derkow Omar Abdi, Assistant Chief, Bute  
Stephen Lerapo, Councillor, Songa  
Abdi Chachana, Councillor, Bute  
Noro O'Osmond, Councillor, Bute  
Golicha Galgalo, Councillor, Butiye  
Ragwa, Agricultural Officer, Bute  
Ilias ?, Headmaster, Primary School, Bute  
Aden Ali, Chief, Godoma  
Galma Dadaso, Chief, Sololo  
Herbert Anderson, Kalacha  
Dr. Paul Robinson, Nairobi