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MINISTRY OF AGRICULTURE AND LIVESTOCK DEVELOPMENT

NATIONAL AGRICULTURAL LABORATORIES

KENYA SOIL SURVEY

SOILS OF THE MOUNT KULAL MARSABIT AREA

(quarter degree sheets 41, 42, 43, 54 and 55)

by

A.J. van Kekem

RECONNAISSANCE SOIL SURVEY REPORT No. R12, 1986

KENYA SOIL SURVEY, NAIROBI

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FOREWORD

The present report is the twelfth in the Kenya Soil Survey series of Reconnaissance Soil Surveys" with multi-purpose land evaluation. The ccompanying soil map is at scale of 1:250,000.

This particular soil survey was carried out within the context of the ntegrated Project on Arid Lands (IPAL), which is part of the Man and the iosphere (MAB) programme of UNESCO. The survey area, situated in one of the riest zones of the country, is considered representative for one of the greatest lobal environmental problems, namely desertification, which leads to the egradation of the vegetation and the soil with negative consequences for human ell-being.

The report gives an ample description of the methods employed and a omprehensive account on the suitability of the area for the possible land use lternatives. However, it should be noted that some of the methods applied are iable to be improved as more experience is gained and complementary data become vailable.

The preparation of the maps and the report is a cooperative effort etween the staff of the Kenya Soil Survey and the Integrated Project on Arid ands of UNESCO. This may be already apparent from the names figuring on the arious maps and appendices. The contributions made and help rendered by various eople during this investigation are greatly acknowledged.

Finally, it is hoped that this report will satisfy the need for nformation on the soils of the Mt. Kulal-Marsabit area and that it will ontribute to the rehabilitation of the degraded environment for the benefit of he people and the development of the area.

F.N. Muchena
Head, Kenya Soil Survey

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SUMMARY

This report describes the soils of the Mt. Kulal-Marsabit area in thern Kenya. The accompanying soil map at scale 1:250,000 covers an area of roximately 1.5 million ha. The survey area is bordered by 2° and 3° N itude in the north and the south respectively, and 37° E longitude and the reline of Lake Turkana in the west and 38° E longitude in the east. A small ension to the south is also included.

The survey area covers the majority of the Rendille territory, while the extreme north some Gabra are living. The major land use is nomadic to i-nomadic pastoralism with cattle, sheep and goats. The mountainous fringes the south and southwest are occupied by a small number of cattle keeping buru and Boran. Agriculture is limited to some small areas on Mt. Kulal and Marsabit.

The climate is hot and dry to very dry in most of the area. Average ual rainfall is about 225mm in the lowland plains. The mountains get more cipitation increasing to 850mm on the top of Mt. Marsabit. About 90% of the vey area belongs to agro-climatic zone VII. The remaining parts fall under es VI to III with decreasing extension. Rainfall distribution is bimodal. long rains from March/April to May are more reliable than the short rains October and November. The probability that rainfall in the lowlands is less n two-third of the potential evapotranspiration during the rainy season is ut 100%.

In the southwest the area is underlain by Precambrian Basement tem rocks, mainly undifferentiated gneisses which outcrop in the Ndoto ntains. Prevolcanic sedimentary rocks occur in the northeast. The shield canoes of Mt. Marsabit, Mt. Kulal and the Asie hills are formed by Miocene Holocene volcanic rocks. They consist of lava and pyroclastics and are rounded by extensive basalt plateaus. The lowlands of the central area tain sediments derived from the Basement System rocks mixed with sediments m volcanic origin.

The topography of the area is characterised by extensive, very gently ulating plains lying in between the volcanic mountains in the east and the t and Basement System rock mountains in the southeast. Stepped lava plateaus ur around Mt.Marsabit and west of Mt. Kulal. Small patches of uplands st on the flanks of the major volcanoes. In the north-central part of the ins the monotonous flat relief is interrupted by minor basalt plateaus. In southern plains isolated hills of Basement System rocks occur besides a ge lava plateau. Also some gently undulating uplands with a low relief ensity can be found here.

Seasonal rivers drain mainly the Basement System mountains as hardly surface flow exists on the very permeable volcanic rocks. Drainage is ected towards the northeast where ultimately all surface flow is collected in closed basin of the Chalbi desert, a seasonal lake. As the water evaporates ts accumulate over the years creating a salt desert.

Parent material and landform have determined to a large extent the tribution of the soils. Mountains and hills of Basement System rocks have llow and stony soils *(Lithosols)*. However, relics of deeper, friable sandy y loam soils exist on the tops of the Ndoto mountains *(Luvisols)*.

The volcanic mountains have an array of soils. Deep friable clays humic topsoil have developed on the upper wetter slopes of Mt. Mars *(Phaeozems)*, while the other volcanic mountain tops have shallow, stony soils *(Cambisols)*. The southern middle and lower slopes of M have deep, stony clay to clay loam soils *(Cambisols/Luvisols)*. On lower slopes of Mt. Kulal and the Asie hills shallow to deep, stony loam to clay soils are found *(Phaeozems/Cambisols)*. On the drier of Mt. Kulal the organic matter content of the topsoil decreases fr here shallow to moderately deep, stony, sandy loam to sandy clay so developed *(Xerosols)*.

The soils of all the lower areas are charaterised by a organic matter content and a faint horizon differentiation. On the plateaus soil depth varies from shallow to very deep. The soil tex from loamy sand to clay and in general the soils are very stony wit exceedingly stony/bouldery surface *(Regosols, Cambisols* and *Yermosol* a sandcover varying in thickness from a few mm to 100cm occurs on t Moderately deep, stony, cracking clay soils have developed on some plateaus of Mt. Marsabit *(Vertisols)*. The stepped plateaus on the side of Mt. Kulal have moderately to very deep, saline-sodic, clay soils with an exceedingly bouldary surface *(Solonetz/Solonchaks)*.

On the footslopes around the Basement System mountains moderately deep to very deep, friable, loamy sand to sandy clay loa developed *(Arenosols/Yermosols)*. The footslopes of the volcanic m carry shallow to deep, friable sandy loam to stony clay soils *(Yermo* and strongly saline-sodic sandy clay loam soils *(Solonchaks)*. Piedm around Mt. Kulal have soils that consist of deep to very deep, very very stony, saline-sodic sandy loam to sandy clay loam *(Yermosols/So*

On the sedimentary plains the soil texture changes gradu pre-dominantly sandy to more clayey in a northeastern direction whil and sodicity increase. In the south very deep sandy soils occur besi clay loam soils *(Arenosols/Yermosols)*. In the west-central plains t soils disappear and sodicity and salinity increase gradually *(Yermos* further to the northeast friable, sandy clay loam to sandy clay soils saline and sodic characteristics *(Solonetz)*. The Chalbi desert, the part of the plains, has very deep, strongly saline and sodic clay soi *(Solonchaks)*.

Soils of the alluvial plains are very deep and consist of sandy material *(Fluvisols)*, or saline-sodic clay loam to clay *(Yermos Vertisols/Solonchaks)*.

Dunes bordering the Chalbi desert have very deep, loose s *(Arenosols)* overlying saline-sodic lake deposits.

The soil fertility is fairly high, except for nitrogen wh low in lowland soils and somewhat better in the mountain soils. Also phosphorus is fairly low in soils with volcanic ash influence.

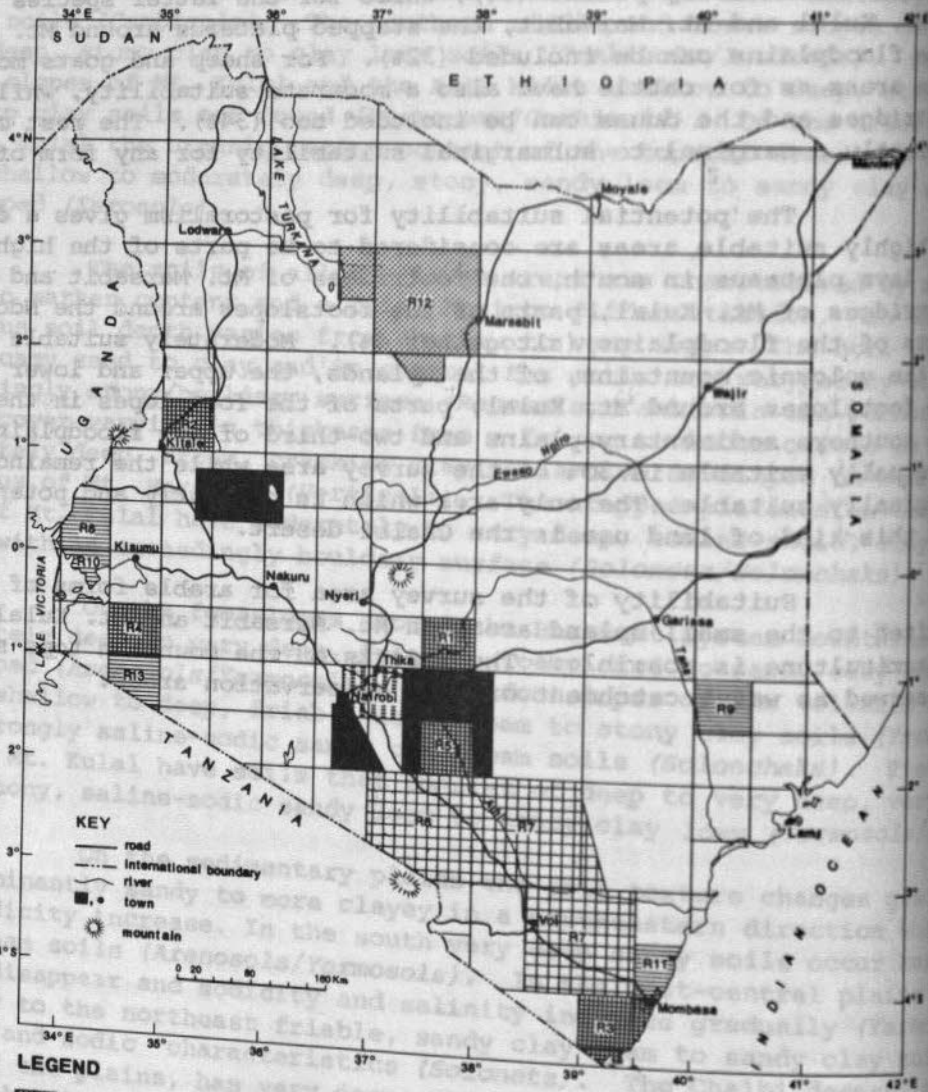
The current suitability for pastoralism varies per livest Highly suitable for camels and cattle are the southern sedimentary pla of the survey area), while for sheep and goats parts of the high level the higher stepped plateaus and the footridges around Mt. Marsabit and the floodplains (5% of the survey area) possess this suitability.

Moderately suitable land for camels and cattle occurs in the northern sedimentary plains (8%), while for the latter species also the tops of Mt. Kulal and Mt. Marsabit, the stepped plateaus around Mt. Marsabit and some floodplains can be included (32%). For sheep and goats more or less the same areas as for cattle have also a moderate suitability, while parts of the footridges and the dunes can be included too (34%). The rest of the area has currently a marginal to submarginal suitability for any form of pastoralism.

The potential suitability for pastoralism gives a different picture. As highly suitable areas are considered to be parts of the high level uplands, the lava plateaus in south, the footridges of Mt. Marsabit and the middle footridges of Mt. Kulal, parts of the footslopes around the Ndoto mountains and parts of the floodplains (altogether 4%). Moderately suitable areas are parts of the volcanic mountains, of the uplands, the upper and lower footridges and the footslopes around Mt. Kulal, parts of the footslopes in the Basement area, the southern sedimentary plains and two-third of the floodplains (25%). Marginally suitable is 30% of the survey area while the remainder is submarginally suitable. The only area which is currently and potentially unsuitable for this kind of land use is the Chalbi desert.

Suitability of the survey area for arable forms of land use is limited to the small upland areas on Mt. Marsabit and Mt. Kulal where some form of agriculture is possible. The forests on the mountain tops should be conserved as water catchment or game conservation areas.

Fig.1 Location map and reconnaissance soil survey programme



1. THE ENVIRONMENT

.1 LOCATION, ADMINISTRATION, COMMUNICATION AND POPULATION

The Mount Kulal-Marsabit survey area, which covers 15,360 sq km ies in the north of the republic of Kenya between 2° and 3° N and 37° nd 38° E (see figure 1). The survey area is extended to the south owards the Baio mountain (1885m) and in the north-west towards the horeline of Lake Turkana.

The area covers the 1:100,000 topographical sheets 42, 43, 54 and 5 completely and partly the sheets 41, 66 and 67.

In the south-west the survey area borders on the Ndoto mountains 2838m), in the west on an outlier Ol Doinyo Mara (2224m) and upon Lake urkana. In the north-west a volcanic mountain, Mount Kulal (2295m) orms a distinct landmark. In the east another volcanic mountain, Mount arsabit which rises to over 1700m forms the boundary of the survey area. n between the mountains lies an extensive plain at an altitude between 00 and 700m above sea level.

The survey area is located in Eastern Province, Marsabit District nd a small part in the south-west in Rift Valley Province, Samburu istrict. The main administrative centre is Marsabit, with the offices f the District Commissioner and District Officers. Marsabit provides ny important facilities for the area like a hospital, a police post nd a post office. It is also an important trading centre.

e survey area comprises three National Forest Reserves:

The Kulal Forest Reserve of 45,000 ha, which were never gazetted. However declared a Biosphere Reserve under Unesco's MAB programme, so far no forest guards have been deployed.

The Marsabit National Reserve covers 202,000 ha. Only the forest on top of the mountain receives special protection.

The Ndoto Forest Reserve of 96,000 ha, almost entirely outside the survey area, was gazetted in 1956. In the 1970's over-use of the forest has resulted in a considerable damage of the vegetation and the soils. More control from Wamba is envisaged.

The Isiolo-Marsabit-Moyale road is the only main road which osses the survey area. It is supposed to be an all-weather road, but n occasionally be impassable during wet periods. All the other roads the area are of a much lower quality. Although some are indicated all-weather roads, severe difficulties can be experienced during the t season.

The survey area covers almost entirely the territory of the ndille. In the north some Gabra people are living. Both these people e nomadic pastoralists who keep camels, sheep and goats. Small numbers Boran and Samburu occupy the mountainous fringes of the survey area. ey are basically cattle-keeping nomadic pastoralists. As a rule, the fferent tribes do not use the same geographic area because of antago- sm and fear of inter-tribal raiding of stock. The mainstay of their

diet is milk from camels or cattle, often mixed with blood, and t
of small stock. Some Turkana and Elmolo people are living alon
shore of Lake Turkana. The Turkana supplement their milk and me
with fish while the Elmolo almost entirely rely on fish.

Lusigi (1981) studied the Rendille in detail and most inf
about them has been drawn from this study. The Rendille are pur
pastoralists mainly dependent on the camel for their livelihood.
other tribes in the study area the Rendille have been subject to
pressures on their territory. They were pushed southwards by th
tions of the Gabra and Boran, while Turkana expansion exerted pr
from the west and Somali and other Boran from the east. The Ma
before the annexation of their territory, exerted pressure from
It is now estimated that the Rendille in total occupy only 8,00
of a former home range of about 58,000 sq. km. Of their present
over 40% is not utilised due to poor security and the fear of ra
neighbouring Turkana and Samburu. From the 1979 census, the Ren
number approximately 13,000 which means they have doubled in the
years.

The Rendille have stuck to their normal pastoral practice
their flexibility and movement have been greatly reduced due to t
ing in their territory and establishment or rigid administrative
ries. There are two major Rendille settlement centres in the st
Korr and Kargi, which have come about as a result of the presenc
permanent water. Although Rendille country is largely degraded d
overgrazing by livestock, these two settlements demonstrate some
worst cases of localised desertification in the study area. Ren
country has never recovered completely from the effects of the 19
drought as many of the people have been on famine relief since th
This has been partly responsible for the present increase of gra
the Rendille diet - mainly maize meal. Sugar and tobacco are als
increasingly used.

The emotional attachment of the Rendille to the camel mak
difficult for them to sell and partly explains the present rate o
stocking. The main cause is due to the increased population and
consequence the increased number of animals.

The traditional structure among the Rendille is still very
and the presently appointed young administrative chief yields lit
authority in terms of traditional practices. The society is stil
ruled by the decisions of the elders.

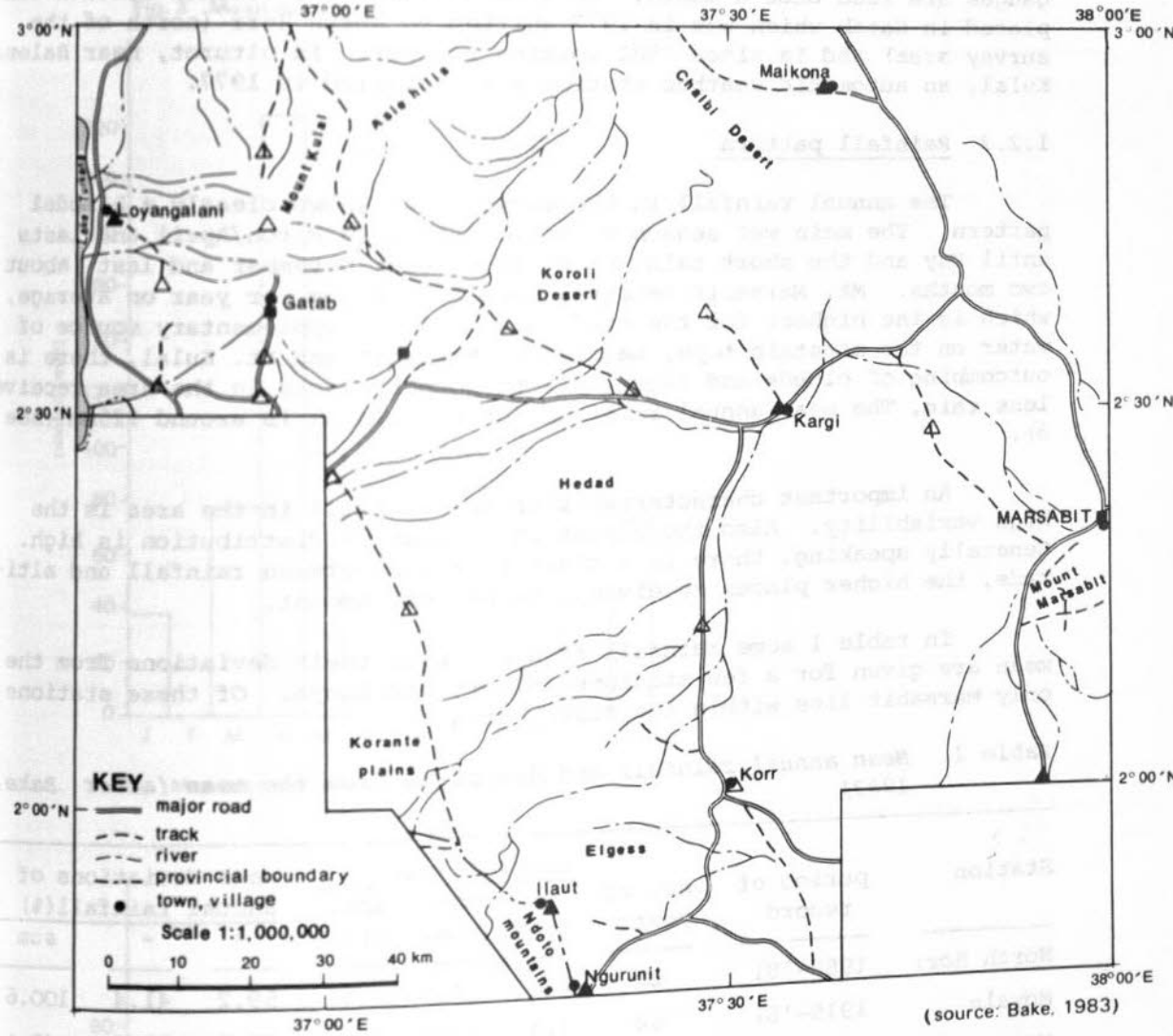
1.2 CLIMATE

1.2.1 Observation stations

Marsabit has the only meteorological station in the study
which has been recording data over a long period (from 1918 onwar
For comparison other stations outside the area with longterm reco
which are not too far from the study area are used as well (North
Moyale, Lodwar).

Rainfall records have been recorded in Gatab from 1971 onw
In 1976 IPAL initiated a climatological programme by installing
matic weather stations and placing raingauges in more than 20 pla

Fig. 2 Distribution of raingauges



LEGEND

- ■ meteorological station
- ▲ daily read raingauge
- △ storage raingauge

throughout the survey area (see fig. 2). The raingauges placed at ... stations, missions and police posts are read daily while the storag... gauges are read once a month. In 1976 an automatic weather statio... placed in Gatab which was in 1977 shifted to North Horr (north of t... survey area) and is since 1981 working in Korr. In Olturot, near h... Kulal, an automatic weather station was installed in 1977.

1.2.2 Rainfall pattern

The annual rainfall in the survey area shows clearly a bimod... pattern. The main wet season normally starts in March/April and la... until May and the short rains start in October/November and last ab... two months. Mt. Marsabit receives more than 800mm per year on aver... which is the highest for the study area. As a supplementary source ... water on the mountain tops, mainly Mt. Marsabit and Mt. Kulal, then ... outcombing of clouds and fogs. All the other places in the area re... less rain. The mean annual rainfall for the plains is around 225mm ... 3).

An important characteristic of the rainfall in the area is th... high variability. Also the variation in spatial distribution is hig... Generally speaking, there is a clear relation between rainfall and a... tude, the higher places receiving the highest amount.

In table 1 some rainfall figures with their deviations from ... mean are given for a few stations in northern Kenya. Of these stati... only Marsabit lies within the survey area.

Table 1. Mean annual rainfall and deviation from the mean (after ... 1983)

Station	period of record	no. of years	rainfall (mm) mean	abs. max.	abs. min.	mean deviations of annual rainfall (%) +	-	s
North Horr	1959-'81	22	157	385	5	59.2	41.4	10...
Moyale	1915-'81	64	713	1290	387	23.7	19.4	4...
Marsabit	1918-'81	53	859	1816	324	32.7	24.3	5...
Lodwar	1919-'81	62	178	498	19	51.0	41.9	9...

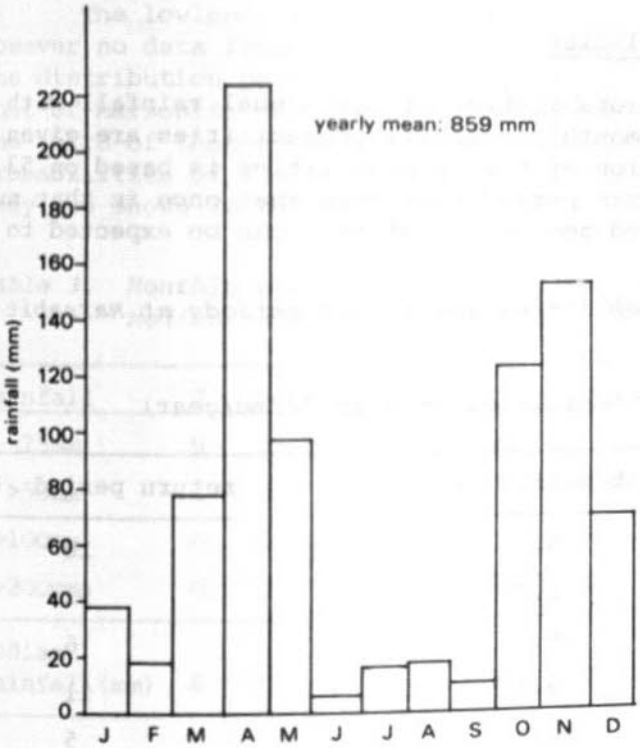
Notes: + *the mean deviation from the average annual rainfall (in %) ... the years that rainfall was above average.*

- *the mean deviation from the average annual rainfall (in %) ... the years that rainfall was below average.*

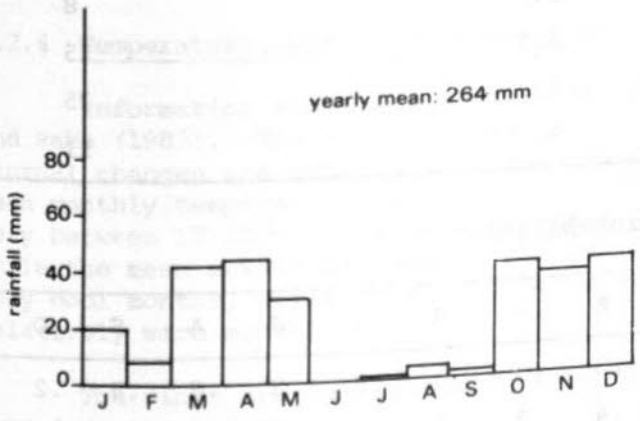
The deviations from the mean are very high. If the stations ... compared, it is clear that the deviation from the mean increases wit... decrease in rainfall. This means that besides a lower rainfall, the ... unreliability increases as well.

Monthly variabilities are very high and reach coefficients of ... variation of more than 350 in the dry season and still more than 70 ... (Marsabit) or ever 100 (Kargi) in the normally wettest months. This ... lines the general climatological problems for range management. It ...

Fig. 3 Mean monthly rainfall



(a) Marsabit (over 50 years of observations)



(b) Fallam, west of Kargi (5 years of observations)

highly uncertain how much rain will fall in the next wet seaso
has of course a big influence on the way of life of the pastor
They can only follow the rains.

1.2.3 Rainfall probabilities

In table 2 the probabilities of the annual rainfall with
periods as well as the monthly rainfall probabilities are give
Marsabit. The calculation of the probabilities is based on 51
rainfall data. The return period indicates that once in that n
years a certain specified amount of rainfall can be expected to

*Table 2. Rainfall probabilities and return periods at Marsabit
Bake, 1983)*

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

rainfall (mm)	probability (%)	return period
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	9.3	11

(b) Monthly rainfall probabilities

rainfall	J	F	M	A	M	J	J	A	S	O
<25mm	.6	.8	.3	0	.3	.9	.8	.8	.8	.2
>50mm	.3	.1	.4	.9	.6	0	0	.1	0	.7
>100mm	.1	.1	.2	.8	.4	0	0	0	0	.5
>200mm	0	0	0	.4	.1	0	0	0	0	.2
median rainfall (mm)	17	4	43	209	70	3	7	7	7	103
average rainfall (mm)	38	19	78	225	98	7	16	18	13	123

It can be seen from table 2 that, even for a wet station, the probabilities for a monthly rainfall of over 50mm, which can be regarded as necessary for a minimal plant growth, are low.

The lowlands receive substantially less rain than the Marsabit area. However no data from a station with long-term observations are available. The distribution pattern of the rainfall in the lowlands is comparable to that of Marsabit. As the mean annual rainfall of the lowlands is about one-third of that of Marsabit it is assumed that in this way also the probabilities of the monthly rainfall for the lowlands can be calculated. They are shown in table 3.

Table 3. Monthly rainfall probabilities for the lowlands (Marsabit/3, Median: 259mm/y) after ILCA (1979)

rainfall	J	F	M	A	M	J	J	A	S	O	N	D
<25mm	.9	.9	.6	.1	.5	1	1	1	1	.4	.4	.7
>50mm	.1	0	.1	.7	.3	0	0	0	0	.3	.4	.1
>100mm	0	0	0	.3	0	0	0	0	0	0	.1	0
>200mm	0	0	0	0	0	0	0	0	0	0	0	0
median rainfall(mm)	6	1	14	70	23	1	2	2	2	34	39	16

Again it follows very clear from table 3 that a probability of a monthly rainfall over 50mm is very low and is highest in April (0.7) and in November (0.4). The probabilities for a rainfall of over 100mm in a certain month are zero or almost zero in 11 out of 12 months.

1.2.4 Temperature, wind and evaporation

Information about temperature is obtained from Edwards et al. (1979) and Bake (1983). The temperatures follow a general trend for the tropics. Diurnal changes are greater than the annual ones. In the lowlands the mean monthly temperatures vary from 27-29°C, while in the mountains they vary between 17-20°C. The mean minima lie around 20° and 13°C respectively, while the mean maxima are around 35° and 26°C. July and August are relatively cool months, while February, March and October can be considered as relatively warm months.

The winds are mainly coming from an easterly direction. Windspeeds over 4m/s are common.

The evaporation in this part of the country is very high. The measured evaporation in a place with similar conditions as the survey area rose well above 3000 mm/year. Calculated figures of Eo vary between 1,800 (Mt. Marsabit) and 2,280 mm/year (lowlands), using Woodhead's methodology (Woodhead, 1968).

Based on Braun's tables (unpublished) the crop water requirement (Et=2/3 Eo) in the lowlands exceeds rainfall in all months. However, on Mt. Marsabit April, May, October and November receive more rainfall than the crop water requirement. For Marsabit monthly data on Eo, Et and r are given in table 4.

Table 4. Monthly potential evaporation (Eo), evapotranspiration (Et) and rainfall (r) in Marsabit (in mm)

	J	F	M	A	M	J	J	A	S	O	N	D
Eo	145	145	164	145	145	145	164	164	164	164	127	127
Et	96	96	108	96	96	96	108	108	108	108	84	84
r	38	19	78	225	98	7	16	18	13	123	154	70

It is assumed that similar values will be reached on Mt. Kulal and Ndoto mountains.

1.2.5 The agro-climatic zones

The agro-climatic zone concept, formerly called ecological zone, was used already in 1966 by Pratt et al. but then it was mainly based on the vegetation. The agro-climatic zones as used by the Kenya Soil Survey are based on an index of the rainfall and the potential evaporation (Jaetzold & Braun, "The agro-climatic zone map of Kenya" in: Sombroek et al. (1982)).

The mean annual rainfall figures are used in combination with the figures for the potential evaporation to define and to delineate the agro-climatic zones.

In table 5 the figures for the rainfall, potential evaporation and the rainfall/potential evaporation ratios are given.

Table 5. Agro-climatic zones

zone	r/Eo (%) [1]	r (mm)	Eo (mm)	Climate designation
III	50-55	900-960	1750-1800	semi-humid
IV	40-50	750-900	1800-1880	semi-humid to semi-arid
V	25-40	525-750	1880-2095	semi-arid
VI	15-25	320-525	2095-2150	arid
VII	<15	170-320	2150-2280	very arid

1) r = average annual rainfall in mm (Bake, 1983)

Eo = average annual potential evaporation in mm (Woodhead, 1968)

The definition of the agro-climatic zones follow those given by Jaetzold & Braun (1982). An exception is made for zone III which was defined by the author as having an r/Eo ratio of 50-65. In the survey area however the value of 65 will not be reached and therefore 55% was chosen as the upper limit for zone III. The values for the mean annual rainfall are based on actual measurements in the field and are characteristic for the area. The lowest mean annual rainfall figure (based on 5 years of observations) is from Loyangalani and is 170mm. The r/Eo ratio for this place is 0.12. Since rain gauges are not present in every agro-climatic zone, interpolation according to altitude was necessary to delineate the different agro-climatic zones. The calculated figures for the potential evaporation are also related to the survey area. The figures for the rainfall and the

evaporation, given in table 5, correspond well with the range of data given by Braun for the 1982 1:1,000,000 agro-climatic zone map of Kenya.

The inclusion of temperature zones in the agro-climatic zone map does not seem to be very relevant for the survey area. More than 80% of the area falls into a zone with high temperatures (average annual between 25° and 29° C). The lowest mean annual temperatures are around 19° C on the mountain tops.

There does not exist a straightforward relationship between the agro-climatic zones and the vegetation, but some relations are present. Zone III and IV are mainly occupied by evergreen forest with *Cassipourea malosana* as the dominating species. On Mt.Kulal, *Juniperus procera* also occurs. The lower limits of zone IV have evergreen to semi-deciduous bushland. Zone V is occupied by a range of vegetation types: from deciduous woodland, via deciduous bushland to deciduous shrubland. Zones VI and VII are primarily covered with deciduous dwarf-shrubland, dominated by *Indigofera spinosa* and *Duosperma eremophilum*. In places shrubs dominate *(Acacia reficiens, A. mellifera* and *Commiphora* species) in other places mainly annual grasses are present *(Aristida mutabilis)*.

1.3 GEOLOGY

The geology of this part of the country has not been systematically mapped and is therefore only partially known. Geological surveys were carried out west and south-east of the area respectively in the South Horr region (Dodson, 1963) and in the Laisamis area (Randel, 1970). Important information on the geology of the Mt. Kulal-Marsabit area was given by Missotten (pers. comm.) a Unesco geologist, who made a reconnaissance trip to the survey area in 1983. Some information was obtained from earlier reconnaissance geological surveys made around Lake Turkana (Fuchs, 1939 and Rhemtulla, 1970) and from an unpublished report by Baker (1970). The author's field observations completed the information (see also fig. 4).

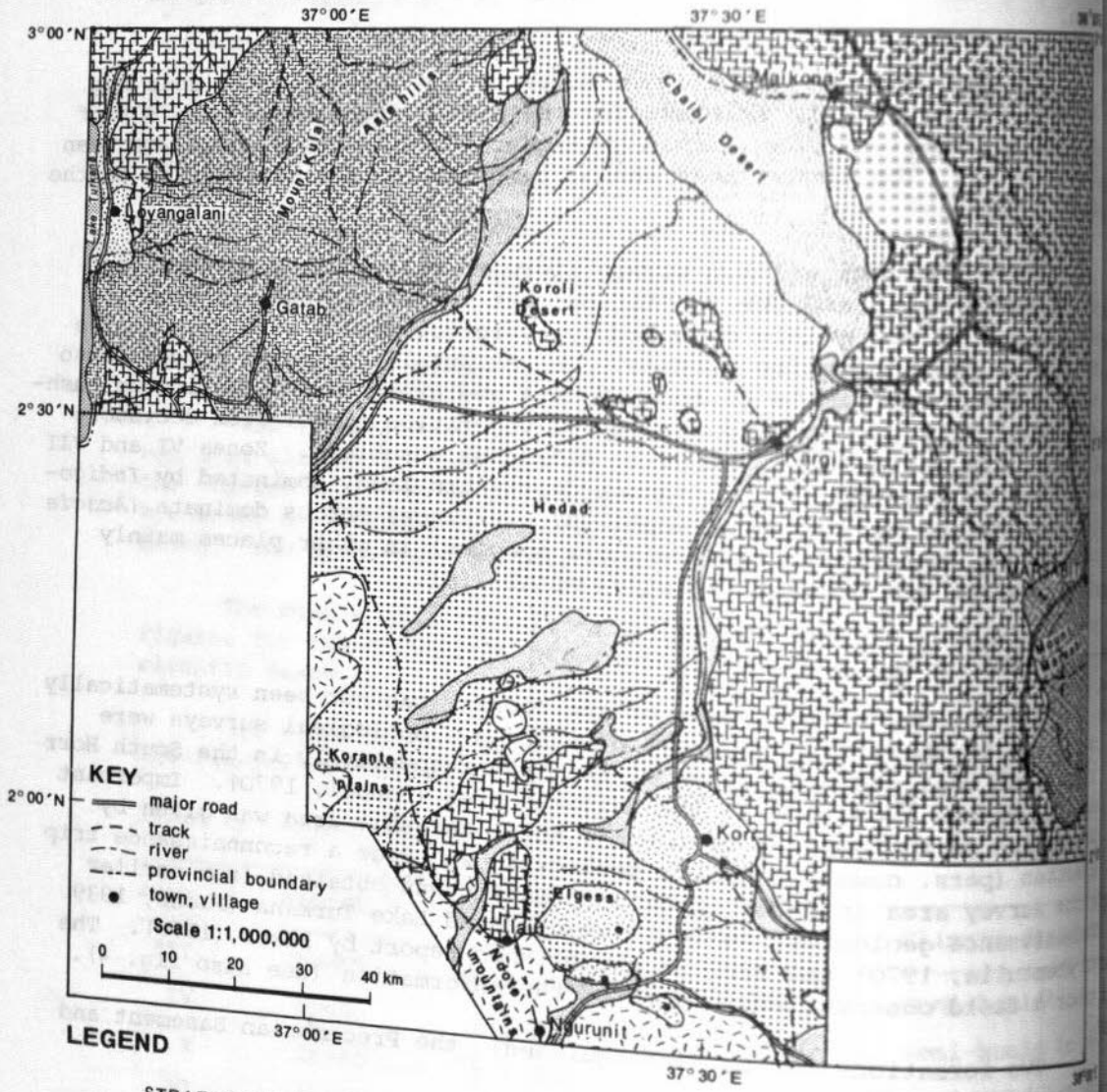
Two formations can be distinguished: the Precambrian Basement and the Cainozoic cover.

Precambrian Basement

The Precambrian Basement System rocks underlie the survey area and crop out in the south and the south-west. The Precambrian is basically confined to the mountain ranges of Ndoto and Ol Donyo Mara in the west and to the inselbergs Baio and Ilim. Other outcrops but with lower relief occur in the Korr and Elgess areas.

The Precambrian rocks belong to the "Basement System" and represent a metamorphosed sequence of calcareous, psammitic, semipelitic and pelitic rocks. The metamorphic processes transformed the calcareous sediments into white to pale blue calcareous rocks occurring in discontinuous bands, and coarse textured, magnetite rich graphitic rocks. The dominant part of this metamorphic sequence consists of biotite gneisses derived from the semi-pelitic rocks. Where more calcium was available hornblende gneiss and garnet epidote-amphibole gneisses were formed instead of the biotite gneiss. Yellow to pink, medium grained, granitoid gneisses were formed in the granitization process of the psammitic sediments. These massive granitoid gneisses are the most resistant rocks in the metamorphic sequence and form

Fig. 4 Provisional geology



prominent physiographic features. Near Baio porphyritic granites crop out while garnet rich pyroxenites occur south of Korr.

Cainozoic cover

During the Paleozoic and Mesosoic era erosion and peneplanation took place periodically and this continued upto the early Tertiary. The onset of an important volcanic activity in Miocene times changed the physiography dramatically.

Near Maikona in the north, and near Kargi situated at the eastern border of the Koroli desert, pre-volcanic sediments are found. These pre-Miocene or Miocene sediments, found south of Maikona, consist of reddish quartzitic sandstones with intercalated conglomeratic layers. They are overlain by basaltic flows. The horizontally-bedded sediments near Kargi were studied in cliff faces with a maximum height of 70m. These sediments consist of well-bedded ferrugineous arkosic sandstones which show graded and crossed bedding. Interlayered in the sandstones, highly calcareous quartsofeldspatic grit horizons were observed. The irregular distribution of the sediment occurrences indicates a deltaic deposition environment or deposition as valley infilling. Several sediments occurrences with similar characteristics and a comparable stratigraphic position were reported west of Lake Turkana and were described as Turkana grits (Rhemtulla, 1970). The Maikona and Kargi sediments can therefore tentatively also be referred to as Turkana grits.

Volcanic activity is a dominant element in the geologic developments in theMarsabit area from the Miocene to the Holocene period. Detailed age differentiations of the individual flows cannot be made as the volcanic activity is mainly basaltic and no systematic geologic mapping was carried out. Nevertheless an attempt is made to distinguish two different phases.

In an initial phase, basaltic extrusions from fissures and small vents formed lava plateaus. The extrusions of this stage of volcanic activity are almost devoid of pyroclastic intercalations. Massive basaltic plateaus form large aprons at the foot of Mount Marsabit, Kulal and Asie. Near Kargi, several small isolated lava plateau occurrences in the sedimentary plain are the only remnants of one or two formerly large plateaus broken up by erosion during the Pliocene or Pleistocene. Often the plateau surface consists of boulders who originated from in situ weathering of lava flows but locally well-preserved basalt columns were found as well. In the south-west near Ilaut, a large massive lava plateau rises to 50m above the Korante plain. Individual basalt flows are upto 10m thick and rest in direct contact with the Precambrian Basement System rocks. Locally roasted sediments and soil fragments were observed. The Ilaut plateau might be younger than the Kargi plateaus as it is less dissected and hardly affected by erosion.

The second phase in the development of the volcanic activity is marked by the formation of the shield volcanoes Mount Asie, Kulal and Marsabit. These multicenter volcanoes developed over the pre-existing plateau lavas and have characteristic parasitic cones and explosion craters on their flancs. They form basaltic ranges in a linear fashion as they erupted along zones of crustal weakness parallel to the Lake Turkana axis.

Violent phreatic explosions on the volcano flancs formed se spherical depressions called maars. Near the shield volcanoes, ma scoria, ash and spatter cones occur. Pyroclastic ejectamenta occu greater volume than in the plateau basalts and consist of ash, agg and lapilli tuffs. Almond or fusiform-shaped bombs or breadcrust b shrinkage cracks can be distinguished.

The sedimentary basins in the survey area contain sediments from Precambrian Basement System rocks mixed with sediments origin the erosion of Caenozoic volcanic material. According to the result resistivity measurements carried out by Borgeson (1983), the sedim cover over the bedrock varies in thickness from 30m at the periphery than 200m in the centre of the basin. The sediments are poorly sor have a coarse sandy character (arenaceous) in the western and south of the area and are more argillaceous towards the east and north-ea Although quartz is the dominant mineral, feldspars and micas are pr well. Only in the eastern parts of the sedimentary plains volcanic were observed in field tests.

Highly calcareous, lacustrine sediments are found in and near Chalbi area. The sediments are silty, clayey and highly saline. So nants of lacustrine sediments are also found near Ilaut and Olturot Balesa Kulal). The fossil content of the latter sediments indicates water deposition environment. The fossil content of the lacustrine reported in the Turkana region outside this survey area indicates ag from Pliocene to recent times (Fuchs, 1939).

At different altitudes along the shore line of Lake Turkana, sediments were found, sometimes in between or mixed with volcanic la Paleo-lake sediments were found near Loyangalani at about 100m above present lake, but the intensely faulted nature of the area makes th rison of their altitude to the present lake level of little value. occurrence of peperites in the Loyangalani sediments shows that vo extrusion products were deposited in the paleo-lake together with la sediments. South of Kargi kunkar or secondary limestone occurs at th

Recent alluvial sediments are found in the flood plains of th rivers, mainly in the sedimentary plains and at the base of the lava west of Mt. Marsabit. The alluvium often has a sandy character, but places be very silty or clayey.

1.4 PHYSIOGRAPHY

1.4.1 Introduction

Landforms are a result of geological processes, like faulting and volcanic activities and geomorphological processes like erosion a sition. Climate has a strong influence on the geomorphological proc Under arid conditions which prevail in the survey area the vegetation is low, which enables erosion processes to dominate while the chemica weathering of rocks is minimal.

Soils show a distinct relation with the landforms in which th occurring and therefore are described in their relation to the physio The landforms of the survey area are described according to their lo

altitude, relief characteristics and slopes. The order in which they are treated is in general from high to low altitude. The relief intensity is defined as the difference in altitude over a square km.

1.4.2 Description of the landforms

- *Mountains (M)*[1)]

The mountains have a relief intensity of 300 to 1000m and slopes ranging from 8 to over 30%. The mountains are important as water catchment areas.

Residual mountains (MU)

The residual mountains consist of Precambrian Basement System rocks. The Ndoto mountains in the south-west form a range which rises upto an altitude of over 2400m. The eastward facing slopes are very steep and often have an escarpment like character (faultline). The tops are rounded. Exfoliation slabs are the omnipresent witnesses of physical weathering. In the south two inselbergs, Baio and Ilim, rise above the plains to an altitude of about 1500 and 900m respectively. In the west the survey area borders outliers of Ol Donyo Mara.

Volcanic mountains (MV)

The volcanic mountains consist of various volcanic rocks mainly basalts. The dominating volcanic mountains are Mt. Marsabit in the east and Mt. Kulal in the north-west. They rise respectively to 1740 and 2230m altitude. Mt. Marsabit has an irregular summit, with some small, flatter plateaus as well as steep cones and craters. The middle and lower slopes consist of a series of older lava plateaus. The base of the mountain is very broad: about 50 by 90km. Mt. Kulal has a summit with irregular and steep slopes, surrounded by steeply incised flanks. The lower slopes are long, gentle and have a concave to straight form. The Asie mountains form an outlier of Mt. Kulal to the north-east and rise to about 1160m elevation.

- *Hills and minor scarps (H)*

The hills and minor scarps have a relief intensity from 50 to 300m, with slopes ranging from 8 to over 30%. Erosion processes can be very active in the hills.

Residual hills (HU)

The residual hills consist of Basement System rocks. They occur mainly in the south-western part of the area. The hills often have almost bare, rounded tops and steep convex slopes.

Volcanic hills (HV, HP)

The Longipi hills, east of Lake Turkana, have steep and irregular summits. They rise upto 1120m elevation. These hills consist mainly of pyroclastic rocks. Many adventive craters and other small pyroclastic

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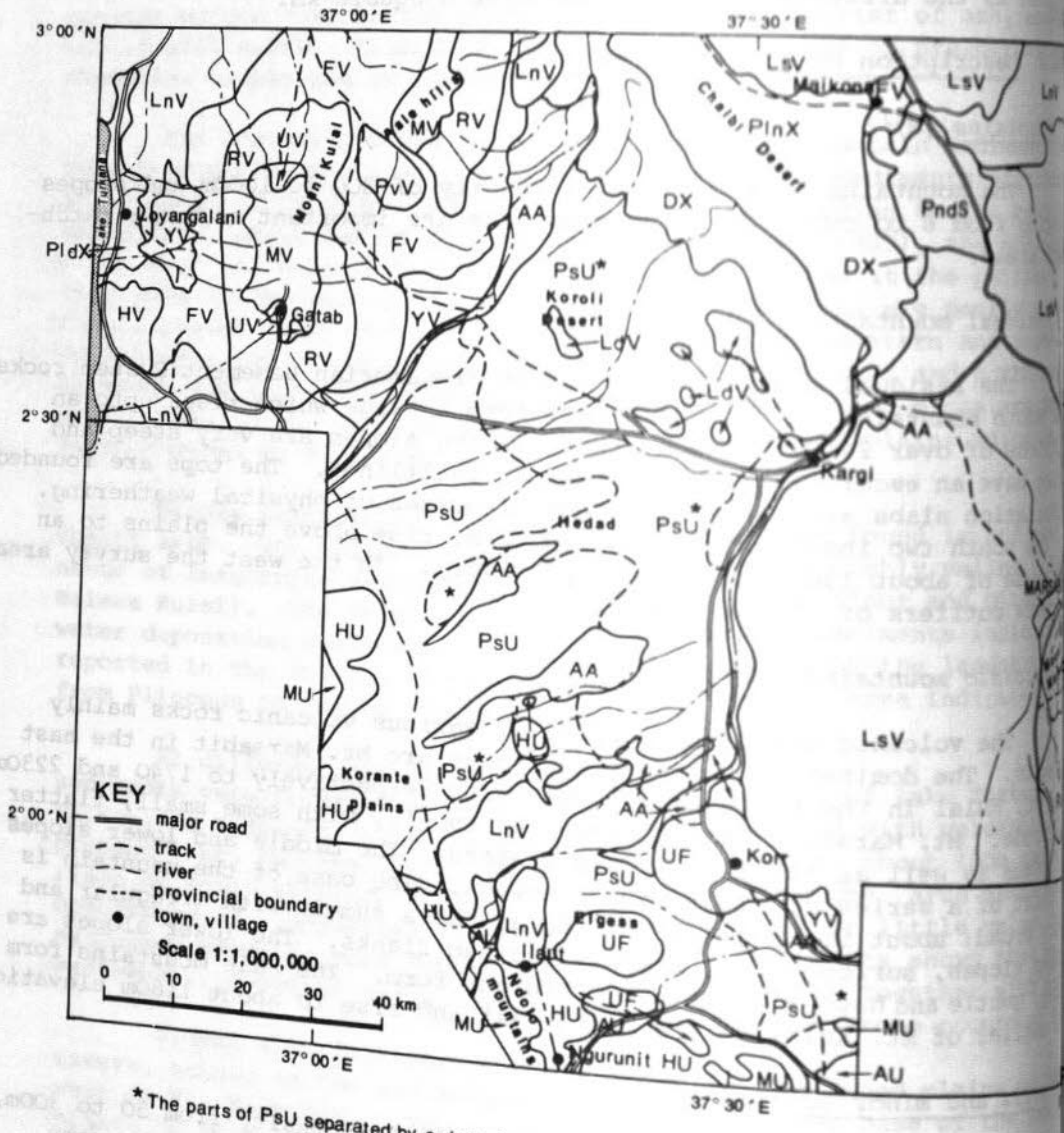
1) The code between brackets refers to the code used on the soil map (appendix 1) and on fig. 5.

Fig. 5 Landforms and geology



*The parts of PsU separated by a dotted line and marked with an asterisk, have strongly sodic soils

LEGEND

MOUNTAINS (relief intensity 300–1000m, slopes from 8 to over 30%)

- MU — Mountains of undifferentiated Basement System rocks (Precambrian)
- MV — Mountains of various volcanic rocks (Mio–Pleistocene)

HILLS (relief intensity 50–300m, slopes from 8 to over 30%)

- HU — Hills and footslopes of undifferentiated Basement System rocks (Precambrian)
- HV — Hills and scarps of various volcanic rocks (Plio–Pleistocene)

UPLANDS (relief intensity 10–100m)

HIGH LEVEL (relief intensity 10–100m, slopes from 2 to over 16%)

- UV — Uplands of various volcanic rocks (Plio–Pleistocene)

LOW LEVEL (relief intensity (10–50m, slopes 1–8%)

- UF — Uplands of gneisses rich in ferromagnesian minerals (Basement System rocks, Precambrian)

PLATEAUS

Ls STEPPED PLATEAUS (relief intensity less than 10m, steps of 10–20m, slopes 0–3%)

- LsV — Stepped plateaus of various volcanic rocks (Mio–Pliocene)

Ln NON–DISSECTED PLATEAUS (relief intensity less than 20m, slopes 0–5 %)

- LnV — Non–dissected plateaus of various volcanic rocks (Mio–Pliocene)

Ld DISSECTED PLATEAUS (relief intensity 10–60m, slopes 1–10%)

- LdV — Dissected plateaus of various volcanic rocks (Mio–Pliocene)

FOOTRIDGES (dissected middle slopes of various volcanic mountains, relief intensity 50–200m, slopes of crests 2–8%, slopes of valley sides over 16%)

- RV — Footridges of various volcanic rocks (Plio–Pleistocene)

FOOTSLOPES (at the foot of mountains, hills and plateaus, relief intensity less than 10m, slopes 1–8%)

- FV — Footslopes of colluvium derived from various volcanic rocks (Pleistocene)

PIEDMONT PLAINS (relief intensity less than 10m, slopes 0–2%)

- YV — Piedmont plains of colluvium and alluvium derived from various volcanic rocks (Pleistocene)

P PLAINS

Pv VOLCANIC PLAINS (relief intensity 5–10m, slopes 0–2 %)

- PvV — Volcanic plains of various volcanic rocks (Plio–Pleistocene)

Pnd NON–DISSECTED AND DISSECTED EROSIONAL PLAINS (relief intensity 0–20m, slopes from 0 to over 16 %)

- PndS — Erosional plains of quartzitic sandstones (Miocene)

Ps SEDIMENTARY PLAINS (relief intensity less than 5m, slopes 0–2 %)

- PsU — Sedimentary plains of unconsolidated sediments derived from undifferentiated Basement System rocks (Pleistocene)

Pln NON–DISSECTED LACUSTRINE PLAINS (relief intensity less than 5m, slopes 0–2 %)

- PlnX — Non–dissected lacustrine plains of sediments derived from various parent materials (Quaternary)

Pld DISSECTED LACUSTRINE PLAINS (relief intensity 5–20m, slopes 0–8 %)

- PldX — Dissected lacustrine plains of sediments derived from various parent materials (Pleistocene–Quaternary)

A FLOODPLAINS (relief intensity less than 5m, slopes 0–2 %)

- AU — Floodplains of alluvial deposits derived from undifferentiated Basement System rocks (Quaternary)
- AA — Floodplains of alluvial deposits (Quaternary)

D DUNES (relief intensity 2–10m, slopes from 0 to over 16%)

- DX — Dunes of aeolian deposits overlying various parent materials (Pleistocene)

NB: All geological periods are tentative.

hills can be found on the slopes of Mt. Marsabit, Mt. Kulal and
stand about 50 to 200m above their surroundings and have steep
various forms. Many are too small to be indicated on the soil
scarp in volcanic material is found at the shore of Lake Turkana,
Loyangalani. This scarp forms a part of the great Rift Valley
Over a distance of 1 to 2km, the surface descends stepwise about
towards Lake Turkana.

- *Plateaus (LV)*

All plateaus are of volcanic origin and consist mainly of
They have in general a rather flat surface with a scarp at least
side. A common characteristic of all the plateaus is the very
or bouldery character of the surface. The plateaus are not very
to erosion.

Stepped plateaus (LsV)

The stepped plateaus have a relief intensity of less than
slopes ranging from 0 to 5%. The steps, forming the transition
different plateaus, are 10 to 20m high. The edges of the plateau
dissected. These plateaus form the middle and lower slopes of Mt.
and range in altitude from about 900m near Marsabit to about 500m
north-east.

Non-dissected plateaus (LnV)

These plateaus have a relief intensity of less than 20m
of 0 to 2%. One is located east of Maikona, separating the Marsa
the Huri hills lava, at an altitude of about 500m. North-east of
another plateau lies at an altitude of about 600m.

A very conspicuous phenomena is the lava plateau east of
is extended in a south-western/north-eastern direction over a
32.5km. This plateau lies about 50m above the surrounding plains
altitude of around 650m. It has a slight dip to the north-east.

Dissected plateaus (LdV)

The dissected plateaus have a relief intensity of 10 to 60
slopes ranging from 1 to 10%. They rise about 50m above the
plains, and are lying at an altitude of around 550m.

- *Footridges (RV)*

Footridges are the strongly dissected middle slopes of
mountains. They consist mainly of basalts and pyroclastic rocks.
relief intensity ranges from 50 to 200m. The slopes of the crests
the canyon like valleys range from 2 to 8%. The slopes of the
sides are over 16% to almost vertical. Footridges are found
Kulal, at the east side of the Asie hills and south-east of Marsabit
Erosion can be very serious.

- *Footslopes (F)*

Footslopes are present at the foot of mountains, hills and
The relief intensity in general is less than 10m. The slopes

1 to 8%. The form of the slope is in general concave at the upper end and straight in the lower part. The upper sections of the footslopes are very sensitive to erosion.

Footslopes of the residual mountains and hills (FU)

The footslopes consist of colluvium derived from Basement System rocks. They occur in the south-western part of the survey area. At the foot of the Ndoto mountains the slopes are strongly dissected by gullies. In general it can be remarked that these footslopes are very short.

Footslopes at the foot of volcanic mountains, hills and plateaus (FV)

The footslopes consist of colluvium derived from various volcanic rocks. They are located mainly in the north-western part of the survey area, at the foot of Mt. Kulal, and the Asie and the Longipi hills. Some small parts are situated near Maikona and west of the Kurkum lava plateau (north-west of Kargi). Around Mt. Marsabit no footslopes were recognised as the slopes of this mountain consist of a series of plateaus. Small footslopes may occur around the isolated lava plateaus. They are however too small to be indicated on the soil map (appendix 1).

- *Piedmont plains (YV)*

The piedmont plains have a relief intensity of less than 10m with straight, long slopes of 0 to 2%. Piedmont plains were recognised only at the foot of Mt. Kulal and in a few places at the south-western base of Mt. Marsabit. They consist of alluvium and colluvium derived from various volcanic rocks. The erodibility of these areas is low.

- *Uplands (UF)*

The low level uplands or small and low hills, have a relief intensity of 10 to 50m, with slopes ranging from 1 to 8%. The uplands consist of gneisses, rich in ferromagnesian minerals belonging to the Basement System rocks. The uplands are located in the southern part of the survey area, around Korr and Elgess. The general level is about 50 to 100m above the surrounding plains, at about 650m altitude. These areas are seriously affected by erosion.

- *Plains*

Volcanic plains (PV)

A small volcanic plain is located between Mt. Kulal and Asie as an intermountainous plain. The relief intensity is 5 to 10m and the slopes range between 0 and 2%.

Erosional plains (PnS/PdS)

On these plains erosional processes dominate. Consequently the soils are shallow. The erosional plains are developed on Pleistocene quartzitic sandstone. They occur in the north-eastern part of the survey area at an altitude of about 500m. The non-dissected part (PnS) has a relief intensity of less than 5m with slopes from 0 to 2%. The dissected part (PdS) has a relief intensity of 5 to 10m with slopes from 2 to over 16%.

Sedimentary plains (PsU)

The sedimentary plains are the result of depositional p
However, this does not mean that no erosion can take place. Th
tary plains have a relief intensity of less than 5m, with slope
2%. These plains consist of unconsolidated sediments derived fr
ment System rocks. The general direction of the very gentle sl
less than 1%) is towards the east-north-east. The general altit
around 600m. These plains occupy an extensive part of the stud
the Koroli desert in the north, via the Hedad in the central pa
Kaisut desert in the south.

Lacustrine plains (PlX)

The lacustrine plains have a relief intensity of less th
slopes of 0.2%. They are located in the north-east of the surv
are known as the Chalbi desert. The Chalbi, lying at an altitud
400m, forms a closed drainage basin filled in with sediments of
origin. Due to the periodic flooding (once or twice yearly) and
salt content of the sediments, the area is virtually bare.

An interesting phenomena, which cannot be shown on the so
(appendix 1) is a longitudinal dune in the centre of the Chalbi.
has a length of 7.5km, is very straight and the top is knife sha
dune consists of sand, silt, clay and salts.

A few rests of lacustrine plains can be found around Loy
at the shore of Lake Turkana.

- *Floodplains (A)*

The relief intensity of the floodplains is less than 5m w
from 0 to 2%. The floodplains consist of alluvial sediments of
rivers with an episodic flow regime. The sediments are derived
ment System rocks (AU) or have various origins (AA).

Many small floodplains are crossing the sedimentary plain
predominantly north-eastern direction. They are however, often
to be shown on the soil map. The many drainage ways on the volc
tains are also too small to be separated on the map.

- *Dunes (DX)*

The dunes have a relief intensity of 2 to 10m with slopes
interdunal flats) to over 16%. The dunes occur at both sides of
desert but are most abundant at the western side. The dunes con
of quartz sand with some weatherable minerals and some volcanic
They overly older lacustrine sediments. The form of the dunes i
general straight with an orientation parallel to the dominating
tion (NE). In several places these dunes are eroded mainly by w
partly also by water, upto the underlying lacustrine sediments,
ing the interdunal flats.

1.4.3 Some aspects of landscape genesis

The geomorphological history of the survey area has close
the geological and climatic past of both which is very little kn

The dating of the various processes and rocks is therefore only provisional.

The oldest rocks present in the area are from Precambrian age. No rocks of the Paleozoic and Mesozoic times have been found. During these periods intensive weathering and erosion took place. The Permian and Triassic sandstone (Duruma) in the eastern part of Kenya are the deposition products of eroded land surfaces, probably also from this area. The oldest known erosion level dates from the Jurassic period (the Gondwana surface) and can be found in the Ndotos (Ojany, 1966). Since then various uplifts have resulted in erosion and weathering cycles mainly in the Cainozoic era (Beckmann, 1982), producing successions of land surfaces. Tertiary volcanism accompanied the faulting and uplifting in this period and the resulting landforms largely dominate the present day landscape.

Deeply weathered and leached soils are, with a few exceptions, not present in the survey area. This is in contrast to soils found in the plains and uplands of north-eastern Kenya which are reported to be of the ferralitic type *(ferralic* subgroups and *FERRALSOLS)* (Sombroek et al, 1976). It is likely that the hot and humid climatic conditions, which are a prerequisite for the formation of *FERRALSOLS*, have also been present in the survey area. However, it is assumed that, due to the more pronounced relief and the position closer to the Rift Valley resulting in higher uplifting, the erosion of the weathered surfaces has been more complete. More recent weathering products are forming the present day surfaces.

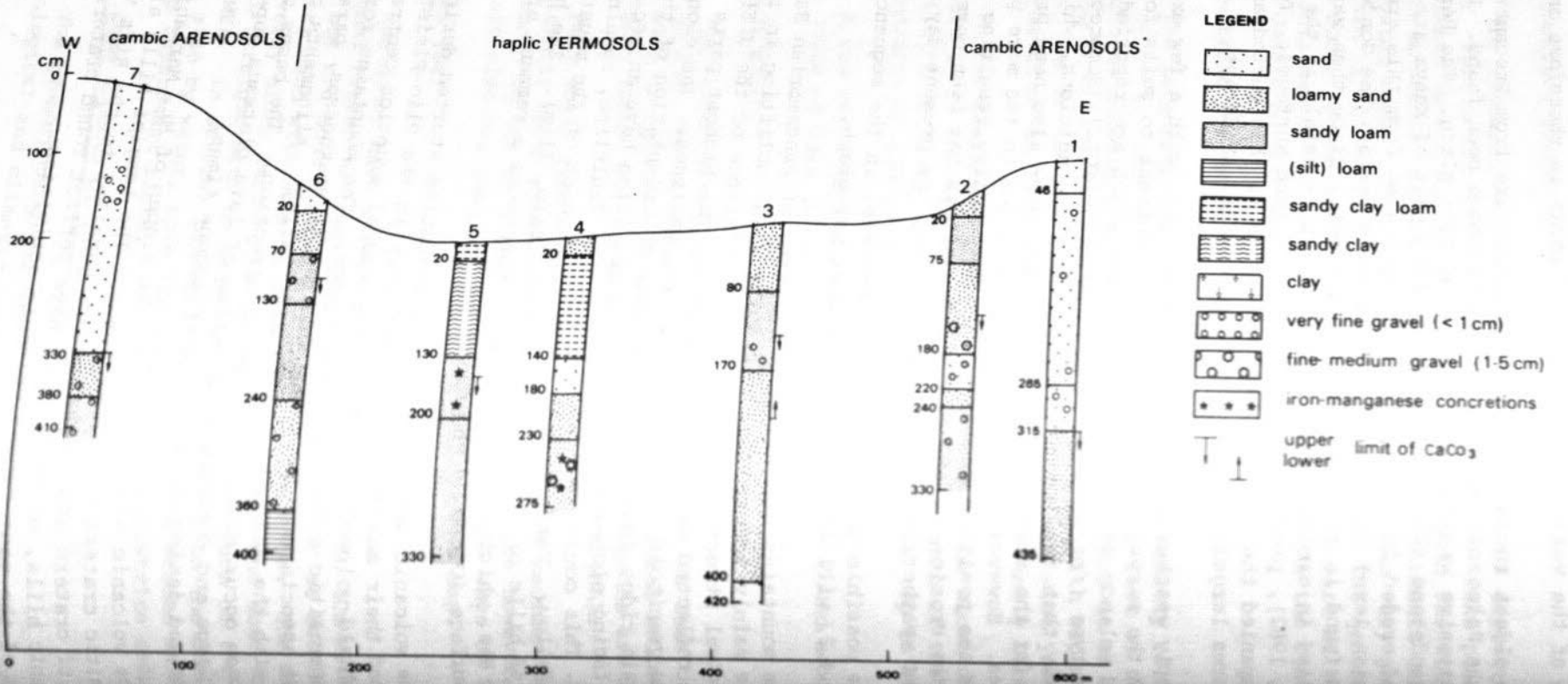
The possible genesis of the landforms, in the sequence as given in chapter 1.4.2, will be given in the next paragraph.

The mountains and hills, consisting of Precambrian Basement System rocks, are mainly the results of faulting and uplifting in the Tertiary. The geological structure and relative resistance of the different rock types are reflected in the physiography. The highest parts are composed of homogenous granitoid and compact biotite gneisses. The elongated form of the mountain ridge follows the regional NS orientation of the strike. The eastward facing slopes are very steep and often have an escarpment-like character. This could well coincide with a faultline, running parallel to the Rift Valley. Various inselbergs occur east of the mountain front in the form of hills or isolated mountains (Baio, Ilim). The higher part of the Ndoto Mts. which is rather flat, represents a remnant of the Gondwana erosion surface (Ojany, 1966).

The volcanic mountains, whose formation started during Miocene times and reached their maximum height possibly in the Plio-Pleistocene have the form of shield volcanoes. They have several eruption centres and characteristic parasitic cones on their flancs. The mountains form linear ranges and can be associated with zones of crustal weaknesses, parallel to or at an angle with the main axe of the Rift Valley. Alignments of craters and cinder cones occur mainly in a SW-NE direction. The bases of the mountains are very large and consist of a series of lava plateaus superimposed on each other and dating from Miocene-Pliocene times.

The volcanic hills found on the slopes of Mt. Marsabit and Mt. Asie are parasitic craters or cinder cones. The Longipi hills also consist of a series of craters and cinder cones, parallel to the Rift Valley system. The volcanic hills, of which some have perfect round craters, are the witnesses of the most recent volcanic activities.

Fig. 6 E–W cross-section between Korr and Ngurunit through a slight depression at observation No. 66/4 (mapping unit PsUA2 of appendix 1)



NOTE
1 corresponds with profile pit observation No. 66/4

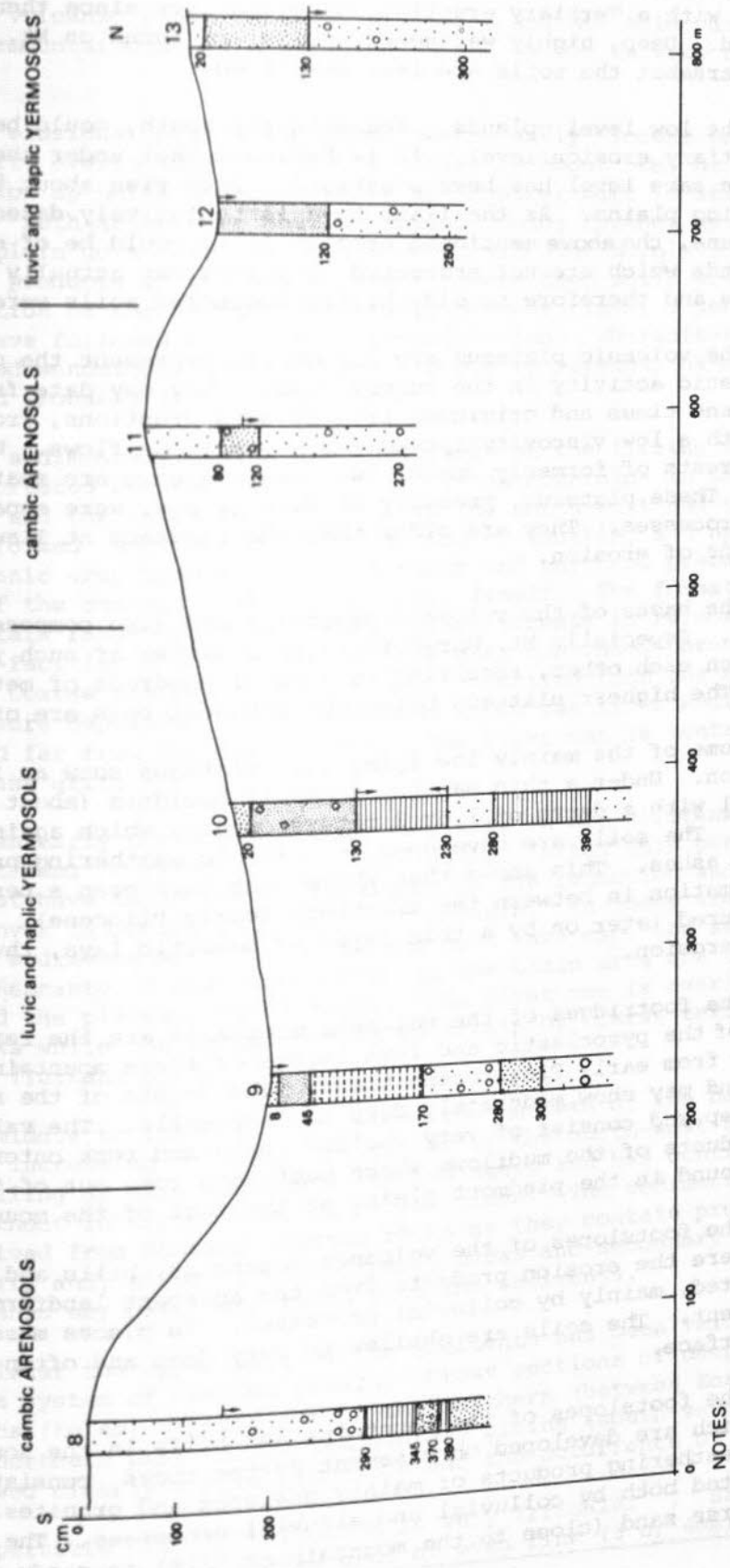


Fig. 7 N - S cross-section in the northern Hedad at observation No. 54/7 (mapping unit PsUA1 of appendix 1)

NOTES:
- 9 corresponds with profile pit observation No. 54/7
- measurements of surface are approximate
- for legend see fig. 6.

The high level uplands, found on Mt. Kulal and Mt. Marsabit, sent relatively flat, more stable areas of the mountains. They co coincide with a Tertiary eruption phase and have since then been r untouched. Deep, highly weathered soils are found on Mt. Kulal w on Mt. Marsabit the soils are less weathered.

The low level uplands, found in the south, could be the re of a Tertiary erosion level. It is believed that under the Ilaut p lavas the same level has been preserved. Both rise about 50m abov surrounding plains. As the Ilaut lava is tentatively dated as late to Pliocene, the above mentioned erosion level could be of early Mi The uplands which are not protected by a lava cap actually undergo processes and therefore no old, highly weathered soils were observ

The volcanic plateaus are thought to represent the oldest p the volcanic activity in the survey area. They may date from late to Pliocene times and originate from fissure eruptions, from where magma with a low viscosity spread out as enormous flows. West of L several rests of formerly one or two lava plateaus are scattered in plains. These plateaus, probably of Miocene age, were separated by sional processes. They are older than the plateaus at Ilaut, which show signs of erosion.

The bases of the volcanic mountains are also composed of lav plateaus. Especially Mt. Marsabit shows a series of such plateaus, imposed on each other, resulting in several hundreds of meters of t lavas. The highest plateaus being the youngest ones are of Pliocen

Some of the mainly low lying lava plateaus show an interesti phenomenon. Under a thin mantle of basalt boulders (about 50cm) a f free soil with a depth of 1 or 2 meters occurs, which again lies on basalts. The soils are developed on volcanic weathering products w volcanic ashes. This shows that there must have been a period suita soil formation in between the eruptions (early Pliocene). The soil been covered later on by a thin layer of basaltic lava, thus protec against erosion.

The footridges of the volcanic mountains are the result of s erosion of the pyroclastic and lava layers of these mountains. They probably from early Pleistocene times. The crests of the ridges ar stable and may show moderately deep to deep soils. The valley sides very steep and consist of very shallow soils and rock outcrops. Th sion products of the mudflows which must have come out of the deep can be found in the piedmont plains at the foot of the mountains.

The footslopes of the volcanic mountains, hills and plateaus areas where the erosion products from the adjacent landforms have b accumulated, mainly by colluvial processes. In places massive lava are present. The soils are shallow to very deep and often stony wi stony surface.

The footslopes of the mountains and hills in the south and s west, which are developed on Basement System rocks, consist of the p ported weathering products of mainly gneisses and granites. They h transported both by colluvial and alluvial processes. The sediments from coarse sand (close to the mountain or hill) to sandy clay loa

lower end of the slope.

The volcanic plain, between Mt. Kulal and Mt. Asie can be regarded as an intermountainous plain situated on the saddle between the two mountains.

The erosional plains are found on the early Miocene sandstones. The western part, overlooking the Chalbi plains by about 50m, has been subject to dissection up until nowadays while the central part is still non-dissected. Both areas have shallow soils. Going further eastward the non-dissected plain gets more and more covered with the mainly coarse grained weathering products of the sandstones and here deep soils are found. After the deposition of the sediments in early Miocene times, a period of weathering must have followed a period of consolidation. Thereafter, the horizontally bedded sandstones (no folding evidence is present) have partially been eroded probably in Pliocene times.

The sedimentary plains are the result of the filling up of the basin which was created between the Basement System mountains in the west and south-west and the volcanic mountains in the north-west and the east. This basin was formed due to a combined action of faulting and uplifting in the west, volcanic eruptions in the north-west and east and probably by block-faulting of the central part of the basin itself. The formation of the Ndoto mountain range could have taken place already in Paleozoic or Mesozoic timed, but faulting and uplifting of the area continued throughout the Tertiary. Coarse grained erosion products derived from the Basement System mountains were deposited in the lowlands while the finer sediments have been transported far from the survey area. The first can be tentatively referred to as Turkana grits.

In an early phase of volcanic activity in Mio-Pliocene times extensive lavastreams covered parts of the basin. After this period, severe erosion must have taken place, resulting in the reduction and cutting up of the lava cover in the central part of the basin. In those areas where the underlying sediments were not protected by a lava cap, the sediments were removed. Remnants of this lava cover in the basin area are the Ilaut plateau and the plateaus NW of Kargi. The first one is overlying Basement System rocks while the second one is underlain by coarse textured sedimentary rocks (Turkana grits).

In middle to late Pliocene times the outlets of the basin were blocked by increasing volcanic activities in the north-west and the east and the filling up with sediments started again and has continued since then, with or without interruptions, to recent times. The sediments have been mainly derived from Basement System rocks as they contain predominantly coarse quartz and, mixed with feldspars, micas and secondary minerals. Volcanic ashes may have been mixed with the sediments.

At least the upper part of the sediments has been laid down by water action in a system of braided rivers. Cross sections of deep augerhole observations (to 4m) carried out in the southern (between Korr and Ngurunit) and in the northern part of the sedimentary plains (south-west of Balesa Kulal) showed clearly a stratification and the occurrence of stream channels. The particle size distribution is very irregular[1]. Silt size fractions occur together with coarse sand or even fine (3 or 4mm) gravel.

1) *Due to technical problems no sieving of the sand fraction was done.*

Deeper in the profile sometimes layers of almost pure silt (mica's) or gravel may alternate (see fig. 6).

In the north-west, the lowest part of the area, a big shallow existed where fine grained lacustrine sediments were deposited (Pla Holocene). Its greatest extent in Quaternary times occurred durin relatively wet period probably 12,000 years B.P. (Nyamweru, pers. c

Alongside lake Turkana a series of lacustrine sediments have deposited during Tertiary times upto recent days. Due to a relativ heaval of the area east of the lake, the oldest sediments can now be at 100m or more above the present lake level.

Clear eolian landforms are found in areas adjacent to the Ch lacustrine plains where extensive zones with dunes are present. Th mainly longitudinal dunes can be up to several metres in height and nowadays stable (if not disturbed by human activities). The sand pa have been blown out of the Chalbi basin in dry periods. The sand wa in the area by the rivers coming from the south-west which were carr erosion products of the mountains and hills. Another source was pro the sandstone south of Maikona.

Recent dune building activity can be found around the villag and Kargi. The dunes often occur as small (20 to 70cm height) obst dunes around dwarf shrubs. These dunes are clearly linked to the cu down of woody vegetation and to a high concentration of livestock ar waterholes and villages (see also Ch. 1.6).

1.5 HYDROLOGY

Surface water is very rare in the survey area. Only after h rains, shallow pools and seasonal water courses as well as the Chal desert may be filled with water for a few days upto a maximum of a f weeks. Lake Turkana is permanently filled with water, but the quali the water is rather poor (pH around 10). Permanent surface water co found near the tops of Mt. Kulal and Mt. Marsabit and in some spring the foot of these mountains. An important spring is Korole, north-w Kargi, where almost daily camels and other livestock species are be watered.

The Chalbi desert forms the lowest part of the survey area an the erosion base for the greater part of it. The waters originatin the north-eastern parts of the Ndoto mountains, Ol Donyo Mara, South (both west of the survey area), the eastern side of Mt. Kulal, the ea and southern side of the Asie hills and from the western and north-w slopes of Mt. Marsabit all end up in the closed Chalbi basin. In m seasons however, the waters will not reach the Chalbi as the riverbe very permeable and the amount of water is not sufficient to fill up rivers completely. The south-eastern part of the survey area has cl river, flowing further south, as erosion base. In the north-west la Turkana serves as erosion base.

The drainage ways in the volcanic areas have bouldery and sa beds. In the plains the riverbeds show a typical sandy and silty ch At the foot of the Marsabit lava the drainage way has a fine texture of the drainage ways seem to be too wide for the existing climatic c tions. They have wide beds with braided characteristics and change

channels. Sometimes, once in 5 or 10 years, the riverbeds will be filled up completely. For example debris is found in trees along the Balesa Kulal river, 2m above the present riverbed. The Balesa Kulal is the biggest river in the area, coming from South Horr (west of the area). It passes the lower slopes of Mt. Kulal and the Asie hills and finally spreads out in the Chalbi.

The drainage pattern of Mt. Kulal is clearly radial. Mt. Marsabit shows a radial drainage pattern as well but there is a marked decrease in density on the western slopes which lie in the rain shadow of the top. The drainage lines in the sedimentary plains have a semi-parallel pattern and have a SW-NE direction. They originate from the Basement System mountains and end up in the Chalbi basin.

The sources of water for the population are various and differ per location. They consist of permanent springs, boreholes and waterholes dug in the riverbeds. At the end of a long dry season, water becomes scarce as the watertable in the rivers becomes very deep and the hand dug wells collapse. Other wells and boreholes sometimes dry up completely.

The general groundwater table throughout the area is very deep, except in places where the Basement bedrock is close to the surface. But even here the groundwater is below 5m depth. The Chalbi desert has a shallower groundwater table, depending on the season, from 0 to 5m depth. However, the water is salty.

An interesting phenomena to note is the occurrence of a N-S ridge of Basement System rocks just north of the Ilaut lava plateau. These rocks form a barrier for parts of the water coming from the west. This explains also the occurrence of strongly sodic soils west of this area.

For more information about the hydrology of the survey area the reader is referred to IPAL technical report B-2 (1983).

1.6 EROSION

In almost any environment erosion takes place. This is a natural process. Man has often enhanced the speed and occurrence of erosion. The cutting of trees and shrubs by the pastoralists for construction purposes (fences, houses) and fuel is a major cause for the increase of erosion. In the survey area the unbalanced use of the vegetation by the livestock of the people causes overgrazing and degradation of the vegetation and consequently, as the protective soil cover is removed, accelerates the natural erosion enormously.

The erosional processes can be classified as follows:

(a) Processes by water
- fluvial processes (stream bank erosion)
- splash and rillwash (sheet erosion)
- rill erosion
- gully erosion
- pipe erosion
- mass movements

(b) Processes by wind (aeolian)

- deflation

Fluvial processes are limited to the riverbeds. A decrease vegetation cover in the catchment area and consequently lower infil rates increases the runoff, especially during heavy rains, while th of eroded materials increases. During heavy floods the riverbeds change their courses. The major shaping of the rivers takes place heavy floods while normal floods modify the courses only a little.

As the vegetation cover in the major part of the survey area low, especially at the end of the dry season, splash and rillwash very common during the rains. In particular areas with sodic topo affected. The run-off has the tendency to form channels as it is the micro and meso relief and also by the vegetation. As a result is not affecting the whole soil surface in a homogeneous way nor identical rate. This makes it difficult to assess the amount of material. Bake (in: IPAL, 1983) calculated the amount of eroded as about 135m^3/km^2 a year. His attempts to measure the amount we mainly due to loss of equipment. Mounts around *Duosperma* and *Indi* dwarf shrubs show that in places about 20-50cm have been eroded du life time of these shrubs. It should be noted that most of the ero materials do not reach the valley floors, but are deposited nearby.

Rill erosion is common all over the survey area where even slopes are present. Small rills resulting from the splash and rill erosion may join and form the beginning of a somewhat deeper rill. process of rill erosion becomes more serious where the natural veg has been damaged. The strongly overgrazed slopes in the Ngurunit a heavily affected by this kind of erosion.

Steeper slopes with increased runoff may induce gully erosi mountain areas and the footslopes around them are mainly affected type of erosion. Deep gullies can be found in the Ngurunit area Gatab where the process is most recent and was initiated by cattle stock tracks as well as by roads. Some gullies near Ngurunit are initiated by roads. The Marsabit area is also threatened by gully In the sedimentary plains, gully erosion hardly occurs as the gene of the terrain is very low.

Pipe erosion is difficult to detect unless the pipe or tunn collapses. Several processes may initiate this kind of erosion bu beyond the scope of this paper to deal with this. It is noted tha erosion only occurs in often cracking, heavy clay soils. Pipe ero not occur at a big scale but in some areas, e.g. south of Korr, it affect grazing. The bigger animals can step in the invisible pipe their legs.

On some steep slopes on the upper parts of Mt. Marsabit land occur. The area affected is currently very small, but could increa trend to graze and cultivate even on steep slopes continues. Cattl which are present in many places on the Mt. Marsabit slopes, are th of regular animal movements and can initiate a landslide.

Aeolian processes are very common throughout the survey are good indicators of overgrazing and desertification processes. Dust

may occur anywhere in the plains but are most spectacular and effective in the overgrazed areas around the settlements in the lowlands. But even around Marsabit dust storms may occur when the cultivated fields are bare.

Fossil dunes, formed during a drier period in the recent geological past, are most prominent around the Chalbi. Presently these dunes are fixed by grasses and dwarf shrubs. Overgrazing however can easily reactivate them as can be seen east of Kargi where moving sands are covering shrubs and small trees. Moving sands are very obvious south of Kargi and around Korr. The sand often accumulates around dwarf shrubs thus forming mainly small obstacle dunes. In places these dunes may rise up to a height of 1m, but they are often washed away in a very wet season. The eroded sands are accumulated in a nearby riverbed from where they are blown out again after the rains. The erosion of the fine materials both by water and by wind left behind a desert pavement on the higher parts of the uplands in the Korr area.

It seems that the maximum of aeolian activity occurs just after the first rains. By the splash effect of the falling drops the thin algae crust on the topsoil is destroyed so that the wind can blow away the loose sand particles.

It has been shown by IPAL (1983) that sand movement can be stopped. At Kargi there is an enclosure which is completely protected from grazing. After the first rains grasses sprouted, creating aerodynamic resistance which enabled the moving sands to settle. This accumulation formed the first rooting possibilities for more grasses and, later on, for dwarf shrubs and shrubs, which in turn gave the opportunity for further sand accumulation. Before the enclosure was built there was only bare residual rock.

1.7 VEGETATION

Much research in the survey area has been carried out by various Unesco-IPAL scientists or consultants on both the woody vegetation and the herb and grass layer. The most extensive study accompanied by a map published so far is Herlocker's "Vegetation of south-western Marsabit District" with map at 1:500,000 (Herlocker, 1979). This author recognises 9 primary physiognomic vegetation types, which include 73 tertiary vegetation types defined according to their composition.

Ngurunziza and Lusigi give a description of the major range units of the area and present it on a simplified map at an approximate scale of 1:300,000 (in: IPAL, 1983). The range type descriptions include physical attributes (soil, climate, geomorphology), vegetation attributes (composition, cover and biomass), human impact, range condition and the estimated carrying capacity. Lamprey gives in the same publication a description of the woody vegetation.

Only a summary of the major vegetation types mainly based on the work of Herlocker (1979) follows below.

The summits of Mt. Kulal, Mt. Marsabit and the Ndoto mountains which occur in agro-climatic zone III and/or VI are covered with evergreen forest. The forest is dominated by *Cassipourea malosana*, *Diospyros abyssinica*, *Olea hochstetteri* and *Teclea simplicifolia*. On Mt. Kulal *Juniperus procera* occurs as a successional species at the forest edge. Mt. Marsabit has no *Juniperus* but here *Strombosia scheffleri*, *Ekebergia capensis*, *Premma maxima* and *Croton megalocarpus* are other important species.

The montane forest is bordered by a zone of evergreen to se deciduous bushland, which corresponds more or less to agro-climatic The most characteristic and often dominant species are *Rhus natale Carissa edulis, Euclea divinorum, Aspilia mossambicensis, Lippia* and *Juniperus procera. Harrisonia abyssinica* is a common shrub on Marsabit. In the open areas between the trees and shrubs perennial occur: *Dichanthium/Themeda*. On the northern part of Mt. Kulal th vegetation is partly lost and a perennial grassland has taken over. duous woodland occurs on some parts of Mt. Kulal and south of the zone on Mt. Marsabit. The dominating species are *Combretum molle, etbaica, A. nilotica, A. drepanolobium* and *A. tortilis*. Perennial like *Chrysopogon plumulosus, Themeda triandra* and *Dichanthium insc* form the understory. The lowland woodlands occur along the major lines (riverine forest) and are dominated by *Acacia tortillis*. East Ndoto Mts. and Ol Donyo Mara and west and south-east of Mt. Kulal bushland occurs. Bushland is the principal transitional vegetatio between upland and lowland areas. The trees occurring in this typ *Acacia tortilis, A. senegal, Balanites aegyptiaca* and *Commiphora* The dominant shrub species are *Acacia mellifera, A. senegal* and Co *spp*. This vegetation type can be associated with agro-climatic zon although it occurs partly in zone V and partly in zone VII.

The major part of the survey area is covered with deciduous shrubland. It occurs in the southern, central and eastern parts of sedimentary plains, on the middle slopes of Mt. Marsabit, on the d on the lower slopes of the Asie hills. The two dominating species *Duosperma eremophilum* and *Indigofera spinosa*. The latter occurs o textured soils or soils with only a sandy topsoil. The former is water demanding and therefore occurs in the slight depressions whic have coarse to fine textured soils or on soils with a high availabl ture content. *Indigofera spinosa* can also be associated with dry c conditions. Annual grasses like *Aristida spp*. and to some extent form the herbaceous layer. Much of the dwarf shrubland has a scatt open overstory of shrubs of various *Acacia spp*. and *Commiphora spp*. boundaries between annual grasslands, dwarf shrublands and shrubla not always very clear and intrusions often occur.

Deciduous shrubland occurs in the northern and north-eastern of the sedimentary plains, on the Asie hills, around Mt. Kulal, on t middle slopes of Mt. Marsabit and on the Ilaut lava plateau. The d species is *Acacia reficiens*, while *Acacia mellifera* and *Commiphora* the other most abundant species. An understory of dwarf shrubs of and *Duosperma* and annual grasses like *Aristida* is common.

Annual grasslands mainly occur on the western and northern slopes of Mt. Marsabit, and between Mt. Kulal and Lake Turkana. Th ting grasses are *Aristida mutabilis* and *A. adscensionis. Eneapogon Cenchrus spp*. occur as well. Dwarf shrubs as *Indigofera, Duosperma* shrubs like *Acacia reficiens, A. mellifera, Commiphora spp*. often f overstory.

The Chalbi desert has no vegetation at all, due to the very concentration of salts in the soil. At the edges salt tolerant spec occur, such as *Sporobolus spicata, Sporobolus consimilis, Suaeda mon* and *Dasysphaera prostrata*.

Trees play an important role in the arid zones of northern Kenya. They provide firewood, materials for the construction of houses and livestock enclosures and browse for the livestock (camels, sheep and goats) of the pastoralists. In addition trees provide shade which is very important for cattle and small livestock. Trees further are valued for edible and medicinal products, for fibre, for rope making and for the gum of certain *Acacia* species. Trees also play a role in the maintenance of soil fertility by N fixation if they are leguminous and may reduce soil erosion and dessication. The major trees or shrubs present in the lowland areas are *Acacia reficiens*, *A. mellifera* and *A. tortilis*.

Acacia reficiens is relatively unpalatable but is the main source of wood for the Rendille people (Lamprey in: IPAL, 1983). The foliage of *A. mellifera* and *A. tortilis* is browsed by camels and goats. The fallen leaves and flowers are eaten by sheep. The fruits of *Acacia tortilis* are eaten by all livestock species. Other shrubs or small trees, although not occurring extensively, provide also browse for the livestock. These are *Maerua spp.*, *Salvadora persica*, *Cordia sinensis* and *Acacia senegal*.

Most of the consumed wood is used for the construction of livestock enclosures, estimated at 1.5-3.0 m^3/head/year, arriving at a maximum of 38.700 m^3 per year for the 12,900 Rendille living in the area. The requirement for fuel wood is approximately 5% of the requirement for fence construction material. Lamprey (in: IPAL, 1983) shows that only about 1,500 km^2 of *Acacia* shrublands can satisfy the need of the people, taking into account the calculated wood production of the shrubs. The people are however, not evenly distributed over the area, tendencies to sedentarisation increase and thus a gross depletion of woody vegetation around the settlements takes place.

2. SURVEY METHODS

2.1 OFFICE METHODS

The available topographical and geological maps and the ... literature on the survey area were collected and studied before ... the fieldwork. The area is covered by the topographical maps at ... 1:100,000 of the Survey of Kenya series Y633, sheets Nos. 41, 42, 55, 66, 67. Except for sheet No. 42 which has contours at 100 ... these maps are very poor in topographical information. The area ... covered by 1:250,000 topographical maps of the Survey of Kenya, ... NA-37-6, NA-37-9, NA-37-10.

The area is not covered by geological maps, except for a ... in the south-west and south-east.

Aerial photographs of the area, obtained from the Survey ... are approximately at a scale of 1:50,000. The photographs were ... and 1975. The quality is good, except above Mt. Kulal, Asie hills ... and parts of the Mt. Marsabit summit, where clouds are disturbing ...

Excellent Landsat images of the survey area were available ... is covered by the images with path and row 181/58, 180/58, 181/59 ... Scenes from 1973, 1976 and 1979 were obtained from the Regional ... Sensing Facility in Nairobi. The images of 24th January 1976 ... the interpretation for soil survey purposes since it was a partic... period when vegetation least obscured the underlying soil reflec... patterns.

A satellite image interpretation was carried out prior to ... work. It was found out that the best method was to project a tr... colour positive of the image directly on the 100,000 topographic... The positive, at the original 1:1,000,000 scale was a false colo... of bands 4, 5, 6 and 7.

The interpretation units, delineated on the map, were chec... field with augerhole observations and/or soil pits. After a fie... more definite boundaries could be drawn, either from another inte... of the satellite images or with the aid of aerial photographs. ... the correlation between the Landsat images and the situation in ... hardcopy false colour prints at a scale of 1:250,000 were used ...

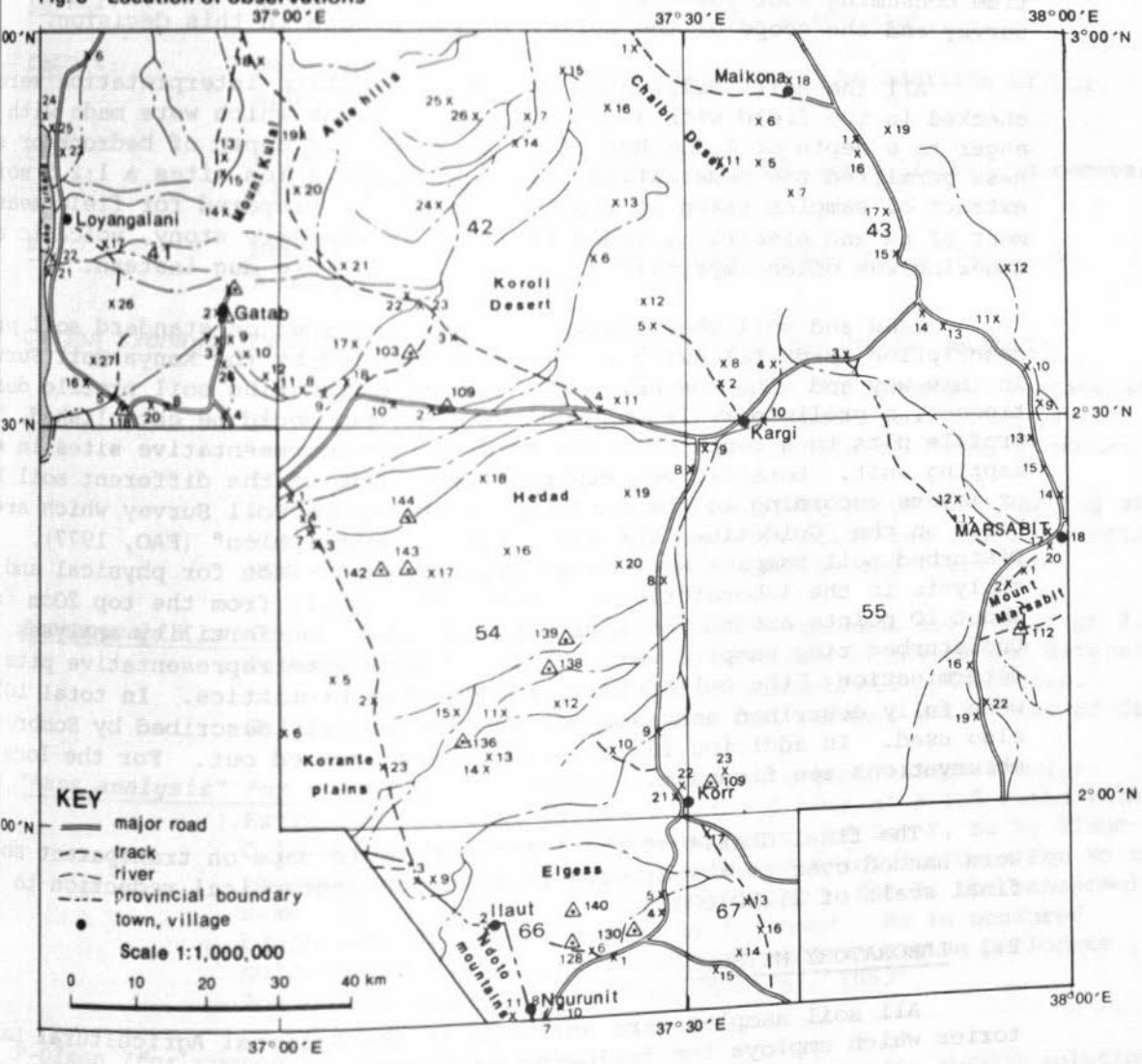
No systematic aerial photo-interpretation was carried out. ... photographs were used to obtain more details on small mapping u... soil or landform boundaries more accurately and for orientation ...

2.2 FIELD METHODS

The field survey was carried out between August 1980 and ... 1983. Survey trips were made for periods of about 3 weeks. Use ... of the Unesco-IPAL fieldcamps in Gatab, Ngurunit, Olturot, Korr, ... Marsabit. In total 156 days were spent in the field.

Some parts of the survey area were not visited, due to the ... accessibility of the terrain. These areas are the Asie hills wi... footridges and parts of their footslopes and the stepped plateau...

Fig. 8 Location of observations



x 42 profile pit observation with reference number

△ 138 augerhole observation with reference number (fertility sample)

x 55 topographical sheet number (1 100.000)

Marsabit. Through extrapolation and interpretation tentative de
could be made. As rockiness and extreme stoniness are expected
dominating properties, it was considered not to be justified to
time consuming foot safaris. Also the limited time available fo
survey and the scope of the survey played a role in this decisio

All the units delineated with the satellite interpretatio
checked in the field with augerhole observations which were mad
auger to a depth of 1.20m but often to 2.00m, if depth of bedroc
ness permitted the penetration. At most observation sites a 1:2
extract of samples taken at regular depths was prepared for fiel
ment of pH and electrical conductivity. In the very stony, volc
augering was often impractical and small pits were dug instead.

Land and soil characteristics were recorded on standard s
description forms following the methods applied by the Kenya Soil
In this way and with the help of the already existing soil profi
tions[1], a preliminary legend for the soil map could be establis
profile pits to a depth of 1.50m were dug at representative site
mapping unit. Detailed descriptions were made of the different
or layers according to the concepts of the Kenya Soil Survey whic
based on the "Guidelines for soil profile description" (FAO, 197
Disturbed soil samples were taken from every horizon for physica
analysis in the laboratories. A composite sample from the top 2
about 10 points around the soil pit was taken for fertility analy
Undisturbed ring samples were collected from some representative
determination of the bulk density and pF characteristics. In tota
were fully described and sampled, and 25 formerly described by So
also used. In addition 168 augerings were carried out. For the
observations see figure 8.

The final drafts of the 1:100,000 field maps on transparen
were handed over to the drawing room for photographical reductio
final scale of 1:250,000

2.3 LABORATORY METHODS

All soil samples were analysed at the National Agricultura
tories which employs the following methods:

(a) Standard analysis

All samples entering the laboratory received the following treatm

Preparation: Air drying, breaking up of aggregates by careful p
with pestle and mortar; sieving through 2mm sieve.
that passes the sieve is analysed.

Texture (limited pretreatment): No chemical treatments to remov
agents; shaking overnight with sodium hexametaphosp
sodium carbonate. Measurement of silt + clay (0-0.
clay (0-0.002mm) with a hydrometer ASTM 152H after
and 2 hours respectively. Silt fraction (0.002-0.0
obtained by difference and sand fraction (0.05-2mm
rest factor (Day, 1956).

1) extensive use was made of the information collected in the pr
KSS staff for the Exploratory soil map of Kenya (Sombroek et

pH and EC: pH and EC determined in a 1:2.5 soil-water suspension; for soils with an EC above 0.8 mmho/cm also a saturation extract is prepared for pH and EC determination.

pH-KCl: Measurement in a 1:2.5 soil-N KCl suspension.

CaCO3%: Determination of volume of CO2 after the addition of HCl, Scheibler method.

C% Walkley & Black method (Black, 1965, pp. 1372/6); no recovery factor is used.

N% Semi-micro Kjeldahl method (Black, 1965, pp. 1374/5), on A-horizons only.

Cation Exchange Capacity (CEC): The CEC is determined by two methods:

1. Successive leaching of the soil with N sodium acetate of pH 8.2, 95% ethyl alcohol and N ammonium acetate of pH 7.0. Determination of Na in the last leachate by flamephotometer (for most of the samples).
2. Saturation with N ammonium acetate of pH 7.0, washing with 95% ethyl alcohol and leaching with acidified sodium chloride. NH4 is determined by steam distillation and titration.

Exchangeable cations: Leaching of the soil with N ammonium acetate of pH 7.0. Determination of Na, K and Ca by flamephotometer and determination of Mg with the atomic absorption spectrophotometer. Saline soils are prewashed with 70% ethanol until free of Cl.

"Mass analysis" for available nutrients (composite topsoil samples only): Extraction of soil by shaking for 1 hour at a 1:5 ratio with 0.1N HCl/0.025N H2SO4. Determination of Ca, K, Na by flamephotometer, after an anion resin treatment for Ca. For Mg the same procedure as for exchangeable Mg. For P, the vanadomolybdophosphoric yellow method is followed. Mn is measured colorimetrically using phosphoric acid-potassium periodate for colour development (Mehlich et al, 1962).

P-Olsen (for composite topsoil samples): Extraction of soil by shaking for ½ hour with NaHCO3 solution (pH 8.5,0.5N). To the soil extract is added a reagent mixture of H2SO4, ammonium molybdate, ascorbic acid and antimony potassium/tartrate solution. The colour intensity is measured with a spectrophotometer or a colorimeter (Watanabe and Olsen, 1965).

All analyses were carried out in singlefold. Only in case of doubtful results repeats were done.

(b) *Standard calculations*

C/N: C% divided by N% (for A horizons only).

Base saturation: 100 x sum of exchangeable cations divided by CEC.

ESP: 100 x exchangeable sodium divided by CEC.

CEC-clay and CEC-carbon: The calculation of these two values is bas
the assumption that the clay mineralogy and organic mat
are uniform throughout the soil profile. For the calcu
a CEC-carbon is assumed, e.g. 500 me/100g or 5 me per 1
%C of each horizon is then deducted from the CEC-soil (
The remaining CEC is entirely attributed to the clay fr
By dividing the remaining CEC value of each horizon by t
corresponding clay content (texture limited pretreatmen
multiplying by 100 the CEC-clay for each horizon is obt
If these values decrease with a declining C% the calcul
is repeated with a higher value for the CEC-carbon, e.g.
600 me/100g. The opposite is done if the CEC-clay incre
with a decreasing C%. The calculation is repeated until
CEC-clay is approximately the same throughout the profil

(c) *Additional analyses for soil samples of representative profiles*

Texture "USDA": Chemical pretreatment with hydrochloric acid and hyd
peroxide; leaching with water and, after removal of exc
electrolyte, end-over-end shaking overnight with dispers
agent (see texture hydrometer). Determination of the s
fractions with sieves of 0.05, 0.10, 0.25, 0.50 and 1.0
Determination of the silt + clay (0-0.05mm) and clay fr
(0-0.002mm) by pipette method based on Stoke's law. Th
fraction (0.002-0.05mm) is obtained by subtracting the c
fraction from the silt + clay fraction. The percentage
calculated on the basis of the sum of all fractions rec
Due to technical problems in the laboratories no sand fr
were determined.

Bulk density: Determination of the oven dry (105°) weight of a soil
known volume (Richards, 1954).

pF-curve: Determination of moisture percentages at suctions of 0.
and 0.32 and pressures of 5.0 and 16.0 atmospheres (pF
2.5, 3.7 and 4.2 respectively). Undisturbed core sample
used for the three lowest pF-values, which were determi
kaolin boxes (van der Harst and Stakman, 1965). Distur
samples were used for the two highest pF-values, which
measured with standard moisture extraction equipment as
by Soil Moisture Co., Santa Barbara, California, U.S.A.
and van der Harst, 1962). To transfer the weight/weight
disturbed samples to weight/volume, the results were m
with the bulk density. Published data for bulk density
three lower pF-values are the average of 4-5 replicates
the two high pF values the average of 4 replicates was

Clay mineralogy: The fraction 0-0.002mm is separated after pretreatm
with hydrochloric acid, to make the suspension acid, an
peroxide followed by dispersion with sodium hexametaphos
sodium carbonate. X-ray diffraction analysis is carried
samples saturated with Mg and K, using standard clay mi
for semi-quantitative estimation. Peak/area ratios rat
peak/height ratios are considered. Techniques involvin
tion with ethylene glycol and heating to 500°C are emplo
well. The apparatus used is a Philips direct recording
diffractometer, using copper K α r radiations (Theisen
Hayward, 1962; Theisen and Bellis, 1964). For the dete
of palygorskite th

2.4 CARTOGRAPHIC METHODS

General

The survey area is completely covered by topographical maps at scale 1:250,000. The relevant parts of these sheets contain too much information to be used unchanged as a base map for the soil map of the same scale. Therefore generalization was necessary. The information required from each topographical sheet was distributed over the following separate plates:

- black plate (topographical names, administrative boundaries, etc.)
- brown plate (road system, quarries, etc.)
- purple plate (contour lines, surface characteristics, etc.)
- blue plate (drainage system)
- green plate ((National Parks and vegetation)

The black, brown and blue plates were generalized. Generalization of the purple plate was technically not feasible. Therefore a new plate was scribed, only showing the required information. The green plate was not used as some of the reserve boundaries shown were not gazetted or fixed.

The original number of 4 base map plates (see above) was reduced by one, by combining the generalized black and brown plates with the neatline, grid ticks and values and master surround into a new black plate. Moreover the new plate with contour line information was changed to a brown plate. Eventually the following 3 base maps were used for the printing of the soil map.

- black plate (topographical names, administrative boundaries, roads, neatline, etc.)
- brown plate (contour lines)
- blue plate (drainage system)

For the black plate two reversals were made, which were later combined with the soils plate.

Soil maps

For the technical information of the coloured and black-and-white soil maps (appendix 1 and 2 respectively) three plates were prepared:

- a soils plate, containing soil boundaries, symbols and legend,
- a screen plate, with screens for mountains, hills, soil depth classes, etc.,
- an agro-climatic zone plate, showing the agro-climatic zonation of the survey area.

After its completion, the soils plate was combined with the base map black plate (see above) to form a new and final soils plate (black).

In addition three plates for the basic colours yellow, red and blue were prepared for the coloured soil map (appendix 1). Combinations of different intensities of these three colours were used to colour the diffe-

CEC-clay and CEC-carbon: The calculation of these two values is base the assumption that the clay mineralogy and organic matt are uniform throughout the soil profile. For the calcul a CEC-carbon is assumed, e.g. 500 me/100g or 5 me per 1 %C of each horizon is then deducted from the CEC-soil (p The remaining CEC is entirely attributed to the clay fra By dividing the remaining CEC value of each horizon by t corresponding clay content (texture limited pretreatment) multiplying by 100 the CEC-clay for each horizon is obta If these values decrease with a declining C% the calcula is repeated with a higher value for the CEC-carbon, e.g. 600 me/100g. The opposite is done if the CEC-clay incre with a decreasing C%. The calculation is repeated until CEC-clay is approximately the same throughout the profil

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Texture "USDA": Chemical pretreatment with hydrochloric acid and hyd peroxide; leaching with water and, after removal of exce electrolyte, end-over-end shaking overnight with dispers agent (see texture hydrometer). Determination of the sa fractions with sieves of 0.05, 0.10, 0.25, 0.50 and 1.0 Determination of the silt + clay (0-0.05mm) and clay fr (0-0.002mm) by pipette method based on Stoke's law. The fraction (0.002-0.05mm) is obtained by subtracting the c fraction from the silt + clay fraction. The percentages calculated on the basis of the sum of all fractions reco Due to technical problems in the laboratories no sand fr were determined.

Bulk density: Determination of the oven dry (105°) weight of a soil known volume (Richards, 1954).

pF-curve: Determination of moisture percentages at suctions of 0.0 and 0.32 and pressures of 5.0 and 16.0 atmospheres (pF 0, 2.5, 3.7 and 4.2 respectively). Undisturbed core sample used for the three lowest pF-values, which were determin kaolin boxes (van der Harst and Stakman, 1965). Disturb samples were used for the two highest pF-values, which w measured with standard moisture extraction equipment as by Soil Moisture Co., Santa Barbara, California, U.S.A. and van der Harst, 1962). To transfer the weight/weight disturbed samples to weight/volume, the results were mul with the bulk density. Published data for bulk density three lower pF-values are the average of 4-5 replicates. the two high pF values the average of 4 replicates was t

Clay mineralogy: The fraction 0-0.002mm is separated after pretreat with hydrochloric acid, to make the suspension acid, and peroxide followed by dispersion with sodium hexametaphos sodium carbonate. X-ray diffraction analysis is carried samples saturated with Mg and K, using standard clay min for semi-quantitative estimation. Peak/area ratios rat peak/height ratios are considered. Techniques involving tion with ethylene glycol and heating to 500°C are employ well. The apparatus used is a Philips direct recording diffractometer, using copper K α r radiations (Theisen a Hayward, 1962; Theisen and Bellis, 1964). For the deter of palygorskite the clay fraction was not pretreated.

2.4 CARTOGRAPHIC METHODS

General

The survey area is completely covered by topographical maps at scale 1:250,000. The relevant parts of these sheets contain too much information to be used unchanged as a base map for the soil map of the same scale. Therefore generalization was necessary. The information required from each topographical sheet was distributed over the following separate plates:

- black plate (topographical names, administrative boundaries, etc.)
- brown plate (road system, quarries, etc.)
- purple plate (contour lines, surface characteristics, etc.)
- blue plate (drainage system)
- green plate ((National Parks and vegetation)

The black, brown and blue plates were generalized. Generalization of the purple plate was technically not feasible. Therefore a new plate was scribed, only showing the required information. The green plate was not used as some of the reserve boundaries shown were not gazetted or fixed.

The original number of 4 base map plates (see above) was reduced by one, by combining the generalized black and brown plates with the neatline, grid ticks and values and master surround into a new black plate. Moreover the new plate with contour line information was changed to a brown plate. Eventually the following 3 base maps were used for the printing of the soil map.

- black plate (topographical names, administrative boundaries, roads, neatline, etc.)
- brown plate (contour lines)
- blue plate (drainage system)

For the black plate two reversals were made, which were later combined with the soils plate.

Soil maps

For the technical information of the coloured and black-and-white soil maps (appendix 1 and 2 respectively) three plates were prepared:

- a soils plate, containing soil boundaries, symbols and legend,
- a screen plate, with screens for mountains, hills, soil depth classes, etc.,
- an agro-climatic zone plate, showing the agro-climatic zonation of the survey area.

After its completion, the soils plate was combined with the base map black plate (see above) to form a new and final soils plate (black).

In addition three plates for the basic colours yellow, red and blue were prepared for the coloured soil map (appendix 1). Combinations of different intensities of these three colours were used to colour the diffe-

rent soil units. The colour separation was carried out at the Netherla Soil Survey Institute (STIBOKA) in Wageningen, which also produced a pr print on "Kromecote" with a Cromalin Proofing machine.

The soil maps were finally printed in the Netherlands on an off-s printing machine. For the coloured soil map 7 plates were used, viz. bl plate (topography and soils), brown plate (contour lines), blue plate (d screen plate and the three plates for the basic colours. For the black- white soil map the same black, brown, blue and green plates were used t with the agro-climatic zones plate.

3. THE SOILS

3.1 PREVIOUS WORK

The FAO has carried out a rangeland survey for the range development in Marsabit District (FAO, 1971). On a 1:500,000 map landsystems are shown, subdivided into land units or landforms. Very brief information on geology, soils and vegetation is given for every landform. No soil analyses or profile descriptions were carried out. An example may illustrate the kind of information provided: Marsabit landsystem; basalts and volcanic ashes; very shallow, stony, brown, clay loam soils.

Bonarius (1975) has given some information on the soils of Mt. Marsabit, but his data are mainly based on the FAO survey. He adds some information on infiltration.

The Exploratory Soil Map of Kenya (1:1,000,000) gives already more information on the soils, although the scale of this survey does not permit details (Sombroek et al, 1982). Nevertheless, the boundaries of the mapping units are in general very accurate although sometimes the interpretation of the landforms differs from the opinion of the author of the present survey. Several soil profile descriptions with analytical data, made by Sombroek's team could be used for the present survey.

3.2 GENERAL PROPERTIES OF THE SOILS

The distribution of soil types is largely determined by physiography and parent material. Ten major physiographic units have been distinguished.

Most soils have favourable drainage conditions. Imperfectly to poorly drained soils occur in depressional areas. The organic matter content of most of the topsoils, is very low (ochric A-horizon), whereas only some volcanic mountain soils have humus rich surface horizons. Soil depth is strongly variable as is rockiness and stoniness, except in the sedimentary plains, floodplains and dunes where the soils are very deep and not stony.

- *Soils of the mountains*

The soils of the mountains on Basement System rocks in the south and south-west consist mainly of rock outcrops and shallow, stony, coarse textured soils. In places very deep, reddish sandy clay loam soils occur. Soil fertility is low.

The soils of the volcanic mountains vary from deep clays with an organic matter rich topsoil on Mt. Marsabit to clays with a highly variable stoniness and depth on Mt. Kulal. The soil fertility varies from moderate to high and physical properties are good.

- *Soils of the hills and minor scarps*

The soils of the hills on Basement System rocks in the south-west are identical to those of the adjacent mountains but without the deeper component.

The volcanic hills in the north-west have strongly calcareous, rocky and bouldery clay soils of variable depth. Soils on pyroclastic hills differ from the preceeding ones by depth (shallow) and by texture (sandy loam to clay).

- *Soils of the uplands*

The relatively flat parts of the high level uplands of the volc mountains have deep to very deep clay soils with favourable physical a chemical properties, although available K and P may be low. The soils uplands on Mt. Kulal show more profile development than those on Mt. M A part of the uplands on Mt. Marsabit has shallow to moderately deep s which are very stony and gravelly.

The soils of the low level uplands on Basement System rocks var deep to very deep with a texture of sandy loam to sandy clay loam to s rocky, very stony and gravelly, coarse textured soils. The deep soils on the nearly flat, lower slopes and the shallow ones on the tops and slopes.

- *Soils of the plateaus*

South-west of Marsabit, near the top of the mountain, deep to v deep, clay soils occur, which in places are very stony. They have fav physical and chemical properties. Further south imperfectly drained, tely deep, slightly calcareous, cracking clay soils occur which are ve bouldery and very stony. These soils have unfavourable physical and properties.

A general characteristic of the other soils of the volcanic pla (stepped, non-dissected and dissected) is the exceedingly bouldery and stony surface. They are all strongly calcareous and the texture is ma clay loam to clay. The soil itself is often stony but sometimes only of boulders is present. This is the case east of Maikona, west of Mt. and on the Ilaut lava plateau. Soil depth is variable. Sodic and sal soils occur on the lower slopes and in low lying places. The soils o plateaus east of Kargi are shallow, non-saline and non-sodic while on Ilaut lava plateau they are deep. North of Marsabit wind blown sands cover the surface. The amount of available nutrients in the soils of volcanic plateaus is in general sufficient.

- *Soils of the footridges*

The footridges on the southern slopes of Mt. Marsabit have mode deep to very deep soils with a texture of very bouldery and stony clay to clay. The soils have favourable physical and chemical properties.

The footridges of Mt. Kulal have an association of three soil depending on the topographical position. On the lower slopes, shallow moderately deep, strongly calcareous soils with a texture of very sto or very gravelly sandy loam to sandy clay occur. The soils are moder well supplied with available nutrients. The middle and upper slopes h shallow to deep soils with a very bouldery to stony clay loam to clay and favourable physical and chemical properties. On the upper slopes rately deep, dark coloured soils with a texture of very stony clay lo found. These soils are sufficiently supplied with available nutrients

- *Soils of the footslopes*

The soils of the footslopes of the hills and mountains on Base System rocks in the south and the south-west of the survey area often an association of coarse and medium textured soils. On the upper and

slopes deep soils with a texture of loamy sand to sandy loam occur. The soils are low in available Mg and K. On the lower slopes, very deep soils with a sandy loam to sandy clay loam texture occur. The soils of the footslopes of the Hafarin hills are more or less identical but slightly to moderately sodic.

South, west and north of Mt. Kulal, shallow to moderately deep, strongly calcareous soils of varying salinity and sodicity occur with a stony and very gravelly sandy loam to sandy clay texture. The footslopes of the Longipi hills have moderately deep to deep, strongly calcareous, moderately sodic soils with a texture of clay and a very rocky and bouldery surface. The footslopes of the Asie hills have a complex soil pattern. The dominating characteristics are the exceedingly stony surface, the salinity and the sodicity.

- *Soils of the piedmont plains*

The soils of the piedmont plains west of Mt. Kulal are moderately deep to deep, strongly calcareous, slightly sodic and have a texture of very stony to very gravelly sandy clay loam. They have an exceedingly stony surface. South-east of Mt. Kulal a complex pattern of moderately deep to very deep, sandy clay loam to sandy clay soils is present which vary in stoniness. The surface is always stony and the soils are moderately saline and strongly sodic. In a small part of the piedmont plains, strongly saline and strongly sodic, fine textured soils occur. In a few places at the foot of the Marsabit lava, deep to very deep, very stony, cracking clay loam to clay soils are found, which are often saline and sodic. The soils of the piedmont plains are generally sufficiently supplied with available nutrients.

- *Soils of the plains*

The soils of the volcanic plains north-east of Mt. Kulal are moderately deep to deep, strongly calcareous and strongly sodic. They have a texture of stony and/or gravelly, sandy clay loam to clay. Except for the sodicity, the soils have favourable chemical properties.

The soils of a part of the erosional plains consist of shallow, rocky and stony, sandy clay loam to sandy clay. The remaining part of the erosional plains is covered with very deep, strongly sodic soils with a coarse texture. The soils are low in available nutrients. In the slight depressions between the sandy soils, heavy, imperfectly drained, strongly sodic and slightly to moderately saline soils are present.

The sedimentary plains show a distinct gradient in certain soil characteristics. Going from south-west to north-east soil texture becomes finer and sodicity and salinity increase. The soils are all very deep and non-stony, except south of Kargi where a petrocalcic horizon occurs close to the surface.

In the southern and western parts of the plains an association of two soil types occur: coarse textured soils with a low fertility on slight elevations and medium to fine textured calcareous and slightly sodic soils with a moderate fertility in the shallow depressions. A major part of the northwestern and central part of the Hedad is occupied by very deep, slightly to moderately sodic soils with a texture of sandy loam to sandy clay loam and with a coarse textured topsoil.

The eastern and north-eastern parts of the sedimentary plains a occupied by very deep, slightly to strongly saline and sodic soils wit texture of sandy clay loam to sandy clay. These soils generally have soil of sand to loamy sand and an abrupt textural change to the B-hori The B-horizon has prismatic or columnar structures and a low permeabil In the most north-eastern and eastern parts the topsoil is partly remov wind and water action and redeposited on top of the profile by wind, t creating a mesorelief of 0.50 to 2.00m.

The soils of the lacustrine plains of the Chalbi desert consis poorly drained, very deep, strongly calcareous, strongly saline and so fine sandy loam to clay, while the soils of the lacustrine plains near Turkana are shallow, very stony, saline and sodic.

- *Soils of the floodplains*

The soils of the floodplains are very deep, calcareous, often so and in places saline and have a variable texture.

Along the Balesa river, slightly sodic, stratified soils are fo a coarse texture while in the Hedad, in places where the rivers spread the sodicity is non-existent and the topsoil consists of silt loam.

- *Soils of the dunes*

The dunes have somewhat excessively drained, very deep, moderat to strongly calcareous, strongly sodic sandy soils. The interdunal de have heavy, imperfectly drained, strongly calcareous, strongly saline strongly sodic soils.

3.3 DESCRIPTION OF THE SOIL MAPPING UNITS

3.3.1 Systematics and nomenclature

A brief description of every mapping unit is given in the lege the soil map (appendix 1). These descriptions reflect the characteri the subsoil (usually the B-horizon) above 100cm depth. Where the tex the topsoil differs significantly from the subsoil, it has also been i

The legend of the soil map is made up of three levels. On the level the major landforms are separated (physiography). On the second within each major landform, a further subdivision is made according to parent material (geology). On the lowest level a separation is made to different soil characteristics.

A code system is used to identify the soil mapping units. Each has a particular code which is composed of 2 letters for landform and material successively. The third code letter gives a subdivision of different mapping units according to differences in certain soil char The following codes are used:

Landforms

M Mountains (relief intensity 300-1000m, slopes from 8 to over 30%)

H Hills and minor scarps (relief intensity 50-300m, slopes from 8 to 30%)

U Uplands (relief intensity 10-100m), subdivided into:

U1 High level (altitude over 1000m, relief intensity 10-100m, slopes from 2 to over 6%)

U2 Low level (altitude around 570m, relief intensity 10-50m, slopes 1-8%)

L Plateaus, subdivided into:

Ls Stepped plateaus (relief intensity less than 10m, steps of 10-20m, slopes 0-3%)

Ln Non-dissected plateaus (relief intensity less than 20m, slopes 0-5%)

Ld Dissected plateaus (relief intensity 10-60m, slopes 1-10%)

R Footridges (dissected middle slopes of volcanic mountains, relief intensity 50-200m, slopes of crests 2-8%, slopes of valley sides over 16%)

F Footslopes (at the foot of mountains, hills and plateaus, relief intensity less than 10m, slopes 1-8%)

Y Piedmont plains (relief intensity less than 10m, slopes 0-2%)

P Plains, subdivided into:

Pv Volcanic plains (relief intensity 5-10m, slopes 0-2%)

Pn Non-dissected erosional plains (relief intensity less than 5m, slopes 0-2%)

Pd Dissected erosional plains (relief intensity 5-10m, slopes from 2 to over 16%)

Ps Sedimentary plains (relief intensity less than 5m, slopes 0-2%)

Pl Lacustrine plains subdivided into:

Pln Non-dissected lacustrine plains (relief intensity less than 5m, slopes 0-2%)

Pld Dissected lacustrine plains (relief intensity 5-20m, slopes 0-8%)

A Floodplains (relief intensity less than 5m, slopes 0-2%)

D Dunes (relief intensity 2-10m, slopes from 0 to over 16%)

Parent material (geology)

Metamorphic Rocks

F Gneisses, rich in ferromagnesian minerals, belonging to the Precambrian Basement System rocks.

U Undifferentiated Precambrian Basement System rocks. Includes also the unconsolidated Quaternary sediments derived from these rocks.

Igneous Rocks

P Pyroclastic rocks; mainly Quaternary tuffs.

V Various volcanic rocks of Tertiary/Quaternary age. Basalts are obviously dominating, but tuffs and ashes played a role in the soil formation as well. The sediments derived from these rocks are also included.

Sedimentary Rocks

S Sandstones, probably of Tertiary (Pliocene?) age.

A Undifferentiated unconsolidated alluvial deposits of varying origin (Quaternary)

X Unconsolidated sediments of varying origin; often a mixture of sedim derived from Basement System rocks and volcanic rocks (Quaternary).

Soils

P, p, K Depth class annotations (see table 6).
If the depth of the soil is variable within a mapping unit, only the shallowest depth class is indicated in the code.

Table 6. Key to depth classes

thickness soil in cm	code+ over rock	code+ over petrocalcic/ pisocalcic material	name
0-50	P	K	shallow
50-80	p		moderately deep
80-120			deep
more than 120			very deep

+ *If a complex of depth classes occurs within one unit only the code of shallowest depth class is indicated*

A Association of soils. An association consists of two or more soil ty occurring in a known systematic pattern which is not separable at the scale of the map.

C Complex of soils. A complex consists of two or more soil types occur in an unsystematic pattern which is not separable at the scale of the

1,2 The figures give a general subdivision between soils reflecting diffe in one or more soil characteristics.

Each soil mapping unit code is a combination of the relevant code landform, parent material and soils. In addition a letter is written u the soil mapping unit code to indicate the dominant slope class of the unit. This code is not indicated for the mountains and hills as they ha wide variety in slope classes. The codes used are given in table 7.

Table 7. Key to slope classes

slope %	slope class code	name of the macro relief
0-2	A	flat to very gently undulating
2-5	B	gently undulating
5-8	C	undulating
8-16	D	rolling
16-30	E	hilly

The terminology used in the legend of the soil map and in the foll descriptions of the soil mapping units follows closely the outline and de

tions given in the 1962 supplement of the "Soil Survey Manual" (Soil Survey Staff, 1951) and in the "Guidelines for Soil Profile Description" (FAO, 1977). The colour indications are based on the "Munsell Soil Color Charts" (Munsell Color Co., 1975).

The descriptions of colour, structure, consistence, salinity and sodicity refer to the subsoil, usually the B-horizon, unless specified otherwise. The colour indications are for moist conditions. It has to be mentioned that the soil during the survey in almost all the cases had to be moistened in order to get moist conditions. This may have had influences on some observations, especially the consistence, which very often appeared to be very friable. Under "natural" moist conditions this could well have been friable.

Where the texture of the topsoil differs significantly from the subsoil it is also described. This occurs only in the sedimentary plains or related land forms. The texture differences may be one or more classes, but generally the increase in clay content from the A to the B horizon is more than 10% or for the coarse textures the ratio of the clay content between the B and the A-horizon is two or more.

The degree of the salinity is mentioned in the descriptions and is based on the electrical conductivity of the saturation extract. Table 8 gives the key to the salinity classes.

Table 8. Key to salinity classes

ECe (mmho/cm)	name
0-4	non-saline
4-8	slightly saline
8-15	moderately saline
>15	strongly saline

The sodicity is based on the percentage exchangeable sodium of the cation exchange capacity (CEC at pH 8.2[1)]). Table 9 gives the key to the sodicity classes.

Table 9. Key to sodicity classes

ESP	name
0-6	non-sodic
6-10	slightly sodic
10-15	moderately sodic
>15	strongly sodic

The transitions between the A and B-horizon are in general clear, between the other horizons they are mostly gradual, unless mentioned otherwise.

The soils are classified according to the FAO/UNESCO legend of the "Soil Map of the World" (FAO/UNESCO, 1974). Small modifications in or additions to this system are developed by the Kenya Soil Survey (Siderius and van der Pouw, 1980). If applicable these have been used and marked with an asterisk (known as the "Kenyan concept").

1) for laboratory methods see chapter 2.3

The classification according to the "Soil Taxonomy" (Soil Survey Staff, is also given. Appendix 4 gives the correlation table between the two classification systems. In those places where it is not clear whether soil moisture regime is aridic or ustic, the author has made a choice ac ing to his best judgement. In the correlation table both possibilities mentioned.

3.3.2 Soils of the mountains

Mapping unit MUC

Total area : 14,200ha.

Location : This unit occurs mainly in the south-western part study area: the Ndoto mountains and some isolated tains in the south as well as an outlier of a moun in the west.

Agro-climatic zone: V and VI.

Parent material : Undifferentiated Basement System rocks; mainly mig gneisses with granites and some limestone bands (Pr cambrian).

Relief : Mountainous, with slopes from 8 (tops) to over 30

Erosion : Due to the predominantly deforested character of t fringe of the mountains, severe rainsplash and rill erosion occurs (further to the west, outside the s area, a more closed natural forest is present) whic led in many places to the exposure of bare rock.

Vegetation : Bare to deciduous bushland with *Acacia senegal* an *Boswellia* and *Commiphora* species as the most comm Grasses may occur as understory.

Land use : In the greater part of this unit heavy grazing pro occur. This results also in man-made fires which spread rapidly.

Surface rockiness : Very to extremely rocky.
stoniness

Soils, pattern : In general two soil types with their intergrades o Towards the west in the forest, a more strongly an weathered profile exists. About 60% of the mapped however, consists of bare rock. Of the two main co of the complex, only the description of the deep follows below. The description of the shallow com is similar to the HUP unit. Only the organic C% i higher on the mountains due to the higher rainfall.

Soils, general The deep to very deep, dark red to dark reddish br soils are well drained, have a texture of sandy cl and show an ABCR profile development with thin cla in the B-horizon. The soil gradually merges via a rock layer of about 70cm thick into the bedrock. indicates soil formation in situ.

colour : A-horizon: brown to strong brown (7.5YR 4/3). The varies, as the A-horizon is often eroded.
B-horizon: dark reddish brown to dark red (2.5YR

texture : A-horizon: sandy loam
B-horizon: sandy clay loam. The silt/clay ratio is 0.3. The clay ratio B/A horizon is 1.6.

structure : Porous massive, moderately to strongly coherent.

consistence : Slightly hard to hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is insufficiently supplied with available nutrients. The organic carbon content is about 0.6%. The CEC is 5 me/100g soil with a base saturation of 50%. The pH-H2O is 6.5 (pH-KCl: 5.4).

B-horizon: the CEC-soil is around 6.5me/100g, the base saturation ranges from 48 to 62%, increasing with depth. The CEC-clay is about 23me/100g.

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

Diagnostic properties : An ochric A-horizon and an argillic B-horizon with a base saturation of more than 50%.

Soil classification : *ferralo*-chromic LUVISOLS.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 1 (observation no. 66-11).

Mapping unit MV1

Total area : 14,300ha.

Location : On the top of Mount Marsabit.

Agro-climatic zone : III and IV.

Parent material : Basalts, tuffs and possibly also weathered ashes, although no positive reaction with NaF occurred (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. In places where the land is used for agriculture, moderate splash and rillwash to heavy gully erosion takes place.

Vegetation : Mist montane forest.

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

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

Soils, general : The soils are dark reddish brown and consist of well drained, deep to very deep, clay. They show a clear ABC profile development. Very clear clay skins are present in the B-horizon.

colour : A-horizon: dark brown (7.5YR 3/2).
B-horizon: dark reddish brown (5YR 3/3).

texture : Clay; in places very stony.

structure : A-horizon: moderate, coarse, crumbs.
B-horizon: strong, fine to medium, subangular t
angular blocky.

consistence : Slightly hard when dry, very friable when moist.
sticky and very plastic when wet.

Chemical properties : A-horizon: the soil is well supplied with availa
Ca and Mg. K and P are low. The organic carbo
content is around 4%. The CEC is around 30me/1
The base saturation is about 70%. The pH-H2O is
(pH-KCl: 4.5).

B-horizon: the CEC-soil is 27me/100g. The base
tion is around 50%. The pH-H2O is 4.8 (pH-KCl:
The CEC-clay is around 50me/100g.

Diagnostic properties: A mollic A-horizon and an argillic B-horizon wi
base saturation of more than 50%.

Soil classification : *luvic PHAEOZEMS, partly stony phase.*

For the description of a representative profile with analytical d
see appendix 3, profile description no. 2, observation no. 55-1).

Mapping unit MV2P

Total area : 17,200ha.

Location : This unit occurs on the top of Mount Kulal.

Agro-climatic zone : III and IV.

Parent material : Mainly basalts, in places also pyroclastic rocks
(tuffs) (Tertiary/Quaternary volcanics).

Relief : Mountainous, slopes from 8 to over 30%, irregul

Erosion : Under natural forest no signs of erosion were
observed. However, with an increasing use for p
with livestock, erosion increases.

Vegetation : Upland evergreen forest with *Cassipourea, Diospy*
Olea and *Teclea* species as the most common.

Land use : Natural forest reserve, wildlife. However, illeg
grazing by domestic animals takes place increasi

Surface stoniness/
rockiness : Rock outcrops and a stony to very stony surface
common.

Soils, general : This unit has dark reddish brown soils, in which
differences in soil depth, stoniness and rockine
occur within short distances. Deep soils are we
drained, have a clay texture and show an ABCR pr
development. Clay cutans are sometimes present
B-horizon. However, the increase in clay conten
not sufficient to fulfill the requirements for a
argillic B-horizon. Very shallow soils have an A
profile development. The C-horizon often consis
highly weathered basalts.

colour : The following description refers to a deep soil.
A-horizon: dark reddish brown (5YR 3/2).
B-horizon: dark reddish brown (5YR 3/3 to 5YR 3/

texture : Clay; in places very stony.

structure : Strong, very fine to medium, angular blocky.

consistence : Hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: low in potassium, moderate in phosphorus and high in calcium and magnesium. Organic C ranges from 2.9 to a maximum of 4%. The CEC of the soil is 38me/100g, with a base saturation of 85%. The pH-H2O is 6.4 (pH-KCl: 5.6).

B-horizon: the CEC-soil is about 22me/100g. The base saturation decreases with depth from 80 to 60%. The pH-H2O changes with depth from 6.3 to 6.0 (pH-KCl from 4.5 to 4.2). The CEC-clay is about 28me/100g.

Diagnostic properties: An ochric A-horizon and a cambic B-horizon.

Soil classification : *eutric CAMBISOLS, stony* and *lithic phase*.

For the description of a deep profile with analytical data see appendix 3, profile description no. 3 (observation no. 41-1).

Mapping unit MVC

Total area : 8,500ha.

Location : At the top of the Asie hills.

Agro-climatic zone : VII.

Parent material : Basalts, tuffs and ashes. Many small craters and cinder cones occur in this unit. (Quaternary volcanics).

Relief : Irregular, mountainous. Slopes from 8 to over 30%.

Vegetation : Deciduous shrubland with *Acacia mellifera/Commiphora* and *Euphorbia/Plectranthus* as the most common species.

Land use : Occasional grazing and browsing.

Soils, general : As the area is virtually inaccessible, and no observations could be made, the following description is a tentative one. It is assumed that this unit consists of a complex of somewhat excessively drained to well drained, shallow to deep, strongly calcareous, very stony, sandy loam to clay soils with a low organic matter content.

Mapping unit MPP

Total area : 2,500ha.

Location : The soils of this unit occur on the cinder cones near the tops of Mount Marsabit and the Asie hills. Some of the cones have a clear crater. Not all the cones could be separated on the map and occur as inclusions in other units.

Agro-climatic zone : Mainly III and IV, minor parts in V.

Parent material : Pyroclastic rocks, mainly tuffs (Quaternary volcanics).

Relief : Hilly to mountainous with straight to convex slopes from 16 to over 30%. The relief intensity of the cones and craters varies from 50 to 300m.

Erosion : Slight gully erosion may occur, but will be limi due to the highly permeable character of the roc

Vegetation : Variable, from forest to perennial grassland.

Land use : Near settlements, extensive grazing. In most pl the land use is limited to grazing and/or brows wildlife.

Surface stoniness/ rockiness : Rocky and very stony.

Soils, general : The somewhat excessively drained, shallow, dark brown to dark yellowish brown, very to extremely and gravelly loamy sand to sandy clay soils show ACR profile development.

colour : A-horizon: dark reddish brown (5YR 2.5/2) to dar yellowish brown (10YR 4/6).

texture : Very to extremely stony and gravelly, loamy sand sandy clay.

structure : A-horizon: strong, fine to medium granular to su blocky.

consistence : A-horizon: slightly hard when dry, friable when slightly sticky to sticky and slightly plastic w

Chemical properties : A-horizon: the soils are low in available K and high in available Ca and Mg. The organic C con is 2%. The CEC is 30me/100g with a base saturati 100%. The pH-H2O is 8.6 (pH-KCl: 7.6).

Diagnostic properties: Only an ochric A-horizon.

Soil classification : *eutric REGOSOLS, stony* and *lithic phase*.

For the description of a representative profile with analytical d see appendix 3, profile description no. 4 (observation no. 55-20).

3.3.3 Soils of the hills and minor scarps

Mapping unit HUP

Total area : 11,700ha.

Location : This unit occurs in the south-western part of the survey area. The hills can be regarded as weather rests (outlier inselbergs) of the Ndoto mountain

Agro-climatic zone : Mainly VI, some hills occur in zone VII.

Parent material : Mainly migmatitic gneisses and granites with loca limestone bands of the Basement System rocks (Pre cambrian).

Relief : Hilly, with slopes ranging from 8 to over 30%. tops of the hills are often rounded.

Erosion : Severe rain splash, rillwash and gully erosion ha resulted in the exposure of the bare rock in many

Vegetation : Bare for the greater part, the rest has annual gr *Commiphora* shrubs.

Land use : Heavy grazing.

Surface stoniness rockiness : Extremely rocky and very stony

Soils, general : About 70% of the area consists of bare rock, the rest is occupied by excessively drained, shallow, dark brown, stony to very stony, loamy sand to sandy loam soils with an ACR profile development. In places the soils are strongly calcareous.

colour : Dark brown (7.5YR 3/4).

texture : Stony to very stony, loamy sand to sandy loam.

structure : Weak, medium to coarse, subangular blocky.

consistence : Soft to hard when dry, very friable when moist, slightly sticky and non-plastic when wet.

Chemical properties : AC-horizon: the soils are low in available potassium, low to moderate in calcium and magnesium (except in calcareous places) but high in available phosphorus. The organic C% is about 0.3. The CEC-soil is about 10me/100g with a base saturation of 100%. The pH-H2O is 7.8 (pH-KCl: 6.9). The CEC-clay is about 50me/100g.

Diagnostic properties: The soils are limited in depth by continuous, coherent hard rock.

Soil classification : *eutric LITHOSOLS, stony phase* and *ROCK OUTCROPS*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 5 (observation no. 66-10).

Mapping unit HVP

Total area : 9,000ha.

Location : This unit comprises the stepped escarpment near Lake Turkana and the Longipi Hills west of Mt. Kulal.

Agro-climatic zone : VII.

Parent material : Various volcanic rocks of which basalts are the most obvious. However, pyroclastic materials have been mixed into the soils as well (Quaternary volcanics).

Relief : Hilly with irregular slopes from 8 to over 30%. Along faults very steep slopes may occur.

Erosion : Slight gully erosion may occur.

Vegetation : *Cenchrus* annual grassland with *Commiphora* shrub and *Indigofera/Sericocomopsis* dwarfshrub overstory.

Land use : Seasonal grazing.

Surface rockiness/ stoniness : Rocky and exceedingly bouldery (basalts).

Soils, general : The soils are somewhat excessively drained, shallow to deep, dark reddish brown, strongly calcareous and show an ABCR profile development. They consist of rocky and stony clay. The soils show a resemblance with the soils of unit FV2p but due to the occurrence on slopes the drainage is more rapid. Also the rockiness and stoniness is greater. (For the description of unit FV2p see chapter 3.3.7).

Mapping unit HP1P

Total area : 1,600ha.

Location : Near the top of Mount Marsabit.

Agro-climatic zone : V and VI.

Parent material : Pyroclastic rocks (Quaternary volcanics).

Relief : Hilly, with slopes ranging from 8 to over 30%.

Erosion : In grazed areas gully erosion occurs.

Vegetation : Shrubs and grasses.

Land use : Often grazing.

Soils, general : The soils are identical to the soils of unit MP (see chapter 3.3.2).

Mapping unit HP2P

Total area : 11,200ha.

Location : This unit, occurring on cinder cones and parasi craters, can be found on the Marsabit lava plate the Asie Hills and the Longipi Hills. Some are present in the middle and lower slopes of Mt. M but are too small to be mapped.

Agro-climatic zone : VII, few hills may fall into zone VI.

Parent material : Pyroclastic rocks, mainly tuffs (Quaternary volc

Relief : Hilly, with slopes ranging from 8 to over 30%.

Erosion : Due to the often bare character of the hills, wa erosion processes may occur. However, due to th permeability of the rock the erosion processes ar severe.

Vegetation : This unit often supports no to very little vegeta (shrubs and annual grasses).

Land use : Occasionally seasonal grazing.

Surface rockiness/ stoniness : Rocky and exceedingly stony.

Soils, general : The excessively drained, shallow, reddish brown t brown, strongly calcareous, non to slightly sodic very stony and gravelly, sandy loam to clay soils a weak ACR profile development.

colour : A-horizon: reddish brown to brown (5YR 4/4 to 7.5 4/4).

texture : Very stony and gravelly sandy loam to clay.

structure : AC-horizon: weak, fine to medium subangular blocky

consistence : AC-horizon: soft when dry, very friable when moist slightly sticky and plastic when wet.

Chemical properties : AC-horizon: the soils are well supplied with avail Ca and Mg, low to moderate in available P and low available K. The organic C content is around 0.3 The CEC ranges from 20 to 30me/100g. The base sat tion is 100%. The pH-H2O is 7.6 (pH-KCl: 7.0). T ESP has a maximum of 8.

Diagnostic properties: Only an ochric A-horizon.

Soil classification : *calcaric REGOSOLS, stony, lithic* and *sodic phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 6 (observation no. 43-14).

3.3.4 Soils of the uplands

(1) Soils of the high level uplands

Mapping unit U1V1

Total area : 1,900ha.

Location : These soils occur on some relatively flat parts on the southern and northern slopes of Mount Kulal.

Agro-climatic zone : IV.

Parent material : Various volcanic rocks, mainly basalts and pyroclastics. Some volcanic ashes may have been mixed into the soil as well (Tertiary/Quaternary volcanics).

Relief : The small areas occupied by this unit are gently sloping to sloping with slopes from 2-8% (slope class BC).

Erosion : Near the villages severe splash and rill erosion occurs. Under grazed bushland moderate splash erosion is present.

Vegetation : Evergreen to semi-deciduous bushland, with *Carissa, Euclea* and *Rhus-Juniperus* species as the most common. Near Gatab bushed grassland.

Land use : Intensive grazing is the general land use practised. Near Gatab heavy grazing takes place. Some small cultivated plots are present.

Surface stoniness : The surface is non to slightly stony (rounded basalts).

Soils, general : The soils of this unit are well drained, deep to very deep, dark reddish brown, with a texture of clay and an ABCR horizon sequence. The B-horizon has in places shiny pedfaces and well developed clay skins.

colour : A-horizon: dark reddish brown (2.5YR 2.5/4)
B-horizon: dark reddish brown (2.5YR 3/4).

texture : Clay; in places very stony.

structure : Moderate to strong, medium, subangular to angular blocky.

consistence : Hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: low in available potassium and phosphorus, moderate for calcium and high for magnesium. The organic C is about 2.5%. The CEC of the soil is about 30me/100g with a base saturation of 85%. The pH-H2O ranges between 5.7 and 6.6 (pH-KCl is about 5.1).

B-horizon: the CEC-soil is 26me/100g with a base saturation of 85%. The pH-H2O is about 6.9 (pH-KCl: 5.5). The organic C content of this horizon is decreasing from 1.6% at the top to 1% at 1m depth. The CEC-clay is

Diagnostic properties: An ochric A-horizon and an argillic B-horizon wi
reddish colours and some shiny ped surfaces.

Soil classification : *eutric NITOSOLS* and *chromic* LUVISOLS*, partly st
phase.

For the description of a representative profile of a *chromic* LUVI*
with analytical data see appendix 3, profile description no. 7 (observati
no. 41-2).

Mapping unit U1V2

Total area : 1,600ha.

Location : Around Marsabit town. The area has wider extensi
to the east, outside the survey area.

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

Parent material : Basalts and pyroclastics. (Tertiary and Quaterna
volcanic rocks).

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

Erosion : Splash and rillwash to slight gully erosion. Ca
tracks are causing rill erosion.

Vegetation : Perennial grassland with shrubs. In places clear
for cultivation.

Land use : Mainly extensive grazing. In places plots are cu
vated.

Surface stoniness : Non to fairly stony (basalts).

Soils, general : The soils are well drained, deep to very deep, da
reddish brown, have a texture of clay and show a
profile development. In places clay cutans can b
observed in the B-horizon.

colour : A-horizon: dark reddish brown (2.5YR 3/4 to 5YR 3
B-horizon: dark reddish brown (2.5YR 3/5 to 5YR 3

texture : Clay; in places stony.

structure : A-horizon: strong, fine to medium, subangular blo
B-horizon: weak, coarse prismatic breaking into m
rate, fine to medium angular to subangular blocky.

consistence : Slightly hard when dry, very friable when moist,
sticky and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with availa
Ca and Mg, P is low and K is low to moderate. Th
organic C content ranges from 1.9 to 2.5%. The CE
ranges from 17 to 28me/100g. The base saturation
around 80%. The pH-H2O is 6.8 (pH-KCl: 5.7).

B-horizon: the CEC is around 25me/100g with a bas
saturation around 80%. The pH-H2O is 6.8 (pH-KCl
5.7). The CEC-clay is around 45me/100g.

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

Diagnostic properties: An ochric A and a red cambic B-horizon.

Soil classification : *chromic CAMBISOLS*, partly *stony phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 8 (observation no. 55-17).

Mapping unit U1V3P

Total area : 5,500ha.

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

Agro-climatic zone : V.

Parent material : Various volcanic rocks, basalts, tuff and ashes (Tertiary/Quaternary).

Relief : Irregular with gentle to steep slopes. Slopes from 2 to over 16% (slope class BCD). Many pyroclastic hills occur within this unit.

Erosion : Heavy (splash and rillwash) 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, general : The soils are well drained, shallow to moderately deep, dark reddish brown, moderately to strongly calcareous, have a texture of very stony and gravelly clay loam to clay and show a not very well developed ABCR profile development.

colour : Dark reddish brown (5YR 3/3).

texture : Very stony and gravelly clay loam to clay.

structure : Weak, fine to medium, subangular blocky.

consistence : Slightly hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is moderately well to well supplied with available nutrients. The organic C content is 0.5 to 1.4%. The CEC is 21me/100g with a base saturation of 80-100%. The pH-H2O is 6.6 (pH-KCl: 5.8).

B-horizon: the CEC is 28me/100g; the base saturation is 100%. The pH-H2O is 7.4 (pH-KCl: 6.5). The CEC-clay is around 75me/100g.

Diagnostic properties: An ochric A-horizon and a cambic B-horizon.

Soil classification : *eutric CAMBISOLS*, *stony* and partly *lithic* or *petric phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 9 (observation no. 55-14).

(2) Soils of the low level uplands

Mapping unit U2F1

Total area	:	15,000ha.
Location	:	Near Korr and in the Elgess area in the southern pa of the survey area. This unit occurs on the lower slopes of the upland areas.
Agro-climatic zone	:	VII.
Parent material	:	Gneisses rich in ferromagnesian minerals (hornblend biotite, amphibole, garnet) belonging to the Basem System (Precambrian).
Relief	:	Nearly flat, slopes from 0 to 2% (slope class A).
Erosion	:	Strong splash and rillwash and slight to moderate gully erosion occur. Deflation takes place as well. Small sand dunes (obstacle dunes) especially in the Korr area are being formed in many places.
Vegetation	:	Bushed dwarf shrubland. The main species are *Duosp eremophilum, Acacia reficiens* and *Commiphora* species The condition of the vegetation is very poor due to the intense use.
Land use	:	Very heavy grazing by livestock. Around Korr severe over-use.
Surface stoniness	:	Non stony.
Soils, general	:	The soils are well drained, deep to very deep, red to yellowish red, with a texture of sandy loam to sandy clay loam. They show a clear ABC profile development. Clay cutans are present in the B-horizon. In places the soils are strongly calcareous and/or slightly so
colour	:	A-horizon: dark red (2.5YR 3/6) to yellowish red 5YR 4/6). B-horizon: dark red (2.5YR 3/6).
texture	:	Sandy loam to sandy clay loam; in places fine gravell
structure	:	Strong, coarse prismatic breaking into weak, coarse, angular blocky.
consistence	:	Hard when dry, very friable when moist, sticky and plastic when wet.
Chemical properties	:	A-horizon: the soils are moderately well supplied wit available nutrients, but low in available phosphorus. The organic C content ranges between 0.2 and 0.4%. The CEC is about 15me/100g. The base saturation is 100%. The pH-H2O is 7.8 (pH-KCl: 6.6). B-horizon: the CEC soil is 24me/100g. The base satur tion is 100%. The pH-H2O is 7.5 (pH-KCl: 6.0). In a few low lying places the soils are slightly sodic and moderately saline in the deeper subsoil. CEC-clay is 75me/100g.
Clay mineralogy	:	Montmorillonite, illite and kaolinite are present.
Diagnostic properties:		A weak ochric A-horizon, an argillic B-horizon and an aridic soil moisture regime.

Soil classification : *luvic YERMOSOLS, partly saline phase.*

Remark : Inclusions of soils developed on coarse textured alluvial sediments are present in the mapping unit.

For the description of a representative profile with analytical data see appendix 3, profile description no. 10 (observation no. 67-17).

Mapping unit U2FA

Total area : 6,200ha (slope class B), 8,500ha (slope class BC).

Location : This unit occurs in the Korr and Elgess area in the southern part of the survey area, on the upper and middle slopes of the uplands.

Agro-climatic zone : VII.

Parent material : Gneisses rich in ferromagnesian minerals (hornblende, biotite, amphibole, garnet) belonging to the Basement System (Precambrian).

Relief : Gently undulating, slopes from 2 to 5% (slope classes B and BC). The slopes of some isolated hills may reach 20%. Slope length is about 50-200 metres.

Erosion : Strong splash, rillwash and slight gully erosion and deflation as well have resulted in a desert pavement. The actual erosion processes are hampered by this pavement. However small sand dunes (obstacle dunes) are being formed in many places.

Land use : Very heavy grazing by livestock. Around Korr, severe over-use.

Surface stoniness : The surface is slightly to exceedingly stony. Angular and subangular gravel and stones form a desert pavement. The material consists mainly of quartz with some feldspars.

Soils pattern : The soils of this unit form an association of two soil types:

(a) Soils of the middle slopes:

Soils, general : The soils of the middle slopes are well drained, moderately deep, red to dark red, have a texture of stony and/or very gravelly, sandy loam to sandy clay loam and show a clear ABCR profile development.

colour : A-horizon: dark red to reddish brown (2.5YR 4/4; 2.5YR 3/6; 5YR 4/4).
B-horizon: red to dark red (2.5YR 4/6 to 2.5YR 3/6).

texture : Stony and/or very gravelly, sandy loam to sandy clay loam. The sand fraction is coarse and badly sorted and might form up to 70% of the total fine earth.

structure : Moderate, fine to medium, subangular blocky.

consistence : Slightly hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are moderately well supplied with available nutrients. The organic C content ranges between 0.1 and 0.3%. The CEC is 14me/100g with a base saturation of 100%. The pH-H2O is 7.8 (pH-KCl: 6.8).

: B-horizon: the CEC-soil is 14me/100g. Base satura is 100%. The pH-H2O is 7.6 (pH-KCl: 6.7). CEC-cl is 70me/100g.

Diagnostic properties: A very weak ochric A-horizon, an aridic moisture regime and a cambic or an argillic B-horizon.

Soil classification : *luvic* and *haplic YERMOSOLS, stony, petric* and par *stone-mantle* phase.*

(b) Soils of the tops and upper slopes:

Soils, general : The soils of the tops and upper slopes are somewha excessively drained, shallow, red to dark red and l a clear ABCR profile development. These soils are expected to have similar physical and chemical cha teristics as the soils of the middle slopes. They however very stony and gravelly and fairly rocky. texture is loamy sand to sandy loam. Therefore th CEC will be somewhat lower than that of the other component. No samples for laboratory analysis were taken from this soil unit.

Diagnostic properties: A coarse texture and characteristics of a cambic B horizon.

Soil classification : *cambic ARENOSOLS, stony* and *lithic phase.*

Remark : Some isolated hills rise above the uplands, especia in the Korr area. They are however small and the soils do not differ much from the rest of the unit.

For the description of a representative profile a *haplic YERMOSOL* wi analytical data see appendix 3, profile description no. 11 (observation no. 54-21).

3.3.5 Soils of the plateaus

(1) Soils of the stepped plateaus

Mapping unit LsV1P

Total area : 3,900ha.

Location : 35 to 50km north of Marsabit.

Agro-climatic zone : VII.

Parent material : Various volcanic rocks, mainly basalts and pyroclast materials (Tertiary/Quaternary). The NaF test was negative.

Relief : Nearly flat, slopes of 1-2% (slope class A).

Erosion : Due to the occurrence of a desert pavement combined with very slight slopes no actual erosion occurs.

Vegetation : Annual grassland *(Aristida/Enneapogon)* with *Indigofe* dwarf shrubs. The vegetation cover is very low.

Land use : Occasionally extensive grazing by livestock.

Surface stoniness : Exceedingly stony and exceedingly gravelly. Stones and gravel consists of subangular basalts and volca bombs.

Soils, general : The soils are somewhat excessively drained, shallow, moderately deep, yellowish red, strongly calcareous, moderately sodic and have a texture of very stony and gravelly loamy sand to sandy loam. They show a vague ACR profile development.

colour : AC-horizon: yellowish red (5YR 4/6).

texture : Very stony and gravelly, loamy sand to sandy loam.

structure : AC-horizon: massive, slightly coherent.

consistence : AC-horizon: soft when dry, very fraible when moist, slightly sticky and slightly plastic when wet.

Chemical properties : AC-horizon: the soil is well supplied with available nutrients, especially P is high. The organic C content is 0.08%. The CEC is 9.1me/100g and the base saturation is 100%. The pH-H2O is 8.8 (pH-KCl: 7.6). The ESP is 11.

Diagnostic properties: Only an ochric A-horizon.

Soil classification : *calcaric REGOSOLS, stony, sodic* and *petric phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 12 (observation no. 43-12).

Mapping unit LsV2

Total area : 6,400ha.

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). A positive reaction with NaF was observed.

Relief : Nearly flat, slopes 0-2%, but interrupted by cinder cones with steep slopes (slope class AB).

Erosion : Slight splash and rillwash erosion. However with increasing grazing pressure, erosion will increase as well.

Vegetation : Evergreen to semi-deciduous bushland with *Acacia hockii /Dichrostachus/Harrisonia* as the main species. Perennial grasses form the understory.

Land use : Grazing by pastoralists.

Surface stoniness : Non to fairly stony (basalts).

Soils, general : The soils are well drained, deep to very deep, dark reddish brown, have a texture of clay (in places very stony) and show a clear ABC profile development. Clay cutans are present in the B-horizon. The increase in clay content is however not always sufficient to fulfil the requirements for an argillic B-horizon.

colour : A-horizon: dark reddish brown (5YR 3/3).
B-horizon: dark reddish brown (2.5YR 3/5).

texture : Clay; in places very stony.

structure : Weak, medium to coarse, angular blocky.

consistence : Hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is moderately well supplied with available nutrients, only phosphorus is low. The organic C content is about 1%. The CEC is about 1 /100g with a base saturation of over 60%. The pH is 6.8 (pH-KCl: 5.6).

B-horizon: the CEC is about 17me/100g with a base saturation of 75%. The pH-H2O is 6.6 (pH-KCl: 5.9). The CEC-clay is around 30me/100g.

Clay mineralogy : Metahalloysite is dominant. Montmorillonite occurs well.

Diagnostic properties: An ochric A-horizon and an argillic/cambic B-horizon with reddish colours.

Soil classification : *chromic* LUVISOLS* and *chromic* CAMBISOLS* partly stony *phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 13 (observation no. 55-16).

Mapping unit LsV3p

Total area : 23,200ha.

Location : South of Marsabit at the southern limit of the survey area.

Parent material : Various volcanic rocks; basalts and pyroclastics (Tertiary/Quaternary).

Agro-climatic zone : Mainly zone VI. The northeastern part lies in zone V.

Relief : Gently sloping with straight, regular slopes (with steps). Slopes from 1-5% (slope class AB).

Erosion : Slight to moderate splash and rillwash erosion occurs.

Vegetation : Deciduous shrubland with *Acacia mellifera* as the most dominant species. Perennial grasses form the understory.

Land use : Moderate grazing with livestock.

Surface stoniness : Very to exceedingly stony, consisting of angular and subangular basalts.

Soils, general : The soils are imperfectly drained, moderately deep, dark reddish brown, slightly calcareous and cracking with a texture of very bouldery and very stony clay. They have a clear ABCR profile development. Slickensides are present in the B-horizon.

colour : Dark reddish brown (5YR 2.5/2).

texture : Very bouldery and very stony clay.

structure : A-horizon: strong, fine, crumb.
B-horizon: weak to moderate, coarse angular blocky.

consistence : Friable to firm when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is well supplied with available Ca and Mg. Available K and P are very low. The organic C content is about 0.8. The CEC is 37me/100g and the base saturation is 100%. The pH-H2O is 8.8 (pH-KCl: 7.6).

: B-horizon: the CEC is 35me/100g. The base saturation is 100%. The pH-H2O is 8.4 (pH-KCl: 7.2). The CEC is around 65me/100g.

Diagnostic properties: Deep, wide cracks, more than 35% clay, slickensides and reddish colours.

Soil classification : *chromic VERTISOLS, stony* and *petric phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 14 (observation no. 55-19).

Mapping unit LsVC1

Total area : 282,300ha.

Location : This unit covers the major part of the Marsabit lava.

Agro-climatic zone : Mainly zone VII, only a relatively small part higher on the mountain lies in zone VI.

Parent material : Basalts, tuffs and ashes (Tertiary/Quaternary volcanics). The NaF test was positive in every observation.

Relief : Gently sloping, with straight, regular slopes of 1-5% (slope class AB), interrupted by steps and small pyroclastic hills.

Erosion : Where the soil is not completely covered with gravel and/or stones, strong splash and rillwash erosion occurs. Slight deflation takes place in places as well.

Vegetation : Bushed dwarf shrub, short grassland with *Aristida/Enneapogon spp., Acacia reficiens* and *Indigofera spinosa* as the main species.

Land use : In the remote areas only occasional grazing takes place. In the vicinity of villages heavy grazing with livestock is practised.

Soils, pattern : Due to the complex nature of the results of various volcanic explosions and eruptions no clear pattern of soil units could be mapped at the scale of this survey. Besides the areas which are occupied by rock outcrops and recent lava flows, two soil types could be distinguished, which occur in a complex pattern.

(a) First component of the complex:

Surface stoniness : Exceedingly stony and/or gravelly. Stones and gravel consist of various lava rocks and small carbonate concretions.

Soils, general : Somewhat excessively drained to well drained, shallow to moderately deep, reddish brown to dark brown, strongly calcareous soils with a very stony and gravelly, sandy loam to sandy clay loam texture. They lie in places over petrocalcic material. In places the soils are slightly sodic below 20cm. The soils have a weak ACR of ABCR profile development.

colour : Reddish brown to dark brown (5YR 4/4 to 7.5YR 4/2).

texture : Very stony and gravelly, sandy loam to sandy clay loam.

structure : Weak, fine to medium, subangular blocky.

consistence : Soft when dry, very friable when moist, slightly st and slightly plastic to sticky and plastic when we

Chemical properties : The soils are moderately well supplied with availab Mg and P, well supplied with Ca, but low in K. The organic C content varies between 0.1 and 0.5%. The soil is about 25me/100g. The pH-H2O is 8.1 (pH-KCl 7.2). In places, below 20cm depth, the soils are slightly sodic with ESP values up to 8. The CEC-cla ranges between 75 and 200me/100g (this high value c be caused by volcanic ashes).

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

Diagnostic properties: No diagnostic horizons other than a very weak ochri horizon or a cambic B-horizon in combination with a aridic moisture regime.

Soil classification : *calcaric REGOSOLS* and *haplic YERMOSOLS, stone-mantle stony* and partly *petrocalcic* and/or *petric phase*.

For the description of a representative profile of a *calcaric REGOSO* with analytical data see appendix 3, profile description no. 15 (observation 55-12).

(b) Second component of the complex:

Surface stoniness : Exceedingly bouldery or exceedingly stony; consistin of subangular basalt, often with a desert varnish.

Soils, general : The soils are well drained, very deep, dark reddish brown, strongly calcareous, slightly to strongly sal and slightly to strongly sodic. They have a texture loam to clay and a clear ABC profile development. I the north a gypsic horizon was observed.

colour : A-horizon: dark reddish brown (2.5YR 3/5-5YR 3/4). B-horizon: dark reddish brown (2.5YR 3/4-5YR 3/4).

texture : Loam to clay, in the topsoil extremely bouldery or s The subsoil is in places slightly gravelly.

structure : Weak, medium to coarse angular blocky to massive, mo rately coherent.

consistence : Slightly hard when dry, very friable when moist, sti and plastic when wet.

Chemical properties : A-horizon: the soils are moderately well to well supplied with available nutrients. Available K is l The organic C content ranges between 0.2 and 0.3%. CEC ranges between 10 and 30me/100g. The base satura tion is 100%. The pH-H2O is about 8.2 (pH-KCl: 7.0). In places moderately saline (ECe of 14mmho/cm) and slightly sodic (ESP around 7).

B-horizon: the CEC ranges from 20 to 30me/100g and th base saturation is 100%. The pH-H2O is about 8.0 (pH-KCl: 7.0). The CEC-clay ranges from 75 to 100me 100g. The ECe ranges between 2 and 18mmho/cm and th ESP between 8 and 50.

Diagnostic properties: A very weak ochric A-horizon, an aridic moisture regime and a cambic B-horizon, partly with a gypsic horizon.

Soil classification : *haplic* and partly *gypsic YERMOSOLS, boulder-mantle*, saline* and *sodic phase*.

For the description of a representative profile of a *haplic YERMOSOL* with analytical data see appendix 3, profile description no. 16 (observation no. 55-13).

Mapping unit LsVC2

Total area : 90,800ha.

Location : This unit occurs north of Marsabit on the lower to middle part of the Marsabit lava plateaus.

Agro-climatic zone : VII.

The soils of this unit are essentially the same as the soils of unit LsVC1. They are however partly or completely covered with an irregular sand layer of varying thickness (a few mm to more than 1m). The sand is often accumulated behind stones and small hills in the form of small obstacle dunes. Some movement of the sand still occurs. In places the sand is well sorted: M50 is 350 micron, maximum grain size: 600 micron. The sand is mainly composed of quartz mixed with some volcanic minerals like olivine and augite. The sands originate probably from the eastern side of Mt. Marsabit as no source is known on the Marsabit lava. Also the satellite images show clearly a striped pattern from a southeastern-northwestern direction in the east, to a more east-west direction in the west of the Marsabit area which coincides with the prevailing winds.

Mapping unit LsXp

Total area : 4,800ha.

Location : North of Marsabit, halfway to Maikona.

Agro-climatic zone : VII.

Parent material : Cover sands mixed with ashes over basalts (Pleistocene).

Relief : Nearly flat to very gently undulating (slope class A); in places small (active) sand dunes occur.

Erosion : Some deflation with redeposition of sand occurs.

Vegetation : Annual and perennial grassland with *Indigofera spinosa* and *Acacia* shrubs. The vegetation cover is very low.

Land use : Occasional grazing with livestock.

Surface stoniness : Bouldery or stony to exceedingly stony, consisting of subangular to angular basalt.

Soils, general : The soils are somewhat excessively drained, moderately deep to deep, reddish brown, moderately calcareous and moderately sodic. The texture is very bouldery and/or very stony sand. The soils show no profile development.

colour : Reddish brown (5YR 4/4).

texture : Very bouldery and/or very stony sand with a median of 300 micron and a maximum grain size of 1400 micron.

structure : Structureless; single grain.

consistence : Loose when dry and moist, non-sticky and non-plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with availa Ca and Mg, high in available P but low in available The organic C content is about 0.1%. The CEC is 3. 100g. The pH-H2O is 9.4 (pH-KCl: 8.0). The ESP is

Diagnostic properties: A very weak ochric A-horizon and a coarse texture.

Soil classification : *calcaric REGOSOLS, bouldery*, sodic* and partly petr *phase.*

(2) Soils of the non-dissected plateaus

Mapping unit LnVl

Total area : 39,100ha.

Location : Ramatrobi lava, east of Maikona.

Agro-climatic zone : VII.

Parent material : Mainly basalts and ashes (Tertiary/Quaternary volca

Relief : Nearly flat, slopes 0-2% (slope class A).

Erosion : None.

Vegetation : Very low cover of annual grasses with *Aristida* and *Enneapogon* as the most common species.

Land use : Slight grazing with livestock.

Surface stoniness : Exceedingly bouldery and/or exceedingly stony, consi ing of subangular basalt.

Soils, general : The soils are well drained, deep to very deep, dark reddish brown, strongly calcareous, slightly to mode tely saline and strongly sodic. They have a texture loam to clay loam and have an ABC profile developmen

colour : Dark reddish brown (5YR 3/4).

texture : Loam to clay loam, in places very stony.

structure : Porous massive, moderately coherent, to weak, medium angular blocky.

consistence : Slightly hard when dry, very friable when moist, sti and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available Ca and Mg, but P and K are low. The organic C conte is around 0.1%. The CEC is 11me/100g with a base saturation of 100%. The pH-H2O is 8.8 (pH-KCl: 7.6). The ESP is 18.

B-horizon: the CEC is 11me/100g. The base saturati is 100%. The pH-H2O is 8.5 (pH-KCl: 7.4). From 30c depth the soil is slightly to moderately sodic. The ECe is 8.5mmho/cm. The ESP is 46 between 30 and 60c depth. The CEC-clay is around 30me/100g.

Clay mineralogy : From 15-30cm depth micas, palygorskite and traces of kaolinite are present. From 30-60cm, palygorskite, illite and small amounts of montmorillonite and kaoli nite are shown by X-ray analysis.

Diagnostic properties: A very weak ochric A-horizon, a cambic B-horizon (and an aridic moisture regime).

Soil classification : *haplic YERMOSOLS, boulder-mantle*, saline, sodic* and partly *stony phase*.

Inclusions : Especially towards Maikona inclusions of unit LsVC2 may occur.

For the description of a representative profile with analytical data see appendix 3, profile description no. 17 (observation no. 43-19).

Mapping unit LnV2

Total area : 24,300ha.

Location : Lava plateau, east of Ilaut.

Agro-climatic zone : VII.

Parent material : Basalts and ashes (Quaternary volcanics).

Relief : Nearly flat, slopes 0-2% (slope class A).

Erosion : Slight splash and rillwash erosion occur, however limited by the exceedingly stony surface.

Vegetation : Deciduous shrubland (*Commiphora* and *Acacia* species) with dwarf shrubs and grasses as understory.

Land use : Occasionally grazing with livestock.

Surface stoniness : Exceedingly bouldery consisting of subangular basalts.

Soils, general : The soils are well drained, deep to very deep, dark reddish brown and strongly calcareous with a texture of clay loam. They show a clear ABCR profile development.

colour : Dark reddish brown (5YR 3/4).

texture : Clay loam, in places very stony.

structure : Weak, coarse prismatic, breaking into weak, medium to coarse angular blocky.

consistence : Slightly hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is well supplied with available nutrients. The organic C content is below 0.1%. the CEC is 30me/100g with a base saturation of 100%. The pH-H2O is 8.2 (pH-KCl: 6.9).

B-horizon: the CEC is around 25me/100g and the base saturation is 100%. The pH-H2O is 8.3 (pH-KCl: 6.8). The deeper subsoil has ESP values up to 4. The CEC-clay is about 65me/100g.

Clay mineralogy : Palygorskite, kaolinite and illite occur.

Diagnostic properties: A very weak ochric A-horizon, a cambic B-horizon and an aridic moisture regime.

Soil classification : *haplic YERMOSOLS, boulder-mantle** and partly *stony phase*.

Inclusions : In places the surface is less stony but the soil itself is more stony.

For the description of a representative profile with analytical data see appendix 3, profile description no. 18 (observation no. 54-14).

Mapping unit LnV3p

Total area	:	6,900ha.
Location	:	Southwest of Mt. Kulal.
Agro-climatic zone	:	VII.
Parent material	:	Basalts and pyroclastics (Quaternary volcanic rock
Relief	:	Flat to gently sloping; slopes from 0 to 2% (slope class A). At the edges the plateau is dissected.
Erosion	:	Splash, rillwash and gully erosion occur but are however limited because of the protective stone cover the surface.
Vegetation	:	Annual grassland, bushed dwarf shrub; with *Aristida* the dominant species and *Acacia mellifera, Commiphora Jatropa* and *Indigofera spp.* as the accompanying shr and dwarf shrubs.
Land use	:	Seasonal grazing, however not often.
Surface rockiness/ stoniness	:	Non to fairly rocky and exceedingly stony to exceedingly gravelly. Stones and gravel consist mainly of basalt, but also some carbonate concretions occur.
Soils, general	:	Well drained, moderately deep, reddish brown to dark reddish brown, strongly calcareous, slightly sodic soils with a very stony and/or very gravelly to slightly gravelly clay loam texture occur in this u They show an ABCR profile development.
colour	:	Reddish brown to dark reddish brown (5YR 4/3 to 5YR 3/2).
texture	:	Very stony and/or very gravelly to slightly gravelly clay loam.
structure	:	Moderate to strong, fine to medium angular to subang blocky.
consistence	:	Slightly hard to hard when dry, very friable when moist, sticky and plastic when wet.
Chemical properties	:	A-horizon: the soils are well supplied with available Ca. Available Mg and P are moderately high. Availa K is low. The organic C content is about 0.2 to 0. The CEC is 35me/100g. The base saturation is 100%. The pH-H2O is 8.5 (pH-KCl: 7.5).
		B-horizon: the CEC is around 35me/100g. The base saturation is 100%. The pH-H2O is 8.4 (pH-KCl: 7.0 Slightly sodic with ESP values up to 9. The CEC-cl is around 105me/100g.
Clay mineralogy	:	The dominant clay mineral is montmorillonite with traces of palygorskite and kaolinite.
Diagnostic properties:		A very weak A-horizon, a cambic B-horizon and an ar moisture regime.
Soil classification	:	*haplic YERMOSOLS, stony, sodic* and *petric phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 19 (observation no. 41-8).

Mapping unit LnV4p

Total area	:	41,600ha.
Location	:	Southwest and northwest of Mount Kulal.
Agro-climatic zone	:	VII.
Parent material	:	Basalts mixed with pyroclastic rocks and ashes (Quaternary volcanics).
Relief	:	Almost flat to gently sloping with slopes from 0 to 5% (slope class B). Especially in the southern part of the unit the various cinder cones are interrupting the relief.
Erosion	:	Due to the stone cover, erosion is limited to the plateau edges and at gully sides.
Vegetation	:	*Aristida/Cenchrus* annual grassland with dwarf shrubs as accessory species. The vegetation cover is very low.
Land use	:	Seasonal grazing.
Surface stoniness	:	Exceedingly bouldery and/or exceedingly stony, consisting of subangular lava stones with desert varnish.
Soils, general	:	The soils are moderately well drained, moderately deep to very deep, dark reddish brown, strongly calcareous, slightly to strongly saline, strongly sodic. They have a texture of clay loam to clay and a clear ABC profile development.
colour	:	Dark reddish brown (5YR 3/3).
texture	:	Clay loam to clay; in places very stony.
structure	:	Massive, moderately coherent to moderate, coarse prismatic.
consistence	:	Slightly hard when dry, friable when moist, sticky and plastic when wet.
Chemical properties	:	A-horizon: the soils are well supplied with available Ca and Mg; available P and K are low. The organic C content is around 0.3%. The CEC is 10me/100g and the base saturation is 100%. The pH-H2O is 8.1 (pH-KCl: 6.1).
		B-horizon: the CEC is around 40me/100g. The base saturation is 100%. The pH-H2O is 8.6 (pH-KCl: 7.1). Below 60cm the soils are slightly to strongly saline with ECe values up to 49mmho/cm. Below 20cm depth the soils are strongly sodic with ESP values up to 30. The CEC-clay is around 80me/100g.
Diagnostic properties:		High salinity in combination with a cambic B-horizon, or a natric B-horizon with or without a high salinity. An aridic moisture regime.
Soil classification	:	*orthic SOLONETZ, boulder-mantle*, saline* and partly *stony phase* and *orthic SOLONCHAKS boulder-mantle*, sodic* and partly *stony phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 20 (observation no. 41-16).

(3) Soils of the dissected plateaus

Mapping unit LdVP

Total area	:	10,700ha.
Location	:	West and northwest of Kargi, as small plateau rem
Agro-climatic zone	:	VII.
Parent material	:	Mainly basalts mixed with ashes. Tuffs occur as (Quaternary volcanics).
Relief	:	Gently undulating to undulating. Slopes f 2[1]) to 10% (slope classes B, BC and C).
Erosion	:	The plateaus are dissected by gullies. Actual ero is limited by a stone cover. Near Kargi severe deflation takes place, caused by over-use (trampli In places small sand dunes are being formed (obsta dunes).
Vegetation	:	Deciduous shrubland with *Acacia senegal* and *Commip* species as the most common. Annual grasses (*Aristi* form the understory.
Land use	:	Near Kargi, heavy grazing with livestock takes pla Further away from the settlements, only slight gra occurs.
Surface stoniness	:	Exceedingly stony.
Soils, general	:	Well drained, shallow to moderately deep, reddish b to dark reddish brown, non to moderately calcareous very stony clay loam to clay soils occur in this un They have an ABCR profile development.
colour	:	Reddish brown to dark reddish brown (5YR 4/4 to 3/4
texture	:	Very stony clay loam to clay with a silt/clay ratio 0.75.
structure	:	A-horizon: strong, medium to coarse, subangular blo B-horizon: strong, prismatic, breaking into weak, medium to coarse, subangular blocky.
consistence	:	A-horizon: soft to slightly hard when dry, very fri when moist, very sticky and plastic when wet. B-horizon: very hard when dry, very friable when mo very sticky and plastic when wet.
Chemical properties	:	A-horizon: the soils are sufficiently supplied with calcium, magnesium and phosphorus. The available p ssium content is low. Organic C is about 0.4%. Th CEC-soil is 35me/100g with a base saturation of 100 The pH-H2O is 7.3 (pH-KCl: 6.8).
		B-horizon: the CEC-soil is 44me/100g. The base sat tion is 100%. The pH-H2O is 8.5 (pH-KCl: 7.4). Th CEC-clay is about 90me/100g.

1) *In the legend of the soil map (appendix 1) the slope percentage has erronously been indicated as 1-10%.*

Diagnostic properties: A very weak ochric A-horizon, a cambic B-horizon and an aridic moisture regime.

Soil classification : *haplic YERMOSOLS, stony, lithic* or *petric phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 21 (observation no. 42-11).

3.3.6 Soils of the footridges

Mapping unit RVp

Total area : 16,200ha.

Location : Southeast of Marsabit.

Agro-climatic 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 rillwash and slight gully erosion.

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

Land use : Seasonal grazing.

Surface stoniness : In places stony (subangular basalt).

Soils, general : The soils are well drained, moderately deep to very deep and dark reddish brown, with a texture of very bouldery to stony clay loam to clay. They show a clear ABCR profile development.

colour : Dark reddish brown throughout (2.5YR 3/4).

texture : Very bouldery to stony clay loam to clay.

structure : A-horizon: moderate, fine to coarse, subangular blocky.
B-horizon: weak, medium to coarse, angular blocky with depth merging into porous massive.

consistence : A-horizon: slightly hard when dry, very friable when moist, sticky and plastic when wet.

B-horizon: very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is moderately well supplied with available nutrients. The organic C content is 1%. The base saturation is 100%. The pH-H2O is 7.9 (pH-KCl: 6.6).

B-horizon: the CEC-soil is 9me/100g. The base saturation is 100%. The pH-H2O is 7.2 (pH-KCl 6.1). The CEC-clay is 12me/100g.

Clay mineralogy : Kaolinite is the dominating clay mineral.

Diagnostic properties: An ochric A-horizon and a cambic B-horizon.

Soil classification : *ferralic CAMBISOLS, bouldery** and partly *petric phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 22 (observation no. 55-22).

Mapping unit RVA

Total area : 46,000ha.

Location : On the footridges of the middle slopes of Mt. Kulal

Agro-climatic zone : Mainly V, some of the lower parts fall into zone VI

Parent material : Basalts, tuffs and ashes of which the basalts are dominating (Tertiary/Quaternary volcanics).

Relief : Gently undulating/undulating to mountainous. The sl of the crests are 2 to 8%. The slopes of the valley sides are over 16% (slope class BE).

Soil pattern : The soils of the footridges form an association of three units, depending on the topographical positio Soils of the upper, the middle to upper and the low slopes. Erosion, vegetation and other characteris are also related to the topographical position and the soils.

(1) Upper slopes of the footridges:

Erosion : The present erosion is very slight due to a very st surface.

Vegetation : Deciduous woodland with dwarf shrub understory. Th dominant species is *Acacia drepanolobium* with *Duos- perma eremophilum* in the understory together with perennial grasses.

Land use : Grazing.

Surface stoniness : Stony to exceedingly stony.

Soils, general : The soils of this unit are well drained, moderately deep, dark reddish brown to dark brown, and in place strongly calcareous. They have a texture of very stony clay loam to clay and show a clear ABCR or AC profile development.

colour : The colour of the whole soil profile ranges from dar reddish brown to dark brown (5YR 3/2 to 7.5YR 3/2).

texture : Very stony clay loam to clay with a silt/clay ratio of about 0.85.

structure : The whole profile has a moderate to strong, fine to medium, subangular blocky structure.

consistence : Slightly hard when dry, very friable when moist, sti and plastic when wet.

Chemical properties : A-horizon: from only one profile, developed on tuffs data on available nutrients are known. This soil is sufficiently supplied with available nutrients, only available potassium is very low. The organic C content ranges from 1.3 to 2%. The CEC-soil is abou 30me/100g. The base saturation is 100%. The pH-H20 ranges from 6 (on tuffs) to 8 (on basalts) (pH-KCl: 5.4-6.7). The CEC-clay ranges from 60 (on basalts) 100me/100g on tuffs.

Diagnostic properties : A mollic A-horizon and an ustic moisture regime.

Soil classification : *haplic* and *calcaric PHAEOZEMS, stony* and *petric* phas

For the description of a representative profile with analytical data see appendix 3, profile description no. 23 (observation no. 41-9).

(2) Middle and upper slopes of the footridges:

Erosion : Severe splash and rillwash erosion takes place, which results in an exposure of rounded basalt boulders. This cover of boulders will help prevent further erosion.

Vegetation : Deciduous woodland with dwarf shrub understory. The main species are *Acacia etbaica, A. nilotica* and *Duosperma eremophilum*. Associated perennial grass species are *Chrysopogon plumulosus, Themeda triandra* and *Dichanthium insculptum*.

Land use : Wet season grazing takes place from time to time, however not every year.

Surface stoniness : Stony to exceedingly stony, consisting of basalt.

Soils, general : The soils of this unit are well drained, shallow to deep, dark reddish brown and in places calcareous, with a very bouldery to stony clay loam to clay texture. They show a clear ABC profile with in places well developed clay skins on ped faces.

colour : Dark reddish brown throughout (5YR 3/3 and 2.5YR 2.5/4).

texture : Very bouldery to stony clay loam to clay. The silt/clay ratio for the B-horizon is about 0.7.

structure : Weak to moderate, medium to coarse, subangular blocky. In clay soils a weak prismatic structure may exist.

consistence : Slightly hard to very hard (for clay) when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are moderately well supplied with available nutrients. The organic C content is about 1%. The CEC-soil ranges between 30 and 40me/100g. The base saturation ranges between 73 and 82%. The pH-H2O is about 6.8 (pH-KCl: is about 5.5).

B-horizon: The CEC-soil ranges between 25 and 35me/100g. The base saturation is about 90%. The pH-H2O is 7.5 (pH-KCl: 6.0). The CEC-clay ranges between 60 and 80me/100g.

Clay mineralogy : X-ray analysis shows amorphous minerals with traces of illite and kaolinite and a few traces of palygorskite.

Diagnostic properties : An ochric A-horizon, a cambic B-horizon and partly an argillic B-horizon.

Soil classification : *eutric* and *chromic** *CAMBISOLS* and partly *chromic** *LUVISOLS, bouldery** and partly *petric phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 24 (observation no. 41-10).

(3) Lower slopes of the footridges:

Erosion	:	Due to the almost complete cover of the surface with gravel and stones, hardly any erosion takes place.
Vegetation	:	Deciduous bushland to shrubland with succulent dwarf shrub understory. The main species are *Acacia mellifera*, *Acacia reficiens*, *Commiphora* spp. and species of *Euphorbia* and *Plectranthus*. Grasses form the lowest story.
Land use	:	Slight seasonal grazing.
Surface stoniness	:	Very stony to very gravelly. The gravel on the top consists of lava parts and carbonate concretions. The stones are composed of basalt.
Soils, general	:	The soils are well drained, shallow to moderately deep, dark reddish brown to dark brown, strongly calcareous, have a texture of very stony and/or very gravelly sandy loam to sandy clay and show a weak ABCR profile development. In places they have a calcic horizon.
colour	:	Dark reddish brown to dark brown (5YR 3/4 to 10YR
texture	:	Very stony and/or very gravelly, sandy loam to sandy clay.
structure	:	Weak to moderate, fine to medium, subangular blocky
consistence	:	Soft when dry, very friable when moist, slightly sticky and slightly plastic when wet.
Chemical properties	:	A-horizon: no figures about available nutrients are known but the fertility and other chemical properties of this unit might be similar to that of unit FVlP.
Diagnostic properties	:	A weak ochric A-horizon, a cambic and/or calcic B-horizon and an aridic moisture regime.
Soil classification	:	*haplic* and *calcic XEROSOLS*, *stony* and partly *lithic* or *petric phase*.

Mapping unit RVC

Total area	:	14,800ha.
Location	:	On the eastern slopes of the Asie hills.
Agro-climatic zone	:	VII.
Parent material	:	Basalts, tuffs and ashes (Quaternary volcanics).
Relief	:	The crests are gently undulating to undulating (2-8%) with moderately steep to steep slopes (over 16%) at the valley sides (slope class CD).
Vegetation	:	Deciduous shrubland with succulent dwarf shrub understory. *Commiphora* with *Euphorbia* and *Plectranthus*.
Land use	:	Occasionally grazing.
Soils, general	:	Due to the inaccessibility of the area no field observations could be made. It is expected that the soils form a complex of well drained, shallow to deep, strongly calcareous, very stony soils with varying colour, consistency and texture. They have a very exceedingly stony surface.

3.3.7 Soils of the footslopes

Mapping unit FU1

Total area : 3,500ha.

Location : At the foot of the Hafarin hills in the southern part of the Hedad.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks.

Relief : Flat to nearly flat, slopes from 0-2% (slope class A).

Erosion : Strong splash and rillwash and very slight gully erosion occur in this unit.

Vegetation : Dwarf shrubland with annual grasses as understory. The main species are *Indigofera spinosa* and *Aristida mutabilis*. A perennial grass which occurs as well is *Dactylanium*.

Land use : Wet season grazing by livestock of pastoralists.

Surface stoniness : None.

Soils, general : The soils are well drained, very deep, reddish brown, slightly to moderately sodic and have a texture of sandy loam to sandy clay loam. They have a clearly developed ABC profile, with clay cutans in the B-horizon.

colour : A-horizon: yellowish red (5YR 4/6).
B-horizon: reddish brown (5YR 4/4).

texture : A-horizon: loamy sand.
B-horizon: sandy loam to sandy clay loam.

structure : Weak, medium, subangular blocky.

consistence : A-horizon: soft when dry, friable when moist, non sticky and non plastic when wet.
B-horizon: hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: low in available nutrients except for P which is moderate to high. The organic C content varies between 0.1 and 0.2%. The CEC is 5me/100g. The base saturation is 100%. The pH-H2O is 8.0 (pH-KCl: 6.8).

B-horizon: the CEC-soil is about 10me/100g with a base saturation of 100%. The pH-H2O is 7.5 (pH-KCl: 6.0). The soils are slightly to moderately saline with ECe values from 7-10mmho/cm below 110cm and slightly to moderately sodic with ESP values up to 10 below 50cm. The CEC-clay is around 45me/100g.

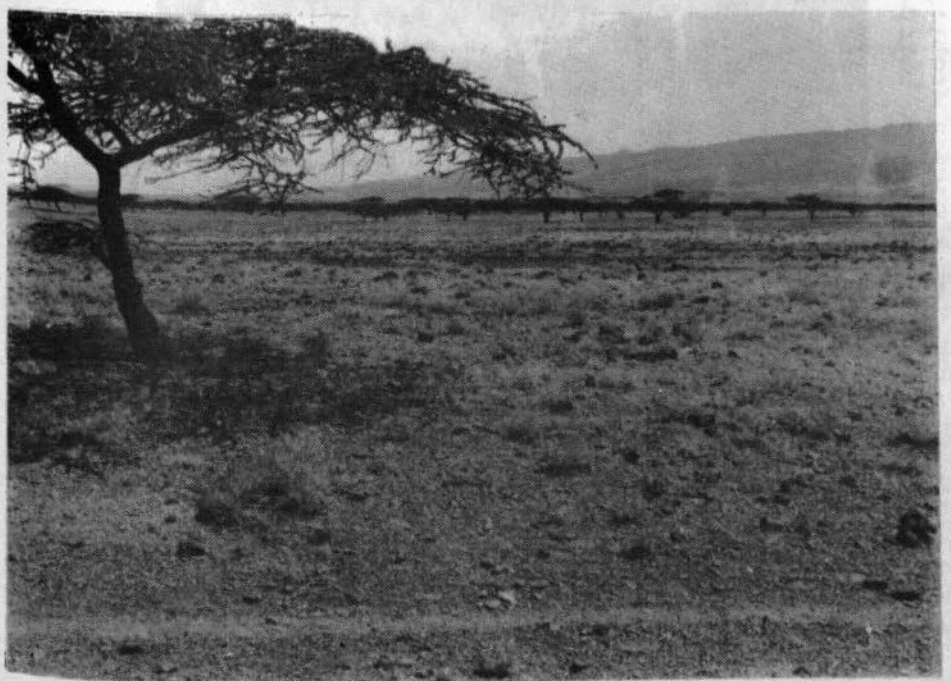
Clay mineralogy : X-ray analysis shows the presence of illite, kaolinite and a mixed layer mineral in about equal amounts.

Diagnostic properties: A very weak ochric A-horizon, an argillic B-horizon and an aridic moisture regime.

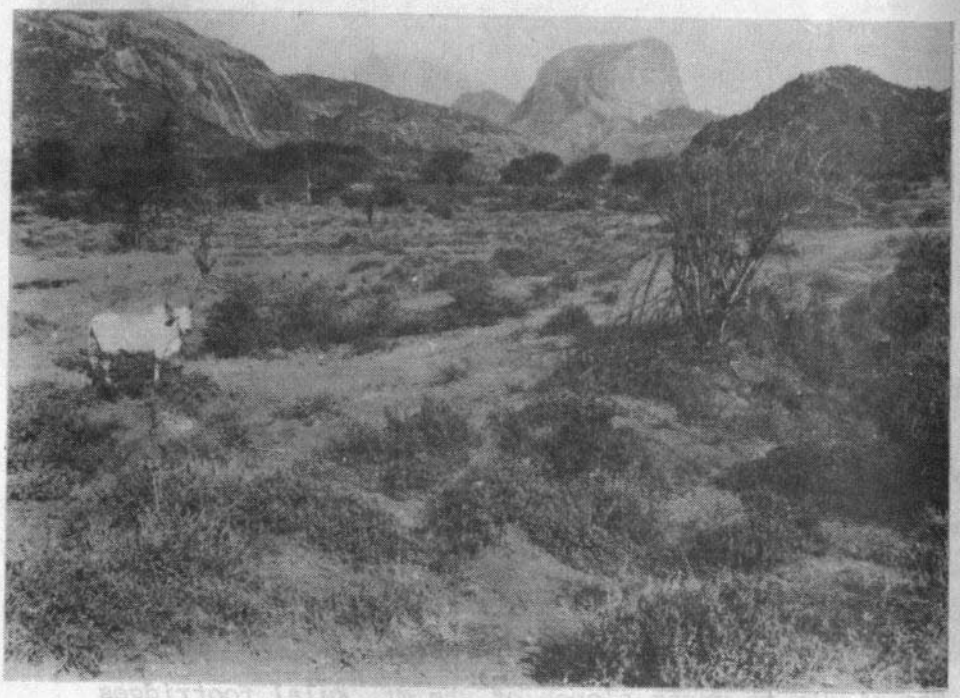
Soil classification : *luvic YERMOSOLS, sodic phase*.

The high level uplands on Mt. Kulal, near Gatab. Left the beginning of a deep, steep sided gorge, right a cinder cone.

The middle to upper slopes of the Mt. Kulal footridges with typical Acacia nilotica trees.

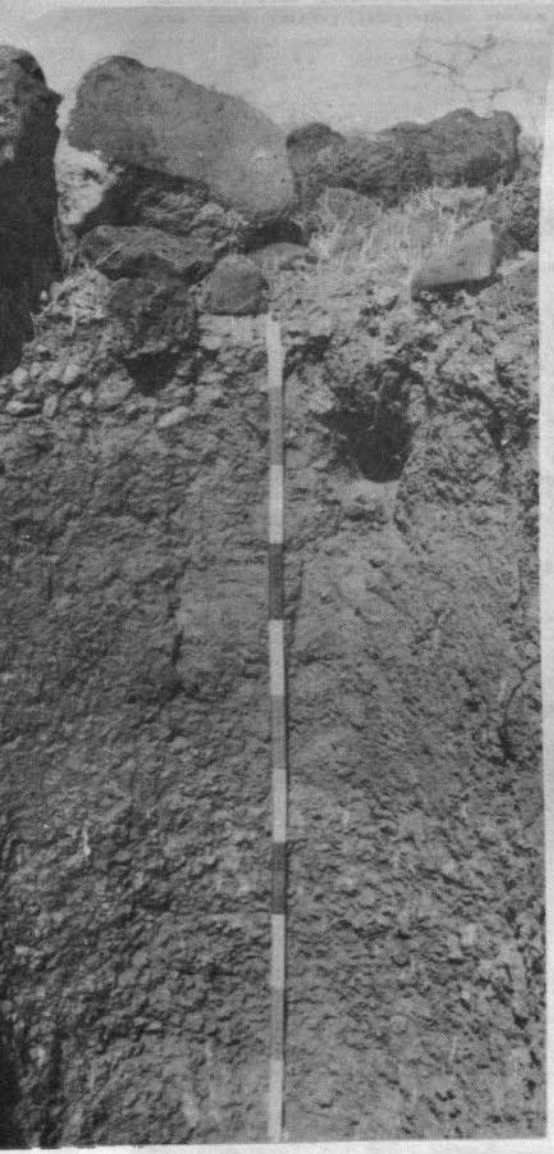


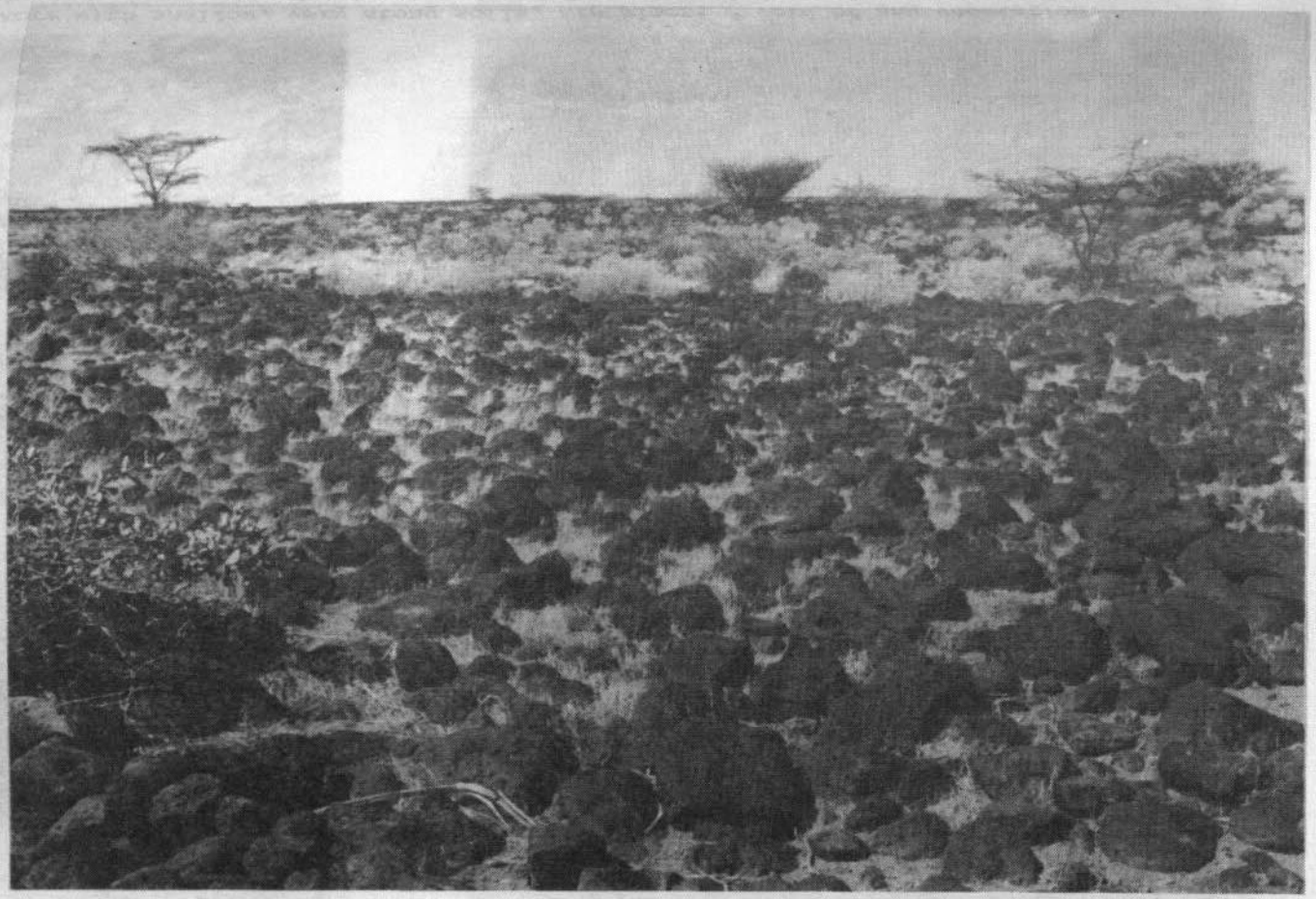
The piedmont plain west of Mt. Kulal with Acacia tortillis trees and Indigofera spinosa dwarf shrubs.



The footslopes of the Ndoto mountains near Ngurunit. The surface shows signs of erosion caused by heavy grazing pressure.

The road to Loyangalani descending the scarp at the eastern shore of Lake Turkana. South Island is in the background.





Stepped plateaus north-west of Marsabit. The soils are covered with a layer of basalt boulders (top), while the soils themselves are not stony (left). (orthic Solonchak, boulder-mantle, sodic and gypsic phase)*

For the description of a representative profile with analytical da see appendix 3, profile description no. 25 (observation no. 54-11).

Mapping unit FUA

Total area : 21,500ha (slope class B); 17,400ha (slope class

Location : This unit is located at the foot of the mountains hills in the southwestern part of the survey are

Agro-climatic zone : Zone VI and VII.

Parent material : Unconsolidated sediments derived from undifferent Basement System rocks.

Relief : Gently undulating to undulating, slopes from 1 t with the majority of the slopes below 4% (slope c B and C).

Erosion : Strong splash and rillwash erosion and slight to gully erosion are common. The severeness of the erosional processes is linked with the land use p and the location. Severe gully erosion occurs m at the foot of the mountains.

Vegetation : Deciduous bushland with dwarf shrub understory, *Acacia senegal, A. reficiens, A. tortilis* and *Bos Commiphora* and *Duosperma* species as the most com

Land use : Heavy grazing is practised, especially near the

Surface stoniness : In places very few stones occur on the upper slop (subangular and angular Basement System rocks).

Soil pattern : The soils of this unit form an association of co textured and medium textured ones. The coarse t soils occur on the upper and middle slopes, whe medium textured soils occur on the flatter lower Where the bedrock was exposed (e.g. in gullies), sharp transition from the soil to the bedrock wa noticed. Therefore the soils do not seem to hav formed in situ on the parent rock, but on transp material.

(1) Upper and middle slopes:

Soils, general : The coarse textured, red soils are somewhat exce drained and moderately deep to very deep, A st calcareous subsoil may occur in places. Along petrocalcic horizons may be exposed, which are very deep in the profile. The soils show a cle profile development. Clay bridges between the grains or cutans are often present in the B-hor

colour : A-horizon: yellowish red (5YR 4/6) to dark brow 3/4).
B-horizon: red (2.5YR 4/6 to 4/8).

texture : Loamy sand to sandy loam. The percentage of sa about 80. The sand is coarse and poorly sorted

structure : A-horizon: massive, weakly coherent, breaking weak, fine to medium, subangular blocky.
B-horizon: porous, massive, weakly coherent.

consistence : Slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet.

Chemical properties : A-horizon: the soils are moderately well supplied with available phosphorus. Available calcium is high; available magnesium and potassium are low. The organic C content is about 0.3%. The CEC is about 6me/100g. The base saturation is 100%. The pH-H2O is about 8.0 (pH-KCl: 7.4).

B-horizon: the CEC-soil is about 6me/100g. The base saturation is 100%. The pH-H2O is 6.8 (pH-KCl: 5.2). The CEC-clay is about 60me/100g.

Diagnostic properties: An ochric A-horizon, a coarse texture and characteristics of a cambic or an argillic B-horizon.

Soil classification : *luvic* and *cambic ARENOSOLS*, partly *stony* and/or *petric phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 26 (observation no. 66-8).

(2) Lower slopes:

Soils, general : The medium textured, red to reddish brown soils are well drained and very deep and show a clear ABC profile development. Clay skins and/or bridges are present in most of the B-horizons.

colour : A-horizon: dark reddish brown (2.5YR 3/5).
B-horizon: red to reddish brown (2.5YR 4/6 to 5.4YR 4/4).

texture : Sandy loam to sandy clay loam. The percentage of (coarse, poorly sorted) sand is more than 70.

structure : Porous massive, breaking into weak, fine to medium, subangular blocky.

consistence : Hard when dry, friable when moist, slightly sticky and plastic when wet.

Chemical properties : A-horizon: the soils of this unit are moderately well supplied with phosphorus. Available calcium, magnesium and potassium are low. The organic C content is very low: 0.1-0.2%. The CEC-soil ranges from 8 to 15me/100g. The base saturation is 100%. The pH-H2O is about 7.0 (pH-KCl: 5.5).

B-horizon: the CEC-soil reaches a maximum of 15me/100g in the B-horizon. The base saturation is 100%. The pH-H2O is about 7.7 (pH-KCl: 6.6). The CEC-clay is about 75me/100g.

Diagnostic properties: An ochric A-horizon, an argillic B-horizon and an aridic moisture regime.

Soil classification : *luvic YERMOSOLS*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 27 (observation no. 67-15).

Mapping unit *FV1P*

Total area : 9,500ha (slope class A); 44,200ha (slope class B).

Location : At the foot of Mt. Kulal, at the foot of a lava plateau in the north and around Maikona.

Agro-climatic zone : The higher part of the footslopes on Mt. Kulal falls in zone VI, the rest of the mapping unit falls in zone VII.

Parent material : Basalts and pyroclastic materials including volcanic ashes (Tertiary/Quaternary volcanics).

Relief : Very gently undulating to undulating. The general slope of the terrain is about 2%. Slopes towards valleys may be up to 8%, which results in an undulating relief (slope classes A and B).

Erosion : Due to the stony and gravelly surface cover, erosion is limited. However, splash and rillwash erosion may still occur.

Vegetation : Deciduous shrubland with dwarf shrub understory to annual grassland. Various *Acacia* and *Commiphora* species occur. *Aristida* grass species are the most common annual grasses.

Land use : Seasonal grazing by livestock of pastoralists.

Surface stoniness : Stony and/or exceedingly gravelly, consisting of carbonate concretions and lava particles (mainly basalts).

Soils, general : Somewhat excessively drained to well drained, shallow to moderately deep, reddish brown to dark brown, strongly calcareous, slightly to moderately saline and slightly to strongly sodic soils occur in this unit. They have a stony and very gravelly sandy loam to sandy clay texture. The soils show a weak ABCR profile development.

colour : Reddish brown to dark brown (5YR 4/3 to 10YR 4/3).

texture : Stony and very gravelly, sandy loam to sandy clay.

structure : Weak to moderate, fine to medium, subangular blocky.

consistence : Soft to slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet.

Chemical properties : A-horizon: the soils are moderately well supplied with phosphorus and magnesium. The available potassium is low. Calcium is very high. Organic C is about 0.3%. The CEC-soil ranges from 16 to 36me/100g. The base saturation is 100%. The pH-H2O is about 8.3 (pH-KCl: 7.0). The ESP ranges from 4 to 16.

B-horizon: the CEC-soil ranges from 30-40me/100g. The base saturation is 100%. The pH-H2O is about 8 (pH-KCl: 7.0). The ECe ranges between 1 and 14mmho/cm and the ESP between 4 and 25. The lower sites have the highest salinity and sodicity. The CEC-clay ranges between 50 and 100me/100g.

Diagnostic properties: A very weak ochric A-horizon, a calcic B-horizon and an aridic soil moisture regime.

Soil classification : *calcic YERMOSOLS, stony, saline, sodic* and partly *lithic* or *petric phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 28 (observation no. 41-18).

Mapping unit FV2p

Total area : 6,400ha.

Location : East of the Longipi hills.

Agro-climatic zone : VII.

Parent material : Basalts mixed with ashes and other pyroclastic materials (Quaternary volcanics).

Relief : Gently sloping, slopes 2-6%. The slope is irregular due to various basalt outcrops (slope class B).

Erosion : Nil.

Vegetation : Annual grassland *(Cenchrus)* with a few dwarf shrubs and shrubs *(Indigofera spinosa* and *Commiphora)*. Very low cover.

Land use : Sporadic seasonal grazing.

Surface rockiness/ stoniness : Very rocky and exceedingly bouldery, consisting of angular basalts, in places with phonolitic characteristics.

Soils, general : The soils are well drained, moderately deep to deep, dark reddish brown, strongly calcareous and moderately sodic. They have a texture of clay. They show a clear ABC profile development. In places clay skins are present on the ped surfaces in the B-horizon. Cracking occurs in places as well.

colour : Dark reddish brown (5YR 3/4).

texture : Clay; in places very stony.

structure : Massive, strongly coherent, breaking into weak, coarse, angular blocky.

consistence : Hard to very hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available P, Ca and Mg, but low in available K. The organic C content is 0.2%. The CEC is 33me/100g. The base saturation is 100%. The pH-H2O is 8.6 (pH-KCl: 7.4).

B-horizon: the CEC is around 32me/100g and the base saturation is 100%. The pH-H2O is 8.3 (pH-KCl: 7.3). The soils are non saline but moderately sodic from 50cm downwards, with ESP values of 9. The CEC-clay is around 66me/100g.

Diagnostic properties: A very weak ochric A-horizon, a cambic B-horizon and an aridic soil moisture regime.

Soil classification : *haplic YERMOSOLS, boulder-mantle*, sodic* and partly *stony* and/or *petric phase* and ROCK OUTCROPS.

For the description of a representiative profile with analytical data see appendix 3, profile description no. 29 (observation no. 41-26).

Mapping unit FV3P

Total area : 21,700ha.

Location : East side of Mount Kulal.

Agro-climatic zone : VI.

Parent material : Basalts, pyroclastics and ashes (Tertiary/Quaternary volcanics).

Relief : Gently undulating, slopes from 2 to 5% (slope class B).

Erosion : Slight sheetwash and in places slight gully erosion.

Vegetation : Deciduous shrubland with dwarf shrubs and grasses. *Acacia mellifera*, *A. reficiens*, *Duosperma eremophilum* and *Aristida* spp. are the most common.

Land use : Slight to moderate seasonal grazing with livestock.

Surface stoniness : Exceedingly stony, stones consist of subangular basalt.

Soils, general : The soils are well drained, shallow to moderately deep, dark reddish brown, strongly calcareous, non to slightly sodic and have a texture of very stony, clay loam to clay. They show an ABCR profile development.

colour : Dark reddish brown (5YR 3/2).

texture : Very stony clay loam to clay.

structure : Strong, fine, angular blocky.

consistence : Hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available Mg and Ca, low in available K and high in available P. The organic C content is around 0.6%. The CEC is 11me/100g. The base saturation is 100%. The pH-H2O is 8.9 (pH-KCl: 7.8). The ESP is around 6.

B-horizon: the CEC is 33me/100g and the base saturation is 100%. The pH-H2O is 8.5 (pH-KCl: 7.4). The CEC-clay is around 70me/100g.

Diagnostic properties: A weak ochric A-horizon, a cambic B-horizon and an aridic moisture regime.

Soil classification : *haplic XEROSOLS*, *stony* and *lithic* or *petric phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 30 (observation no. 42-20).

Mapping unit FVC

Total area : 33,400ha.

Location : Lower slopes around the Asie hills.

Agro-climatic zone : VII.

Parent material : Basalts, pyroclastics and ashes (Quaternary volcanics).

Relief : Gently undulating, slopes from 2-6% (slope class B).

Erosion : Slight splash and rillwash erosion, however, limited due to the stony character of the surface.

Vegetation : Deciduous shrubland with succulent dwarf shrub understory with *Commiphora*, *Euphorbia* and *Plectranthus* as the most common species.

Land use : Occasional grazing with livestock.

Surface stoniness : Exceedingly stony and or exceedingly gravelly mainly consisting of basalt.

Soils, pattern : The soils form a complex of the soils of unit FVlP which occur mainly at the western side, and of the soils described below.

Soils, general : The latter are well drained, deep to very deep, dark reddish brown, strongly calcareous, strongly saline, strongly sodic, slightly gravelly to gravelly clay loam soils which show a clear ABC profile development. Some clay-cutans may be present in the B-horizon.

colour : Dark reddish brown (5YR 3/3).

texture : Slightly gravelly to gravelly clay loam, in places very stony.

structure : Porous massive, moderately coherent, to weak, fine to medium, angular blocky.

consistence : Slightly hard to hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available Ca and Mg but very low in available K and P. The organic C content is around 0.2%. The CEC is 33me/100g with a base saturation of 100%. The pH-H2O is 9.2 (pH-KCl: 8.2). The ESP ranges between 15 and 40.

B-horizon: the CEC is 27me/100g. The base saturation is 100%. The pH-H2O is 9.2 (pH-KCl: 8.2). The ESP ranges between 30 and 70. Strongly saline from about 50cm downwards with ECe values of about 20mmho/cm. Salinity and sodicity will be less on middle and upper slopes. The CEC-clay is around 85me/100g.

Diagnostic properties: A very weak ochric A-horizon, a cambic B-horizon and an aridic moisture regime. In places the soil is strongly saline.

Soil classification : *haplic YERMOSOLS, stone-mantle*, saline, sodic* and partly *stony phase* and partly *orthic SOLONCHAKS, stone-mantle** and *sodic phase*.

For the description of a representative profile of an *orthic SOLONCHAK* with analytical data see appendix 3, profile description no. 31 (observation no. 42-24).

3.3.8 Soils of the piedmont plains

Mapping unit YVlp

Total area : 8,200ha.

Location : At the west side of Mt. Kulal.

Agro-climatic zone : VII.

Parent material : Unconsolidated colluvium and alluvium derived from various volcanic rocks mainly basalts with pyroclastic materials, including ashes (Pleistocene).

Relief : Flat to nearly flat. Slopes less than 2% (slope class A).

Erosion : Splash and rillwash erosion together with deflation take place. However a desert pavement which covers about half of the surface protects the soil partly from erosion.

Vegetation : Wooded dwarf shrubland with *Acacia tortilis* and *Indigofera spinosa* as the main species.

Land use : Grazing with livestock.

Surface stoniness : Stony to exceedingly stony. The stones consist mainly of basalt.

Soils, general : The soils of this unit are well drained, moderately deep to very deep, brown, strongly calcareous, slightly saline and moderately sodic. They have a texture of very stony and/or very gravelly, sandy clay loam. In places the soils are lying over pisocalcic material.

colour : Brown (7.5YR 4/3).

texture : Very stony and/or gravelly, sandy clay loam, with a silt/clay ratio of 1.

structure : A-horizon: strong, fine, subangular blocky.
B-horizon: massive, weakly coherent.

consistence : Soft when dry, very friable when moist, slightly sticky and plastic when wet.

Chemical properties : A-horizon: the soils are moderately well supplied with phosphorus and magnesium. They are very high in available calcium, and very low in available potassium. The organic C content is about 0.3%. The CEC-soil is about 20. The base saturation is 100%. The pH-H2O is 8.3 (pH-KCl: 7.1). The ESP is 12.

B-horizon: the CEC-soil is about 25me/100g. The base saturation is 100%. The pH-H2O is 8.5 (pH-KCl: 7.4). Slightly saline at a depth of 70cm and deeper with an ECe value of 6. The CEC-clay is about 70me/100g.

Clay mineralogy : X-ray analysis shows the presence of palygorskite and a mixed layer mineral together with traces of kaolinite and illite clay minerals.

Diagnostic properties: A very weak ochric A-horizon, a calcic horizon and an aridic moisture regime.

Soil classification : *calcic YERMOSOLS, stone-mantle*, stony, saline, sodic* and partly *petric* or *pisocalcic* phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 32 (observation no. 41-17).

Mapping unit YV2

Total area : 1,000ha.

Location : Small area southeast of Mt. Kulal.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments, mainly derived from volcanic rocks, including volcanic ashes (Pleistocene).

Relief : Nearly flat with slopes from 0 to 2% (slope class A).

Erosion : Moderate to severe rill and gully erosion.

Vegetation : Woodland with dwarf shrub understory. *Acacia tortilis*, *Salvadora persica* and *Suaeda species* are the most common.

Land use : Heavy grazing by livestock. In places the area is used as a salt-lick.

Surface stoniness : Non to slightly stony.

Soils, general : The soils of this unit are moderately well drained, deep to very deep, dark reddish brown, strongly calcareous, strongly saline and strongly sodic. They have a texture of sandy clay loam to clay and show an ABC profile development over soft secondary limestone.

colour : A-horizon: dark brown (7.5YR 3/3).
B-horizon: dark reddish brown (5YR 3/3).

texture : Sandy clay loam to clay, in places very stony.

structure : A-horizon: porous massive, weakly coherent, breaking into weak, medium crumbs.
B-horizon: moderate, coarse, angular blocky.

consistence : Hard to very hard when dry, very friable to friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with calcium and magnesium. Potassium and phosphorus are low. The organic C content is about 0.2%. The CEC-soil is 30 me/100g. The base saturation is 100%. The pH-H2O is about 8.4 (pH-KCl: 7.0).

B-horizon: the CEC-soil is about 35me/100g. The base saturation is 100%. The pH-H2O is about 8.2 (pH-KCl: 7.1). Below 50cm depth strongly saline and strongly sodic with an ECe of 25mmho/cm and ESP values from 14 to 19. The CEC-clay is about 100me/100g.

Diagnostic properties: A high salinity.

Soil classification : *orthic SOLONCHAKS*, *sodic* and partly *stony phase*.

Remarks: This area may well have been a closed basin, filled in with stagnating sweet water. The calcareous deposits may originate from the basic igneous rocks of Mt. Kulal as well as from organisms growing in the water.

For the description of a representative profile with analytical data see appendix 3, profile description no. 33 (observation no. 42-17).

Mapping unit YV3

Total area : 4,800ha.

Location : At the edge of the Marsabit lava, east and northeast of Korr and northeast of Kargi.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from various volcanic rocks.

Relief : Almost flat with slopes from 0-2% (slope class A).

Erosion : Slight splash and rillwash erosion and deflation. The erosion is limited due to the stoniness of the surface. Temporary flooding may occur.

Vegetation : Annual grassland with a few dwarf shrubs and shrubs.

Land use : Seasonal grazing.

Surface stoniness : Exceedingly stony.

Soils, general : Only one augering was made in this unit, but together with surface observations it is assumed that the soils have the following characteristics. The soils are imperfectly drained, deep to very deep, reddish brown, strongly calcareous, moderately to strongly saline and moderately to strongly sodic, with a texture of very stony clay loam to clay. They show an ABC profile development. In places the soil is cracking.

colour : Reddish brown (5YR 4/6).

texture : Very stony clay loam to clay.

consistence : Hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : Probably comparable to the soils of unit AA5.

Salinity, sodicity : Moderately to strongly saline and moderately to strongly sodic.

Diagnostic properties: A very weak ochric A-horizon, a cambic B-horizon and an aridic moisture regime. In places vertic properties.

Soil classification : *haplic* and partly *vertic* YERMOSOLS, stony, saline* and *sodic phase*.

Mapping unit YVC

Total area : 12,800ha (slope class A); 3,700ha (slope class AB).

Location : At the southeastern side of Mt. Kulal, on the lower slopes.

Agro-climatic zone : The western part of this unit falls in zone VI, the eastern part in zone VII.

Parent material : Unconsolidated sediments derived from various volcanic rocks including ashes (Pleistocene).

Relief : Nearly flat to gently sloping with slopes from 0-5% (slope classes A and AB).

Erosion : The present erosion is strongly reduced, due to a protecting stone cover (desert pavement) on the soil surface.

Vegetation : Deciduous shrubland with dwarf shrub understory. The main species are *Acacia mellifera, A. reficiens, Duosperma eremophilum* and *Sericocomopsis hildebrandtii*. Perennial and annual grasses occur as well.

Land use : Wet season grazing by livestock of pastoralists, however not very frequent.

Surface stoniness : Exceedingly bouldery to stony and/or very gravelly. The texture of the pavement ranges from gravel to boulders. The stones consist of subangular and rounded basalt.

Soils, general : The soils of this unit are variable within short distances. They vary in depth, texture, stoniness, sodicity and salinity and also in profile development. Some soils show a clear ABC profile development, whereas others have only an AC profile. In general the soils are well drained, moderately deep to very deep, dark reddish brown to dark brown, strongly calcareous, moderately to strongly saline and slightly to strongly sodic. They consist of very stony to gravelly, sandy clay loam to clay.

colour : Dark reddish brown to dark brown (5YR 3/2 to 7.5YR 3/3).

texture : Very stony to gravelly, sandy clay loam to clay.

structure : Variable.

consistence : Variable.

Chemical properties : A-horizon: the soils are moderately well supplied with available Mg, well supplied with Ca and P but low in K. The organic C content ranges between 0.1 and 0.5%. The CEC-soil is about 30me/100g. The base saturation is 100%. The pH-H2O is about 8.6 (pH-KCl: 7.5).

B-horizon: the CEC-soil varies from 20 to 40me/100g. The base saturation is 100%. The pH-H2O ranges between 8 and 9 (pH-KCl: 7.1 to 7.8). Moderately to strongly saline (ECe up to 17mmho/cm) and slightly to strongly sodic (ESP up to 40). The CEC-clay ranges from 60 to 200me/100g.

3.3.9 Soils of the plains

(a) Soils of the volcanic plains

Mapping unit PvVp

Total area : 6,000ha.

Location : Between Mt. Kulal and Asie hills forming an intramontaneous plain.

Agro-climatic zone : Mainly VII, only a small part at the western margins of the unit falls in zone VI.

Parent material : Basalts and pyroclastic materials, including ashes (Quaternary volcanics).

Relief : Almost flat, slopes 0-1% (slope class A).

Erosion : Slight splash and rillwash erosion.

Vegetation : Bushed annual grassland to shrubland, with *Acacia mellifera, A. reficiens, Commiphora* spp. and *Duosperma eremophilum* as the most common species.

Land use : Occasional grazing in the wet season.

Surface stoniness : Very gravelly and/or stony, consisting of angular to rounded basalt and carbonate concretions.

Soils, general : The soils are well drained, moderately deep to deep, dark reddish brown, strongly calcareous and strongly sodic with a texture of stony and/or gravelly sandy clay loam to clay. They show a clear ABCR profile development with clay-cutans in the B-horizon. In places the soil is cracking.

colour : Dark reddish brown (5YR 3/3).

texture : Stony and/or gravelly sandy clay loam to clay.

structure : Weak to strong, medium to coarse, angular blocky.

consistence : A-horizon: soft when dry, very friable when moist, sticky and plastic when wet.
B-horizon: hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are moderately high in available P and Mg, high in Ca, but low in K. The organic C content is about 0.5%. The CEC is 30me/100g with a base saturation of 100%. The pH-H2O is 8.5 (pH-KCl: 7.6).

B-horizon: the CEC is around 20me/100g and the base saturation is 100%. The pH-H2O is around 8.8 (pH-KCl: 7.7). Strongly sodic from 20cm with ESP values of 28. The CEC-clay is about 60me/100g.

Clay mineralogy : Montmorillonite is the dominating clay material. Palygorskite and kaolinite occur in small amounts.

Diagnostic properties: A very weak ochric A-horizon, partly an argillic B and partly vertic properties, and an aridic moisture regime.

Soil classification : *luvic* and *calcic YERMOSOLS, stony, sodic,* and partly *petric phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 34 (observation no. 42-19).

(b) Soils of the non-dissected erosional plains

Mapping unit PnSP

Total area : 6,000ha.

Location : Southeast of Maikona.

Agro-climatic zone : VII.

Parent material : Quartzitic sandstone with some gravelly layers ("Turkana grits"/Miocene?).

Relief : Flat to nearly flat, slopes 0-2% (slope class A).

Erosion : Strong splash and rillwash erosion has resulted in the formation of a desert pavement. The actual erosion is limited to slight splash and rill erosion and slight deflation.

Vegetation : Nearly bare to annual grassland with a few *Indigofera* dwarf shrubs.

Land use : Occasional grazing with livestock.

Surface rockiness/ stoniness : Extremely rocky and exceedingly stony and gravelly.

Soils, general : The soils are excessively drained, shallow and reddish brown. They have a very stony and very gravelly, sandy clay loam to sandy clay texture and show a weak ACR profile development.

colour : Reddish brown (5YR 4/4).

texture : Very stony and very gravelly, sandy clay loam to sandy clay.

structure : Weak, medium, subangular to angular blocky.

consistence : Slightly hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : No samples were taken.

Diagnostic properties: Soil depth limited by continuous coherent and hard rock.

Soil classification : *eutric LITHOSOLS, stony phase.*

Mapping unit PnSA

Total area : 3,300ha.

Location : Southeast of Maikona.

Agro-climatic zone : VII.

Parent material : Quartzitic sandstone, with bands of conglomerate ("Turkana grits"/Miocene?).

Relief : The general slope is 0-2%, however due to erosion and redeposition of the topsoil, a gently undulating meso-relief exists (slope class B).

Erosion : Strong splash and rillwash erosion and heavy deflation occur. Deposition of silty materials takes place in the closed depressions.

Vegetation : Annual grassland with dwarf shrubs. *Aristida mutabilis* and *Indigofera spp.* are the most common. A single *Balanites* may be present.

Land use : Heavy grazing and browsing.

Surface stoniness : Exceedingly gravelly, consisting of fine, subangular quartz gravel with a diameter of less than 4mm.

Soils, pattern : The soils of this unit form an association of sandy and clayey soils. The sandy soils form the slightly higher lying parts, while the latter occur in depressions.

(1) Higher lying parts:

Soils, general : The dark red sandy soils are somewhat excessively drained, very deep and strongly sodic. They have a not very well developed ABC profile.

colour : A-horizon: dark reddish brown (2.5YR 3/4).
B-horizon: dark red (2.5YR 3/6).

texture : Very coarse, loamy sand; maximum grain size is 3mm (fine gravel).

structure : Massive, weakly coherent to single grain.

consistence : Soft when dry, very friable when moist, slightly sticky and slightly plastic when wet.

Chemical properties : A-horizon: the soils are low in available nutrients and very low in available K. The organic C content ranges between 0.1 and 0.2%. The CEC is about 4me/100g with a base saturation of 100%. The pH-H2O is 8.2 (pH-KCl: 6.9). The ESP is around 28.

B-horizon: the CEC is 8me/100g and the base saturation is 100%. The pH-H2O is 8.0 (pH-KCl: 6.9). Strongly sodic, with ESP values up to 55 between 10 and 50cm. The CEC-clay is around 50me/100g.

Diagnostic properties: Coarse texture, characteristics of a cambic B-horizon and an aridic moisture regime.

Soil classification : *cambic ARENOSOLS, sodic phase.*

(2) Depressions:

Soils, general : The clayey soils are occupying the depressions. The soils are imperfectly drained, deep to very deep, dark reddish brown, slightly to moderately saline and strongly sodic. They show a well developed AEBC profile development. An abrupt textural change exists between the AE and the B-horizon.

colour : AE-horizon: dark reddish brown (2.5YR 3/4).
B-horizon: dark reddish brown (2.5YR 3/4).

texture : AE-horizon: sand.
B-horizon: sandy clay loam.

structure : AE-horizon: massive, slightly coherent.
B-horizon: moderate, coarse, columnar merging with depth into strong, medium to coarse, angular blocky.

consistence : AE-horizon: soft when dry, loose when moist, non sticky and non plastic when wet.
B-horizon: very hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are moderately well to well supplied with available Ca and Mg, while available K and P are low. The organic C content is about 0.1-0.2%. The CEC is 3.8me/100g and the base saturation is 100%. The pH-H2O is 8.0 (pH-KCl: 6.9). The ESP is around 50.

B-horizon: the CEC is around 8me/100g and the base saturation is 100%. The pH-H2O is 8.0 (pH-KCl: 7.9). Below 20cm depth the soils are slightly to moderately saline with ECe values of 9.5mmho/cm. The ESP is around 33. The CEC-clay is 26me/100g.

Diagnostic properties: An ochric A-horizon and a natric B-horizon.

Soil classification : *orthic SOLONETZ, saline phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 35 (observation no. 43-16).

(c) Soils of the dissected erosional plains

Mapping unit PdSP

Total area : 8,100ha.

Location : Southeast of Maikona.

Agro-climatic zone : VII.

Parent material : Quartzitic sandstone with gravelly layers ("Turkana grits"/Miocene?).

Relief : Irregular; from gently undulating in the west to hilly in the east; slopes 2 to over 16% (slope class BCD).

Erosion : Strong splash, rillwash and gully erosion.

Vegetation : Nearly bare to annual grassland with a few *Indigofera* dwarf shrubs.

Land use : Occasional grazing.

Surface rockiness/ stoniness : Very rocky and very stony and/or gravelly.

Soils, general : The soils are similar to those of the PnSP unit. Towards the west the soils are covered with small sand dunes which are increasing in size and cover towards the Chalbi desert. They are 50 to 100cm high and cover 30 to 50% of the area. In places the soils may be slightly deeper than in unit PnSP.

(d) Soils of the sedimentary plains

Mapping unit PsUK

Total area : 2,000ha.

Location : South of Kargi.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks, overlying secondary limestone. Volcanic ash admixtures are present.

Relief : Flat to almost flat with slopes of 0.2% (slope class A).

Erosion : Severe splash and rillwash and strong deflation. In places actual formation of small obstacle dunes.

Vegetation : From bare to bushed grassland. The main species are *Acacia tortilis, A. nubica, Balanites aegyptiaca, Indigofera spinosa* and *Duosperma eremophilum.*

Land use : Overgrazing with livestock.

Surface stoniness : Very gravelly (fine, <1cm). The gravel consists of quartz, feldspars and carbonate concretions and is the result of erosion of the fine earth.

Soils, general : The somewhat excessively drained to well drained, shallow to moderately deep, reddish brown to yellowish red, moderately to strongly calcareous, slightly gravelly, loamy sand to sandy loam soils show an ABC profile development. Near Kargi the soils are heavily eroded, exposing the petrocalcic horizon.

colour : Reddish brown to yellowish red (5YR 4/4 to 5YR 4/6).

texture : Slightly gravelly, loamy sand to sandy loam.

structure : A-horizon: weak, fine to medium, subangular blocky. B-horizon: porous massive, weakly coherent, breaking into weak, medium, subangular blocky.

consistence : Soft when dry, very friable when moist, non sticky and non plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available Ca and P, Mg is moderately high and K is low. The organic C content is about 0.1-0.2%. The CEC is around 4me/100g with a base saturation of 100%. The pH-H20 is 8.3 (pH-KCl: 6.9).

B-horizon: the CEC is 6.0me/100g. The base saturation is 100%. The pH-H20 is 8.2 (pH-KCl: 7.3). In places very slightly sodic with ESP values up to 5. The CEC-clay is around 60me/100g.

Diagnostic properties: Coarse texture, characteristics of a cambic B-horizon.

Soil classification : *cambic ARENOSOL, petrocalcic phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 36 (observation no. 55-9).

Mapping unit PsU1

Total area : 119,300ha.

Location : In the western, northwestern, middle and southern parts of the Hedad.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks. Some volcanic ash enrichments may have taken place in places (Pleistocene).

Relief : Almost flat, slopes from 0-2% (slope class A).

Erosion : Moderate to severe splash, in places slight rill erosion and deflation.

Vegetation : Bushed dwarf shrubland to grassland with *Acacia reficiens* and *Commiphora* species as the most common. *Indigofera spinosa* and *Duosperma eremophilum* form the dwarf shrub layer. Annual and perennial grasses form the understory.

Land use : Slight to heavy grazing by livestock of pastoralists, depending on the location. In the central and western parts of the Hedad only occasional grazing.

Surface stoniness : Non-stony. In many places a coarse sand layer (thickness <1cm) covers the surface.

Soils, general : The soils of this unit are well drained, very deep, red to dark reddish brown and slightly to moderately sodic. They have a texture of sandy loam to sandy clay loam and show a very clear ABC profile development. In places the soils are strongly calcareous and/or slightly saline.

colour : A-horizon: yellowish red to dark brown (5YR 4/6 to 7.5YR 4/4).
B-horizon: red to dark reddish brown (2.5YR 4/6 to 5YR 3/4).

texture : A-horizon: sand to loamy sand (coarse, poorly sorted).
B-horizon: sandy loam to sandy clay loam with often more than 60% coarse, poorly sorted sand.

structure : A-horizon: single grain to weak to moderate, fine subangular blocky.
B-horizon: porous massive, breaking into weak, medium to coarse, subangular blocky.

consistence : A-horizon: soft when dry, loose to very friable when moist, non sticky and non plastic when wet.
B-horizon: hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are high in available P, moderate in available Ca and Mg and low in available K. The organic C content ranges from 0.2 to 0.5%. The CEC is 5-11me/100g with a base saturation of 100%. The pH-H2O ranges from 7.5-8.8 (pH-KCl: 6.1-7.6).

B-horizon: the CEC-soil ranges from 10-20me/100g. The base saturation is 100%. The pH-H2O is 6.5-8.2 (pH-KCl: 5.5-7.2). In a few places the soils are slightly saline in the subsoil with ECe values between 4 and 8 mmho/cm. From a depth of about 50cm the soils are very slightly sodic (ESP: 3-5), from 80cm downwards the soils are moderately sodic (ESP: 10-15). The CEC-clay ranges from 30 to 60me/100g.

Clay mineralogy : Illite is the dominating clay mineral. Kaolinite occurs as well: from traces to a clear presence. In places montmorillonite occurs as well. In general, there is a remarkable absence of palygorskite.

Diagnostic properties: A very weak ochric A-horizon, an argillic B-horizon and an aridic moisture regime.

Soil classification : *luvic YERMOSOLS, sodic* and partly *saline phase*.

Inclusions: Inclusions of unit PsUA1 may occur, especially in the western part of the survey area.

For the description of a representative profile with analytical data see appendix 3, profile description no. 37 (observation no. 54-18).

Mapping unit PsU2

Total area : 2,200ha.

Location : Southwest of Kargi.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks overlying secondary limestone. Some volcanic ash enrichments may have taken place (Pleistocene).

Relief : Almost flat, slopes less than 2% (slope class A).

Erosion : Severe splash, slight to moderate rill erosion and deflation takes place. Closer to Kargi, the erosion is more severe due to more frequent use.

Vegetation : Dwarf shrubland with *Indigofera spinosa* as dominant species. *Acacia tortilis* occurs along the drainage lines. Annual grasses like *Aristida mutabilis* occur in the understory.

Land use : Heavy grazing by livestock.

Surface stoniness : Non-stony. Some coarse sand grains occur on the surface.

Soils, general : The soils of this unit are well drained, deep, reddish brown and moderately sodic. They have a texture of sandy loam to sandy clay loam and show an ABC profile development. At about 100cm depth pisocalcic material is present which merges at greater depth into a petrocalcic horizon.

colour : A-horizon: reddish brown to yellowish red (5YR 4/4 to 4/6).
B-horizon: reddish brown (2.5YR 4/4 to 5YR 4/4).

texture : A-horizon: sand to loamy sand.
B-horizon: sandy loam to sandy clay loam. Up to 70% of the fine earth is coarse, poorly sorted sand.

structure : A-horizon: moderate, fine to medium, subangular blocky.
B-horizon: porous massive, breaking into weak, fine to medium, subangular blocky.

consistence : Slightly hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is moderately well supplied with available nutrients, but P is high. The organic C content is about 0.2%. The CEC soil is 10me/100g. The base saturation is about 70%. The pH-H2O is 7.8 (pH-KCl: 6.4).

B-horizon: the CEC is about 15me/100g. The base saturation is about 85%. The pH-H2O is 7.7 (pH-KCl: 6.4). At about 80cm depth and deeper the soil is moderately sodic, with ESP values up to 12. The CEC-clay is about 70me/100g.

Clay mineralogy : Illite is the common mineral, together with a mixed layer mineral but traces of kaolinite, smectite and palygorskite are present as well.

Diagnostic properties: A very weak ochric A-horizon, an argillic B-horizon and an aridic moisture regime.

Soil classification : *luvic YERMOSOLS, sodic* and partly *pisocalcic* phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 38 (observation no. 55-8).

Mapping unit PsU3

Total area : 22,800ha.

Location : In the eastern part of the Hedad.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks; in many places covered with a thin layer of recent alluvial deposits. Influences of volcanic ashes occur as well (Pleistocene).

Relief : Flat to nearly flat, slopes 0-1% towards the northeast (slope class A).

Erosion : Severe splash and rillwash to slight rill erosion. In many places deposition of fine material occurs as well. Flooding for a few days may occur after heavy rains.

Vegetation : Shrubland with dwarf shrubs and perennial grasses as understory. The most common species are: *Acacia reficiens, A. senegal, Cordia synensis, Indigofera cliffordiana, Duosperma eremophilum, Sporobolus fimbriatus.*

Land use : Grazing.

Surface stoniness : Nil.

Soils, general : The soils are well drained to moderately well drained, very deep, dark reddish brown, slightly to moderately saline and strongly sodic. They have a texture of sandy clay loam to sandy clay. The texture of the top soil is loam to clay. The soils show a clear ABC profile development. The transition between the A and the B-horizon is abrupt. Clay cutans are present in the B-horizon.

colour : A-horizon: yellowish red (5YR 4/6).
B-horizon: dark reddish brown (2.5YR 3/4).

texture : A-horizon: variable; sand, loamy sand to loam or clay. The loam to clay can be regarded as a more recent deposit on top of the original profile. It covers about 70% of the surface area.

B:horizon: sandy clay loam to sandy clay.

structure : A-horizon: weak, fine to medium, subangular blocky. The loamy to clayey topsoil may be slightly layered.
B-horizon: weak, medium, prismatic, breaking into moderate, medium to coarse angular blocky.

consistence : A-horizon: soft to slightly hard when dry, very friable when moist, non sticky to sticky and non plastic to plastic when wet.

Chemical properties : A-horizon: the soil is well supplied with available nutrients (P is high). The organic C content varies between 0.1 and 0.2%. The CEC is variable, due to the variable clay content (8-20me/100g). The base saturation is 100%. The pH-H2O is 8.0 (pH-KCl: 7.0).

B-horizon: the CEC soil is 20me/100g., the base saturation is 100%. The pH-H2O is 8.0 (pH-KCl: 6.9). Slightly to moderately and in places strongly saline in the deeper subsoil with ECe values up to 35mmho/cm. Strongly sodic, with ESP values over 15 between 60 and 100cm. The CEC-clay is 60me/100g.

Diagnostic properties: A very weak ochric A and a natric B-horizon.

Soil classification : *orthic SOLONETZ, saline phase.*

Inclusions : Inclusions of unit PsU4 and PsU1 may occur.

For the description of a representative profile with analytical data see appendix 3, profile description no. 39 (observation no. 54-20).

Mapping unit PsU4

Total area	:	94,200ha.
Location	:	In the central and northeastern part of the Hedad.
Agro-climatic zone	:	VII.
Parent material	:	Unconsolidated sediments derived from undifferentiated Basement System rocks. Volcanic ash enrichments may have taken place (Pleistocene).
Relief	:	Almost flat with slopes less than 2% (slope class A).
Erosion	:	Strong splash, rillwash and slight rill erosion. The erosion processes have caused a meso-relief of about 40cm high. Accumulations of silt and clay in lower places (e.g. drainage lines) gives rise to dust in the dry and mud in the rainy season.
Vegetation	:	Deciduous shrubland with dwarf shrub understory. *Acacia reficiens* and *Duosperma eremophilum* are the dominating species.
Land use	:	Grazing by livestock of pastoralists, not frequent and mainly in the wet season.
Surface stoniness	:	Nil.
Soils, general	:	The soils of this unit are well drained to moderately well drained, very deep, reddish brown to dark reddish brown, slightly to strongly saline and strongly sodic. The deeper subsoil is strongly calcareous. They have a texture of sandy clay loam to sandy clay, with a topsoil of loamy sand to sandy loam. These soils have a clear ABC profile development with clay cutans in the B-horizon. The transition between the A and the B-horizon is abrupt. In places the A-horizon is removed through erosion processes.
colour	:	A-horizon: reddish brown (5YR 4/4). B-horizon: reddish brown to dark reddish brown (5YR 3/4 to 4/4).
texture	:	A-horizon: loamy sand to sandy loam. B-horizon: sandy clay loam to sandy clay with a silt/clay ratio of about 0.23. The sand fraction amounts to about 50% of the fine earth. The sand is coarse and badly sorted.
structure	:	A-horizon: single grain to weak, fine, subangular blocky. B-horizon: moderate, coarse, angular blocky structure; in places moderate, coarse columnar, merging into moderate, coarse angular blocky.
consistence	:	A-horizon: soft when dry, loose to very friable when moist, non sticky and non plastic when wet. B-horizon: very hard when dry, friable when moist, sticky and plastic when wet.
Chemical properties	:	A-horizon: available Ca and Mg range from low to high. Available potassium is low. Available phosphorus is very high. The organic C content ranges from 0.1 to

0.3%. The CEC-soil is about 15me/100g. The base saturation is 100%. The pH-H2O ranges between 8.0 and 9.0 (pH-KCl: 7.0-7.4). The ESP ranges from 4 to 10.

B-horizon: the CEC-soil is about 19me/100g. The base saturation is 100%. The pH-H2O ranges from 7.5 to 9.2 (pH-KCl: 6.6-7.5). Below 50cm the soil generally is slightly to strongly saline. In places the salinity occurs higher in the profile. ECe values range between 6 and 30mmho/cm. The whole B-horizon is strongly sodic with ESP values from 30 up to 100 (when free salts are present). An ESP of about 50 is common. The CEC-clay is about 55me/100g.

Clay mineralogy : Illite is the dominating clay mineral. Palygorskite is often present as well, the amount increases with depth. Kaolinite is present in small amounts.

Diagnostic properties: An ochric A and a natric B-horizon.

Soil classification : *orthic SOLONETZ, saline phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 40 (observation no. 42-3).

Mapping unit PsU5

Total area : 86,100ha.

Location : This unit occurs at the eastern and northeastern sides of the sedimentary plains and in two small areas at the western side.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks. Some volcanic ashes may have been mixed in the parent material (Pleistocene).

Relief : Almost flat, slopes less than 2% (slope class A). Meso relief is present as "pseudo-dunes" which may reach heights up to 2.0m. Heights of 50-100cm are however common.

Erosion : Severe splash and rillwash, moderate rill erosion and slight to moderate deflation.

Vegetation : Deciduous shrubland to bushed dwarf shrubland with *Acacia reficiens, Commiphora spp, Indigofera spinosa* and *Duosperma eremophilum* as the most common species. Annual and perennial grasses are present in the understory. It has to be remarked that the depressions are often almost bare, whereas the deep sandy parts support mainly *Indigofera spinosa* and annual grasses.

Land use : Slight to moderate grazing by livestock of pastoralists.

Surface stoniness : Nil.

Soils, general : The soils of this unit are well drained to imperfectly drained, very deep, dark red to dark reddish brown, in places strongly calcareous, slightly to strongly saline and strongly sodic. The deeper subsoil is always strongly calcareous. They have a texture of sandy clay loam to sandy clay, with a topsoil of sand. The soils

show a very pronounced ABC profile development with an abrupt horizon transition between the A- or E-horizon and the B-horizon.

The original surface which was flat, has been subject to splash, rillwash and rill erosion, removing the sandy material. In the dry season deflation and redeposition of the eroded material took place. In this way a strong meso-relief was developed. This process is still continuing.

colour : A-horizon: yellowish red (5YR 4/6).
B-horizon: dark red to dark reddish brown (2.5YR 3/5 to 5YR 3/4).

texture : A-horizon: coarse, poorly sorted sand.
B-horizon: sandy clay loam to sandy clay.

structure : A-horizon: single grain.
B-horizon: strong, coarse, columnar breaking into weak, coarse, angular blocky merging with depth into porous massive, moderately to strongly coherent.

consistence : A-horizon: loose when dry, loose when moist, non sticky and non plastic when wet.

B-horizon: very hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils of this unit are low in available potassium. Available P is high. Calcium and magnesium are low to moderately well supplied. Where the top of the B-horizon is at the surface, sodium toxicity may occur. Organic carbon ranges from 0.1 to 0.2%. The CEC is about 8me/100g. The base saturation is 80 to 100%. The pH-H2O ranges from 8.0 to 8.5 (pH-KCl: 6.0 to 7.0). The ESP is around 6.

B-horizon: the CEC-soil ranges from 10 to 35 with a base saturation from 60 to mostly 100%. The pH-H2O is about 8.5 (pH-KCl: 6.5 to 7.5). The soils are non to strongly saline from 50cm depth with ECe values up to 22mmho/cm. The deeper subsoil is always strongly saline. The soils are moderate to strongly sodic from the top of the B-horizon downwards, with ESP values up to 50. The CEC clay ranges from 50 to 100me/100g (N.B. Base saturation below 100% at pH 8.5 is not possible).

Clay mineralogy : X-ray analysis reveals mainly illite but also some montmorillonite, traces of kaolinite and palygorskite may be present.

Diagnostic properties: An ochric A-horizon and a natric B-horizon.

Soil classification : *orthic SOLONETZ, saline phase.*

Remarks: In the depressions between the "pseudo-dunes" the B-horizon is at the surface. Regeneration of vegetation in this part is almost impossible because:

- the very hard surface makes rooting difficult
- the seeds are easily blown off the surface
- toxicity of Na may occur

Inclusions of unit PsU4 may occur. In the northeast, the transition to the dunes (unit DXA) is gradual. Close to this boundary the meso-relief is very well pronounced.

For the description of a representative profile with analytical data see appendix 3, profile description no. 41 (observation no. 54-8).

Mapping unit PsUA1

Total area : 37,200ha.

Location : At the western side of the Hedad.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks.

Relief : Almost flat, slopes less than 2% (slope class A).

Erosion : Moderate to severe splash and rillwash erosion occurs on slight elevations. In the shallow depressions, slight gully erosion as well as deposition may occur.

Vegetation : Bushed dwarf shrubland with *Indigofera spinosa* dominating on the higher parts and *Duosperma eremophilum* in the lower parts. *Acacia reficiens* and *Commiphora spp.* are the most common bushes and these are mainly concentrated in the slightly lower parts.

Land use : Grazing by livestock in the wet season, but not every year.

Surface stoniness : Nil.

Soils, pattern : The soils of this unit form an association of the following two types:

(1) The soils of the slight elevations, which have a coarse texture.

(2) The soils of the shallow depressions, which have a medium texture.

(1) Slight elevations:

Soils, general : The soils are somewhat excessively drained, very deep and dark reddish brown to dark brown. They have a texture of sand to loamy sand and an ABC profile development.

colour : A-horizon: reddish brown (5YR 4/4) to brown (7.5YR 4/4). B-horizon: dark reddish brown (2.5YR 3/5) to dark brown (7.5YR 3/4).

texture : Sand to loamy sand. The sand is coarse and badly sorted.

structure : Porous massive, weakly to moderately coherent to weak, medium, subangular blocky.

consistence : Soft when dry, loose to very friable when moist, non sticky and non plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available calcium and high in phosphorus. Available magnesium and potassium are low. The organic C content is about

0.2 to 0.3%. The CEC is about 8me/100g. The base saturation is 100%. The pH-H2O is about 7.5 to 8.0 (pH-KCl: 6.3 to 7.0).

B-horizon: the CEC-soil is around 9me/100g. The base saturation is 100%. The pH-H2O is about 8.0 (pH-KCl: 7.0). Below 1.50 m the soils are slightly sodic, with ESP values up to 10. The CEC-clay is around 80me/100g.

Clay mineralogy : The X-ray analysis shows moderately crystallized illite, palygorskite and traces of poorly crystallized kaolinite.

Diagnostic properties: A coarse texture and characteristics of a cambic B-horizon.

Soil classification : *cambic ARENOSOLS*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 42 (observation no. 54-4).

(2) Shallow depressions:

Soils, general : The soils of the slight depressions are well drained, very deep, dark reddish brown to dark brown and in places strongly calcareous and slightly sodic. They have a texture of sandy loam to sandy clay loam and show a clear ABC profile development. The deeper subsoil is strongly calcareous. In places clay cutans are present in the B-horizon.

colour : A-horizon: yellowish red (5YR 4/6) to dark brown (7.5YR 3/4).

B-horizon: dark reddish brown (5YR 4/4) to dark brown (7.5YR 3/4).

texture : A-horizon: loamy sand to sandy loam.
B-horizon: sandy loam to sandy clay loam.

structure : Porous massive, moderately to strongly coherent, in places breaking into weak, medium to coarse, subangular blocky.

consistence : A-horizon: soft when dry, very friable when moist, slightly sticky and slightly plastic when wet.

B-horizon: slightly hard to hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available nutrients, only available potassium is low. Available P is high. The organic C content is around 0.2%. The CEC is about 10me/100g. The base saturation is 100%. The pH-H2O is 8.7 (pH-KCl: 7.3).

B-horizon: the CEC-soil is about 8me/100g. The base saturation is 100%. The pH-H2O is around 8.4 (pH-KCl: 7.2). Below 50cm the soils are slightly sodic, with ESP values up to 7. The deeper subsoil is slightly saline. The CEC-clay is around 50me/100g.

Clay mineralogy : Illite is dominating, kaolinite and montmorillonite are present in small amounts.

Diagnostic properties: A very weak ochric A-horizon, an aridic moisture regime, partly a cambic B-horizon and partly an argillic B-horizon.

Soil classification : *luvic* and *haplic YERMOSOLS, sodic phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 43 (observation no. 54-7).

Mapping unit PsUA2

Total area : 38,800ha.

Location : Between Korr and Ngurunit, in the southern part of the survey area.

Agro-climatic zone : VII.

Parent material : Unconsolidated sediments derived from undifferentiated Basement System rocks.

Relief : Nearly flat to very gently undulating with slopes from 0 to 2% (slope class A).

Erosion : Moderate to heavy splash and rillwash erosion occurs on the slight elevations. In the lower parts rill erosion as well as deposition takes place.

Vegetation : Dwarf shrubland with some shrubs in the drainage lines. On the slight elevations *Indigofera spinosa* is dominant with annual grasses as understory (mainly *Aristida mutabilis).* In the shallow depressions *Duosperma eremophilum* is the most common. *Acacia mellifera, A. reficiens* and *Commiphora spp.* dominate the shrub layer.

Land use : Moderate to heavy grazing by pastoralists.

Surface stoniness : Nil.

Soils, pattern : The soils of this unit form an association of two types:
(1) the soils of the slight elevations and
(2) the soils of the shallow depressions.

(1) Slight elevations:

Soils, general : The soils are somewhat excessively drained, very deep, reddish brown with a texture of sand to loamy sand. They have an ABC profile development.

colour : A-horizon: dark reddish brown to yellowish red (5YR 3/4 to 4/6).
B-horizon: reddish brown (5YR 4/4).

texture : Sand to loamy sand, coarse, poorly sorted. Some very fine gravel (quartz, feldspar) may occur.

structure : Massive, weakly coherent, breaking into very weak, fine subangular blocky.

consistence : Soft when dry, loose to very friable when moist, non sticky and non plastic when wet.

Chemical properties : A-horizon: available potassium, calcium and magnesium are low. Available phosphorus is high. The organic C content is about 0.3%. The CEC-soil is about 5me/100g. Base saturation is close to or at 100%. The pH-H2O is 7.4 (pH-KCl: 6.3).

B-horizon: the CEC-soil is about 6me/100g. The base saturation is 100%. The pH-H2O is about 8.0 (pH-KCl: 7.0). The subsoil below 2m is slightly saline with ECe values of maximally 8mmho/cm. Below 1m depth, the soils are slightly sodic with ESP values up to 10.

Clay mineralogy : Illite, kaolinite and a mixed layer mineral occur in small amounts. Traces of smectite were also found.

Diagnostic properties: A coarse texture and characteristics of a cambic B-horizon.

Soil classification : *cambic ARENOSOLS*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 44 (observation no. 66-4).

(2) Shallow depressions:

Soils, general : The soils of the slight depressions, which are mainly seasonal drainage ways, are well drained, very deep, dark reddish brown to dark brown. They show an ABC profile development. In places clay skins are present in the B-horizon. In places cracking occurs. The texture of the soils in the drainage ways is variable, due to variations in the depositional processes in the past and at present. The soils are however mainly fine textured. In places the soil may be layered.

colour : A-horizon: reddish brown (5YR 4/4) to strong brown (7.5YR 4/6).

B-horizon: dark reddish brown (5YR 3/4) to dark brown (7.5YR 3/4).

texture : Sandy loam to sandy clay.

structure : A-horizon: strong, medium, subangular blocky.
B-horizon: weak, coarse, prismatic, breaking into weak, coarse, angular blocky to massive.

consistence : A-horizon: slightly hard when dry, very friable when moist, sticky and plastic when wet.

B-horizon: hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are sufficiently supplied with available nutrients. The organic C content ranges between 0.1 and 0.3%. The CEC-soil ranges from 15 to 20me/100g. The base saturation is 100%. The pH-H2O is about 7.5 (pH-KCl: 6.5).

B-horizon: the CEC-soil is about 25me/100g depending on the texture. The base saturation is 100%. The pH-H2O is about 7.0 (pH-KCl: 5.7). Below 1.0m the soils are slightly sodic with ESP values up to 10. Deeper than 2m the soils may be slightly saline. The CEC-clay is about 60me/100g.

Clay mineralogy : Illite, kaolinite, smectite and a mixed layer mineral are present in small amounts.

Diagnostic properties: A very weak ochric A-horizon, an aridic moisture regime and a cambic B-horizon, partly with vertic properties.

Soil classification : *vertic** and *haplic YERMOSOLS*, partly *sodic phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 45 (observation no. 66-5).

(e) Soils of the non-dissected lacustrine plains

Mapping unit PlnX1

Total area	:	59,600ha.
Location	:	Chalbi desert, in the north of the survey area.
Agro-climatic zone	:	VII.
Parent material	:	Unconsolidated lacustrine sediments derived from various sources. The possible sources are: Basement System rocks, volcanic rocks, volcanic ashes and sandstones. The Chalbi is possibly underlain by sandstone; at least in the eastern part.
Relief	:	Flat. Slopes 0-1% (slope class A).
Erosion	:	Non to slight deflation. Deposition of sediments takes place after heavy rains.
Vegetation	:	Bare.
Land use	:	None to salt-lick for wild and domestic animals.
Surface rockiness/ stoniness	:	In places rock outcrops occur (sandstones/limestone).
Soils, general	:	The soils are poorly drained, very deep, reddish brown to olive grey, strongly calcareous, strongly saline and strongly sodic. They have a texture of clay. They have not well developed ABC or AC profile characteristics. Flooding occurs once or twice yearly after heavy rains.
colour	:	A-horizon: dusky red (2.5YR 3/2) to reddish brown (5YR 4/4).
		B or C-horizon: reddish brown (5YR 5/3) to olive grey (7.5YR 5/2).
texture	:	Clay.
structure	:	Massive, moderately coherent, in places breaking into medium, angular blocky.
consistence	:	Friable when moist, sticky and plastic when wet.
Chemical properties	:	A-horizon: the organic C content is about 0.6% in the top few cms, but is rapidly decreasing to 0.2-0.3%. The CEC is about 30-50me/100g. The pH-H2O varies between 8.2 and 10.0 (pH-KCl: 7.9-9.6). ECe varies from 20 to 70mmho/cm. ESP is over 30.
		B or C-horizon: the CEC is around 30 to 50me/100g. The base saturation is 100%. The pH-H2O is 9.6 to 10.2 (pH-KCl: 8.9 to 9.8). Strongly saline, with ECe values from 30 to 180mmho/cm, and strongly sodic with ESP values from 30 or higher. The CEC-clay varies from 60 to 125me/100g.
Clay mineralogy	:	Illite and montmorillonite are present in small amounts. Amorphous materials are dominating the clay fraction.

Diagnostic properties: A high salinity.

Soil classification : *orthic SOLONCHAKS, sodic phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 46 (observation no. 42-16).

Mapping unit PlnXA

Total area : 10,100ha.

Location : Chalbi desert.

Agro-climatic zone : VII.

Parent material : See PlnX1.

Relief : Flat.

Erosion : See PlnX1.

Vegetation : Bare.

Land use : None to salt-lick for wild and domestic animals.

Surface rockiness/ stoniness : In places outcrops of sandstone occur.

Soils pattern : The soils form an association of the soils of unit PlnX1 on the slightly higher lying parts and of the soils in the very shallow depressions.

Shallow depressions:

Soils, general : The soils of the very shallow depressions are poorly drained, very deep, greyish brown, strongly calcareous, strongly saline and strongly sodic. They have a texture of fine sandy loam to clay and an AC profile development.

colour : A-horizon: reddish brown (5YR 4/4).
C-horizon: greyish brown (2.5YR 5/2).

texture : Fine sandy loam to clay.

structure : Massive, moderately coherent, breaking into weak, medium to coarse, angular blocky.

consistence : Friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the organic C content varies between 0.1 and 0.4. The CEC varies between 20 and 30me/100g. The base saturation is 100%. The pH-H2O is 8.8 to 10.8 (pH-KCl: 8.4-9.8).

B-horizon: the CEC is about 35me/100g with a base saturation of 100%. The pH-H2O is around 10.4 (pH-KCl: 10.0). The whole profile is strongly saline and strongly sodic, with ECe values between 15 and 180mmho/cm. The ESP values vary between 40 to over 100%. The high values could be calculated because no correction for free salts was included. The CEC-clay is around 75me/100g.

Diagnostic properties: A high salinity.

Soil classification : *takyric SOLONCHAKS, sodic phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 47 (observation no. 43-5).

(f) Soils of the dissected lacustrine plains

Mapping unit PldXC

Total area	:	8,000ha.
Location	:	South and north of Loyangalani, along Lake Turkana.
Agro-climatic zone	:	VII.
Parent material	:	Sediments derived from various sources. This includes colluvium of volcanic rocks from Mt. Kulal, volcanic ashes deposited in the lake and fine, calcareous and lacustrine sediments (Pleistocene).
Relief	:	Irregular, from flat to gently undulating. Slopes from 0-5% (slope class AB).
Erosion	:	Slight rill erosion and slight deflation. Erosion is limited, due to the surface stoniness.
Vegetation	:	A very low cover with grasses and/or dwarf shrubs; at the lower level dominated by *Sporobolus spicatus*, at the higher levels also *Aristida spp.* and *Indigofera spinosa*.
Land use	:	Intensive grazing.
Surface rockiness/ stoniness	:	Exceedingly stony to exceedingly gravelly. Stones and gravel consist mainly of angular and subangular lava.
Soils, general	:	The soils form a complex of excessively drained to well drained, shallow to deep, dark brown to yellowish brown, strongly calcareous, moderately to strongly saline, moderately to strongly sodic, very stony and/or very gravelly loamy sand to clay soils with an ACR profile development. In places the soils are stratified.
colour	:	Dark brown (7.5YR 3/2) to yellowish brown (10YR 5/6).
texture	:	Very stony and/or very gravelly loamy sand to clay.
structure	:	Variable.
consistence	:	Variable.
Chemical properties	:	A-horizon: from only one profile, chemical data are available. The soils are well supplied with available Ca, Mg and P, but low in available K. The organic C content is 0.2%. The CEC is 28me/100g. The base saturation is 100%. The pH-H2O is 9.2 (pH-KCl: 7.8). The ESP is 10. C-horizon: the CEC is 25me/100g. The base saturation is 100%. The pH-H2O is 8.5 (pH-KCl: 7.6). The ECe is 16mmho/cm and the ESP is 12. The CEC-clay is 60me/100g.
Soil classification	:	Varies from *LITHOSOLS* and *FLUVISOLS* to *REGOSOLS*.

3.3.10 Soils of the floodplains

Mapping unit AUC

Total area	:	11,400ha.

Location	:	In the southern part of the study area.
Agro-climatic zone	:	VI and VII.
Parent material	:	Recent and sub-recent alluvial deposits derived from undifferentiated Basement System rocks.
Relief	:	Flat to nearly flat, slopes 0-2% (slope class A).
Erosion	:	Slight gully erosion and in places deflation. However, deposition occurs after heavy rains.
Vegetation	:	Deciduous woodland (riverine); dominated by *Acacia tortilis* with *Duosperma eremophilum* as understory.
Land use	:	Grazing with livestock and cutting for building material. The intensity of use depends on the location. Close to settlements the use is very intensive.
Surface stoniness	:	Nil.
Soils, general	:	The soils form a complex of well drained, very deep, brown, moderately to strongly calcareous, in places slightly saline, loamy sand to sandy clay soils. Profile development may be present, but is often very limited. Stratified soils as well as cracking soils occur.
colour	:	Mainly brown (7.5YR 5/4 and 4/4).
texture	:	Loamy sand to sandy clay.
structure	:	Variable.
consistence	:	Variable.
Chemical properties	:	A-horizon: the soils are moderately well supplied with available Ca and Mg. Available K is low to moderate and available P is very high. The organic C content ranges between 0.15 and 0.7%. The CEC is highly variable, depending on the texture. The pH-H2O is 7.5-8 (pH-KCl: 6.3-7.0).
		B or C-horizon: variable, depending on the texture and the location. In places slightly saline from 50cm downwards. Non sodic.
Soil classification	:	Variable.

Mapping unit AA1

Total area	:	1,400ha.
Location	:	The floodplains of the rivers near Lake Turkana.
Agro-climatic zone	:	VII.
Parent material	:	Alluvial deposits, mainly derived from various volcanic rocks, including ashes.
Relief	:	Flat to nearly flat, slopes 0-2% (slope class A).
Erosion	:	Erosional and depositional processes are going on together. Flooding occurs after heavy rains.
Vegetation	:	*Acacia tortilis* woodland with *Indigofera spinosa* dwarf shrubs. In places *Hyphaena coriacea* (doum palms).
Land use	:	Heavy grazing as well as cutting for domestic purposes.

Surface stoniness : Exceedingly stony and gravelly, consisting mainly of basalt.

Soils, general : The soils are somewhat excessively drained, very deep, dark brown, moderately calcareous and stratified. They have a texture of very stony and very gravelly loamy sand and do not show profile development, except for a very weak ochric A-horizon.

colour : Dark brown (7.5YR 3/2).

texture : Very stony and very gravelly loamy sand.

structure : Structureless, single grain.

consistence : Loose when dry and moist, non sticky and non plastic when wet.

Chemical properties : No samples were taken.

Diagnostic properties: The soils are developed on recent alluvial deposits and do not have diagnostic horizons other than an ochric A-horizon.

Soil classification : *calcaric FLUVISOLS, stony phase.*

Mapping unit AA2

Total area : 5,900ha.

Location : Balesa floodplain.

Agro-climatic zone : VII.

Parent material : Alluvial deposits, derived from various sources (Basement System rocks; Pleistocene volcanic rocks and ashes).

Relief : Flat to nearly flat. Slopes less than 1% (slope class A). In places however, small river dunes occur.

Erosion : Erosional and depositional processes both occur. Deflation occurs often in the dry season. Flooding of the floodplain rarely occurs.

Vegetation : Deciduous woodland with dwarf shrub understory. The main species are *Acacia tortilis, Salvadora persica, Duosperma eremophilum* and *Indigofera spinosa. Aristida* and *Sporobolus* grasses form the understory.

Land use : Grazing.

Surface stoniness : In a few places slightly stony (rounded basalts).

Soils, general : The soils are somewhat excessively drained, very deep, brown to strong brown, strongly calcareous, slightly sodic to (in places) strongly sodic and stratified. They have a texture of slightly gravelly sand to sandy loam and do not show profile development, except for a very weak ochric A-horizon.

colour : Brown (7.5YR 4/4).

texture : Slightly gravelly sand to sandy loam (stratified).

structure : Structureless; single grain.

consistence : Loose when dry and moist, non sticky and non plastic when wet.

Chemical properties : A-horizon: the soil is moderately well supplied with available Ca and Mg, K is low, P is high. The organic C content is about 0.2%. Base saturation is 100%. The CEC is 4-8me/100g. The pH-H2O is 7.5-8.5 (pH-KCl: 6.8-7.5).

C-horizon: the CEC is about 6me/100g. Base saturation is 100%. The pH-H2O is 7.5-8.5 (pH-KCl:6.4-7.5). Non saline and slightly sodic throughout the profile, with ESP values from 2 to 8. In places strongly sodic.

Clay mineralogy : Illite and kaolinite are the dominant clay minerals.

Diagnostic properties: Soils developed on recent alluvial deposits with only an ochric A-horizon.

Soil classification : *calcaric FLUVISOLS, sodic phase.*

For the description of a representative profile with analytical data see appendix 3, profile description no. 48 (observation no. 42-23).

Mapping unit AA3

Total area : 31,700ha.

Location : In the western, central and eastern parts of the Hedad.

Agro-climatic zone : VII.

Parent material : Alluvial deposits with sediments mainly derived from Basement System rocks often enriched with volcanic ashes.

Relief : Flat, slopes less than 1% (slope class A).

Erosion : Slight to moderate gully erosion and susceptible to heavy deflation after clearing of the vegetation. After heavy rains, flooding may occur for a few days with deposition of fresh materials.

Vegetation : Bushed grassland to grassland. *Acacia reficiens, A. tortilis, Balanites spp., Aristida spp., Bracharia spp. Cenchrus ciliaris* and *Leptothrium senegalense* are the most common species.

Land use : Grazing. The intensity depends on the location.

Surface stoniness : Nil.

Soils, general : The soils are well drained, very deep, brown and moderately to strongly calcareous. They consist of stratified sand to loam and show no profile development, except for a very weak ochric A-horizon. Buried A-horizons may occur. The topsoil consists of silt loam to loam.

colour : Brown (7.5YR 4/4 and 3/4).

texture : Sand to loam, varies with the different layers. In places gravelly layers occur. The topsoil has a texture of silt loam to loam.

structure : Single grain or porous massive, breaking into weak, medium, subangular blocky.

consistence : Loose to soft when dry, loose to very friable when moist, non to slightly sticky and non to slightly plastic when wet.

Chemical properties : A-horizon: the soils are low in available potassium, low to high in Mg, moderate to high in Ca and high in P. The organic C content ranges between 0.1 and 0.3%. The CEC soil is 10-18me/100g. The base saturation is 100%. The pH-H2O is 8.2 (pH-KCl: 7.1).

C-horizon: the CEC-soil ranges between 5 and 25me/100g. Base saturation is 100%. The pH-H2O is 7.5-8.5 (pH-KCl: 7.4-8.4). The CEC-clay is about 80-100me/100g.

Clay mineralogy : Kaolinite, illite and a mixed layer mineral are present in small amounts. Traces of smectite occur as well.

Diagnostic properties: The soils are developed on stratified, recent alluvial deposits and have only an ochric A-horizon as a diagnostic one.

Soil classification : *calcaric FLUVISOLS*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 49 (observation no. 54-9).

Mapping unit AA4

Total area : 2,100ha.

Location : North of Marsabit, on the lower slopes, about halfway to Maikona.

Agro-climatic zone : VII.

Parent material : Alluvial deposits derived from volcanic rocks, including ashes (Pleistocene).

Relief : Flat with slopes less than 1% (slope class A).

Erosion : Severe splash, rillwash and deflation.

Vegetation : Dwarf shrubland with *Duosperma eremophilum* and *Indigofera spp.* as the most common. Annual grasses occur as well.

Land use : Occasionally grazing.

Surface stoniness : In places stony and gravelly, consisting of basalt and very fine (less than 1cm) quartz, olivine, augite and basalt gravel.

Soils, general : The soils are well drained, very deep, dark brown, strongly calcareous, strongly saline and moderately to strongly sodic. They have a texture of stony and/or gravelly sandy loam to sandy clay loam and hardly any profile development.

colour : Dark brown (7.5YR 3/4).

texture : Stony and/or gravelly sandy loam to sandy clay loam.

structure : A-horizon: weak, fine to medium subangular blocky. C-horizon: porous, massive to moderately coherent.

consistence : Soft to slightly hard when dry, very friable when moist, slightly sticky to sticky and slightly plastic when wet.

Chemical properties : A-horizon: the soils are moderately well to well supplied with available nutrients, but low in potassium. The organic C content is about 0.1%. The CEC is 9me/100g.

Base saturation is 100%. The pH-H2O is 8.3 (pH-KCl: 7.2).

C-horizon: the CEC is about 20me/100g. Base saturation is 100%. The pH-H2O is around 7.8 (pH-KCl: 7.4). Strongly saline from 50cm depth (ECe up to 45mmho/cm) and moderately sodic from 15cm to strongly sodic after 90cm (ESP 10-20). The CEC-clay is about 120me/100g.

Clay mineralogy : Montmorillonite is dominant, but palygorskite and illite are present as well.

Diagnostic properties: A high salinity and no diagnostic horizons other than an ochric A.

Soil classification : *orthic SOLONCHAKS, stony* and *sodic phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 50 (observation no. 43-10).

Mapping unit AA5

Total area : 10,500ha.

Location : At the western and southern edge of the Marsabit lava.

Agro-climatic zone : VII.

Parent material : Alluvial deposits, sediments derived from both Basement System and volcanic rocks including volcanic ashes (Pleistocene).

Relief : Flat (slope class A).

Erosion : Slight gully erosion may exist. However deposition takes place during flooding after heavy rains. Deflation may take place especially after trampling by livestock.

Vegetation : Bushed grassland to grassland with *Acacia tortilis, A. seyal, Salvadora persica* and annual and perennial grasses as the most common species.

Land use : Grazing.

Surface stoniness : In general not stony, but close to the lava plateau the surface may be stony.

Soils, general : The soils are moderately well drained, very deep, reddish brown, slightly to strongly saline and slightly to strongly sodic. They have a texture of clay loam to clay. They are in places strongly calcareous and/or cracking. In places a hummocky microrelief is present.

colour : Reddish brown (5YR 4/4).

texture : Clay loam to clay.

structure : Weak, medium, prismatic, breaking into moderate fine to medium, angular blocky, with depth merging into massive, moderately coherent.

consistence : Hard when dry, very friable when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soils are well supplied with available nutrients, only K is low. The organic C content is

about 0.2%. The pH-H2O is 7.9 (pH-KCl 6.9). The CEC is 27me/100g. Base saturation is 100%.

B/C horizon: the CEC is around 30me/100g. Base saturation is 100%. The pH-H2O is 8.2 (pH-KCl: 7.1). Slightly to strongly saline, slightly to strongly sodic (based only on field data). The CEC-clay is 60me/100g.

Diagnostic properties: A very weak ochric A-horizon, an aridic moisture regime, a cambic B-horizon or deep cracks with a gilgai micro-relief.

Soil classification : *haplic YERMOSOLS* and *chromic VERTISOLS, saline* and *sodic phase*.

For the description of a representative profile with analytical data see appendix 3, profile description no. 51 (observation no. 55-10).

Mapping unit AAC

Total area : 13,400ha.

Location : At the lower course of the Balesa river, west of the Chalbi desert.

Agro-climatic zone : VII.

Parent material : Alluvial deposits, derived from various sources.

Relief : Flat to nearly flat, slopes 0-1% (slope class A). In places dunes occur, consisting of fine sand and silt.

Erosion : Severe rill erosion and moderate deflation.

Vegetation : Wooded shrubland with dwarf shrubs and annual grasses in the understory.

Land use : Seasonal grazing.

Soils, general : The soils of this unit form a complex of somewhat excessively drained to well drained, very deep, strongly calcareous soils of varying colour, consistence, salinity sodicity and texture.

Chemical properties : A-horizon: the soils are well supplied with available Ca and Mg, P is low to moderate, K is low. The CEC is variable, but often around 20me/100g. The base saturation is 100%. The pH-H2O is around 9.0 (pH-KCl: 7.6). Na toxicity may occur in places.

B/C-horizon: variable.

Soil classification : Variable.

3.3.11 Soils of the dunes

Mapping unit DXA

Total area : 55,200ha.

Location : At the eastern and western sides of the Chalbi desert.

Agro-climatic zone : VII.

Parent material : Aeolian deposits, overlying various parent materials (Pleistocene). The aeolian sands contain volcanic ashes. They overlie lacustrine sediments and, in the northwest,

sediments derived from Basement System rocks. In the east sandstones may underlie the dune area.

Relief : The dunes have an undulating to rolling relief with slopes from 2 to over 16% (slope class CDE). The interdunal depressions are flat.

Erosion : On the dunes, moderate splash and rillwash and slight deflation. In the depressions heavy rill erosion.

Vegetation : Bushed dwarf shrubland with *Euphorbia cuneata*, *Indigofera spinosa*, annual and perennial grasses as the most common species.

Land use : Slight to moderate, seasonal grazing with livestock.

Surface stoniness : Nil.

Soils, pattern : The soils form an association of two units. (1) The soils of the dunes and (2) the soils of the interdunal depressions. The soils of the dunes cover about 70-80% of the area.

(1) Dunes:

Soils, general : The soils are somewhat excessively drained, very deep, reddish brown to reddish yellow, moderately to strongly calcareous and strongly sodic. They have a texture of sand and show a not very well developed ABC profile development. The sand is often layered.

colour : A-horizon: brown (7.5YR 5/4 to 4/6).

B or C-horizon: reddish brown (5YR 4/4) to reddish yellow (7.5YR 6/6).

texture : Medium to fine sand, with a M50 of 200 to 400 micron.

structure : Structureless; single grain to massive, weakly coherent.

consistence : Loose to soft when dry, loose when moist, non sticky and non plastic when wet.

Chemical properties : A-horizon: the soils are very low in available K, Mg is low. Ca and P are moderate. The organic C content is below 0.1%. The CEC is 4me/100g. Base saturation is 100%. The pH-H2O is 9.0 to 9.8 (pH-KCl: 8.0-8.6).

B-horizon: the CEC is around 7me/100g. Base saturation is 100%. THe pH-H2O ranges from 9.4-10.0 (pH-KCl: 8.5-9.0). Strongly sodic, in places from the top of the profile with ESP values up to 30.

Clay mineralogy : Illite and montmorillonite occur in small amounts besides amorphous materials.

Diagnostic properties: A coarse texture and characteristics of a cambic B-horizon.

Soil classification : *cambic ARENOSOLS, sodic phase.*

Remark : In a few places, especially north of Kargi, the dunes are overlying lacustrine limestone and/or secondary limestone.

For the description of a representative profile with analytical data see appendix 3, profile description no. 52 (observation no. 43-4) which describes a dune soil overlying saline lacustrine sediments.

(2) Interdunal depressions:

Soils, general : The soils of the interdunal depressions cover about 20-30% of the surface area. They occupy the areas where the dunes have been completely eroded. These soils are imperfectly drained, very deep, yellowish red to dark brown, strongly calcareous, strongly saline and strongly sodic. They have a texture of sandy clay loam to clay and show AC or C-horizon characteristics.

colour : Yellowish red (5YR 4/6) to dark brown (7.5YR 4/2).

texture : Sandy clay loam to clay.

structure : Strong, coarse prismatic merging with depth into moderate, fine, angular blocky.

consistence : Hard when dry, friable to firm when moist, sticky and plastic when wet.

Chemical properties : A-horizon: the soil is deficient in available nutrients, except for Ca. Sodium toxicity occurs as well. The organic C content is about 0.1-0.2%. The CEC is around 20-35me/100g with a base saturation of 100%. The pH-H2O is around 9.0 (pH-KCl: 8.0).

C-horizon: the CEC-soil ranges from 20 to 35me/100g. The base saturation is 100%. The pH-H2O is 10.5 (pH-KCl: 9.4). The soils are strongly saline with an ECe of about 25mmho/cm, in places higher and strongly sodic with ESP values from 20 to over 70. These values may occur in the topsoil already. The CEC-clay ranges from 85 to 100me/100g.

Clay mineralogy : Montmorillonite and illite are the dominant clay minerals.

Diagnostic properties: A high salinity and no other diagnostic horizons than an ochric A-horizon.

Soil classification : *orthic SOLONCHAKS, sodic phase.*

3.4 SOIL CLASSIFICATION, CORRELATION AND GENESIS ASPECTS

3.4.1 Soil classification of the mapping units

For the purpose of classifying and correlating soils the FAO-Unesco (1974) legend for their "Soil Map of the World" has been used. The reasons for the selection of this system are explained in various Kenya Soil Survey publications (van de Weg and Mbuvi (eds), 1975; Sombroek et al, 1982). The FAO-Unesco system has been used in different types of soil surveys but most extensively in the various reconnaissance soil surveys and in the exploratory soil map. During its intensive use in these surveys the need was felt for adaptations and additions to this system. Some modifications and adaptations of the first and second level as well as the application of a third level terminology have been introduced. These additions and adaptations, known as "Kenyan concepts", are explained in the relevant Reconnaissance Soil Survey Reports (see fig. 1 and References) and in the Exploratory Soil Survey Report (Sombroek et al, 1982), while a summary is given by Siderius and van der Pouw (1980).

In appendix 4 the soil characteristics which are significant for classification are given. This table gives also the classification of the soils according to the Soil Taxonomy (Soil Survey Staff, 1975).

In addition to the already existing "Kenyan concepts" some new concepts are introduced. The following are being proposed:

At the second or subgroup level:

- *vertic YERMOSOLS*, being *YERMOSOLS* with vertic properties. They key out immediately after *luvic YERMOSOLS*. This could apply for *XEROSOLS* as well.

At the phase level:

- boulder-mantle phase. This concept was already used by Sombroek et al. (1982) in their exploratory soil survey but for this survey the definition is more precised. The boulder-mantle phase marks areas where the presence of boulders at the surface makes any arable use impossible and extensive range management impracticable or difficult. There should be a marked difference between the amount of boulders at the surface and in the soil. The surface needs to be exceedingly bouldery while the soil below is not very bouldery.

- stone-mantle phase. As for boulder-mantle phase, but with stones. The soil below the surface is not very stony.

Where there is no marked difference between the amount of boulders (stones, gravel) at the surface and in the soil, the bouldery (stony) phase is used. Bouldery (stony) phase and boulder (stone) mantle phase are mutually exclusive.

A description of the major soil classification units which occur in the survey area is given below (for the mapping unit codes and distribution see appendix 1).

(a) YERMOSOLS

YERMOSOLS are soils having an aridic moisture regime and a very weak ochric A-horizon. They show an ABC horizon sequence with gradual horizon boundaries. An aridic moisture regime is defined as having no period as long as 90 consecutive days when there is moisture in some or all parts of the moisture control section while the soil temperature is continuously above 8°C.

The criteria for separating *YERMOSOLS* from the *XEROSOLS* and both groups from the other units are at present not very satisfactory. They will be discussed further in chapter 3.4.2.

The *YERMOSOLS* in the survey area commonly have medium textures, but fine textured soils occur as well. The structure varies from porous massive to weakly or moderately well developed subangular blocky. The chemical fertility of these soils is mostly sufficiently high. The pH-H2O is 7 or higher. The dominating clay minerals are illite or palygorskite. In lower lying places montmorillonite occurs as well.

YERMOSOLS with a cambic B-horizon, the *haplic* ones, and with an argillic B-horizon, the *luvic* ones, are the most common. The argillic B-horizon shows clay skins and has a clay ratio B/A horizon of 1.2 or more but is not very well developed. Therefore, the *haplic* and *luvic* ones sometimes occur together in

the same mapping unit (mapping units U2FA and PsUA1). The *calcic YERMOSOLS* have over 15% secondary carbonates in the calcic horizon. The *vertic YERMOSOLS* have cracks of more than 1cm wide and are found in combination with *haplic YERMOSOLS* (mapping units YV3 and PsUA2). A gypsic horizon with enrichment of secondary calcium sulfate, was found in places in mapping units LsVC1 and LsVC2. The soils are classified as *gypsic YERMOSOLS*.

A summary of the different subgroups and the mapping units in which they occur is given below. It emphasizes the great extent of the *YERMOSOLS*.

luvic YERMOSOLS - U2F1, U2FA, FU1, FUA, PvVp, PsU1, PsU2, PsUA1

gypsic " - LsVC1, LsVC2

calcic " - FV1P, FVC, YV1p, PvVp

haplic " - HVP, U2FA, LsVC1, LsVC2, LnV1, LnV2, LnV3p, LdVP, FV2p, FVC, YV3, PsUA1, PsUA2, AA5

vertic " - YV3, PsUA2

Within the *YERMOSOLS* many phases had to be used. Boulder-mantle, stone-mantle, stony, lithic, petric, pisocalcic, petrocalcic, saline and sodic phases all occur, often in combination of two or more.

(b) XEROSOLS

XEROSOLS, like the *YERMOSOLS*, occur on those parts of the area which have an aridic soil moisture regime. The only difference between the two units is that *XEROSOLS* have a higher organic matter content in the A-horizon. Figure 9a clearly shows the difference between the organic matter content of a very weak ochric A-horizon and a weak ochric A-horizon as defined by FAO-Unesco (1974). It becomes also clear from this figure that for soils with a low sand/clay ratio the difference in the required organic matter content for a very weak ochric and a mollic A-horizon is minimal. Some more remarks on this differentiating criterion will follow in chapter 3.4.2.

The *XEROSOLS* usually have an ABC horizon sequence with gradual boundaries between the horizons, a weakly developed structure and favourable chemical properties. These soils only occur in mapping units RVA and FV3P. Those soils which have more than 15% secondary carbonates are classified as *calcic XEROSOLS*, while the soils with a cambic B-horizon have been mapped as *haplic XEROSOLS*. Where appropriate a stony, lithic or petric phase is indicated.

(c) SOLONETZ

SOLONETZ are soils with a natric B-horizon. The natric B-horizon has clayskins on the ped surfaces, a very clear increase in clay content from the A to the B-horizon due to illuviation (>20% in the B-horizon than in the A-horizon) and a columnar or prismatic structure in at least the upper part of the horizon. The upper part of the B-horizon has more than 15% exchangeable sodium. The soils show a clear A(E)BC horizon sequence whereby the boundary between the A(E) and the B is abrupt. In places the E horizon is tonguing into the B. There is a clear textural difference between the A(E) and the B-horizon, especially in unit PsU5 where a sandy topsoil in overlying sandy clay loam to sandy clay. The natric B-horizon has a low infiltration capacity, especially when wet. Hydromorphic properties however are not clearly present.

In the survey area only *orthic SOLONETZ* occur (without hydromorphic properties, without a mollic A-horizon) in mapping units LnV4p, PnSA, PsU3,

PsU4 and PsU5. The pH-H2O of the soils is 8 or higher. The nutrient availability is variable, but never very low. Available P is always high. The dominating clay minerals are illite, but palygorskite occurs as well. Mapping units PsU3, PsU4 and PsU5 have a saline phase and mapping unit LnV4p has a boulder-mantle, saline and partly stony phase.

(d) ARENOSOLS

The *ARENOSOLS* in the survey area are soils showing characteristics of argillic or cambic B-horizons which however do not qualify as diagnostic because of the textural requirements. Consequently the soils are coarse textured. The soils show an ABC horizon sequence with gradual boundaries between the horizons. The pH of the soils is neutral or higher.

In mapping unit FUA are, besides *cambic ARENOSOLS*, *luvic* ones present, showing lamellae of clay accumulation. *Cambic ARENOSOLS*, with characteristics of alteration, mainly through evidence of removal of carbonates or stronger chroma or redder hues than the underlying horizon, occur in mapping units U2FA, PnSA, PsUK, PsUA1, PsUA2 and DXA. Stone-mantle, stony, lithic, petric, petrocalcic and sodic phases were added when appropriate. The *cambic ARENOSOLS* without a phase (mapping units PsUA1 and PsUA2) or with a sodic phase (mapping units DXA and to a lesser extent PnSA) cover extensive areas.

(e) SOLONCHAKS

The *SOLONCHAKS* are soils characterised by a high salinity, viz. an electric conductivity of the saturation extract of more than 15mmho/cm. The soils have an AC or ABC horizon sequence and have medium to fine textures. In the survey area only *takyric*, with a heavy texture, a cracked surface when dry and with a platy or massive surface crust and *orthic SOLONCHAKS* occur (mapping units PlnXA and LnV4p, FVC, YV2, PlnX1, AA4 and DXA respectively). All the *SOLONCHAKS* have a high ESP and therefore a sodic phase. In places a stone-mantle, stony or petric phase occurs as well.

(f) REGOSOLS

REGOSOLS are soils developed on unconsolidated materials, exclusive of recent alluvial deposits, having no diagnostic horizons other than an ochric A-horizon. These soils have an AC horizon sequence with gradual boundaries between the horizons. Most of the *REGOSOLS* occurring in the survey area are calcareous at least between 20 and 50cm and are therefore classified as *calcaric REGOSOLS* (mapping units HP2P, LsV1P, LsVC1, LsVC2 and LsXp). The other subgroup indicated on the map are the *eutric REGOSOLS*, with a base saturation of 50% or higher (mapping units MPP and HP1P). Most of the *REGOSOLS* present in the survey area are shallow to moderately deep, except in mapping unit LsXp where the soils are deeper. Bouldery, stony, lithic, petric and sodic phases are indicated where appropriate.

(g) LUVISOLS

LUVISOLS are soils with an argillic B-horizon which has a base saturation of 50% of more. The B-horizon has clayskins on the ped surfaces and an increase in clay content through illuviation resulting in a clay ratio B/A-horizon of over 1.2. In the survey area the B-horizons are still porous and very permeable. The consistence (moist) is very friable to friable and the texture varies between sandy clay loam and clay. The dominating clay minerals are illite and/or kaolinite. Where kaolinite dominates the CEC-clay is below 24me/100g as is the case in mapping unit MUC. These soils are classified as

ferralo- chromic LUVISOLS*, being intergrades to *FERRALSOLS* and having reddish colours in the B-horizon. The other *LUVISOLS* always occur together with either *CAMBISOLS* or *NITOSOLS*. They have reddish colours in the B-horizon and are therefore classified as *chromic* ones (mapping units UlVl, LsV2 and RVA). Where appropriate a bouldery, stony or petric phase is indicated.

(h) CAMBISOLS

CAMBISOLS comprise soils with an ABC horizon sequence in which the B-horizon shows signs of alteration such as structure development, decalcification and stronger chromas or redder hues than the underlying horizon. They usually have a subangular blocky structure, a significant amount of weatherable minerals and a high CEC-clay. The consistence when moist is very friable to friable. The pH-H2O ranges from 6 to over 7. The clay minerals present vary from montmorillonite, illite to kaolinite. Where kaolinite is dominant, as in mapping unit RVp, the CEC-clay is below 24me/100g and the soils are classified as *ferralic CAMBISOLS*. The other two subgroups occurring are the *eutric CAMBISOLS*, having a base saturation of 50% or more at least between 20 and 50cm from the surface, and the *chromic** *CAMBISOLS* which have a high base saturation in combination with red colours in the B-horizon (mapping units MV2P, UlV3P, RVA and UlVl, LsV2 and RVA, respectively). A bouldery, stony, lithic or petric phase is indicated where appropriate.

(i) FLUVISOLS

FLUVISOLS are soils developed from recent alluvial deposits, having no diagnostic horizons other than an, in this area usually very weak, ochric A-horizon. They generally have an organic matter content which decreases irregularly with depth and show a clear stratification. They receive new sediments at irregular intervals. All the *FLUVISOLS* in the survey area are calcareous at least between 20 and 50cm from the surface and are therefore classified as *calcaric FLUVISOLS*. Mapping unit AAl has a stony phase, AA2 has a sodic phase and AA3 has no phase.

(j) PHAEOZEMS

PHAEOZEMS are soils with a mollic A-horizon and lacking a calcic or a gypsic horizon and concentrations of soft powdery lime within 125cm of the surface. The mollic A-horizon has dark colours and at least a moderately well developed structure and a consistence when dry which is slightly hard or softer. The organic matter content is at least 2%. In the survey area *PHAEOZEMS* with an argillic B-horizon are found in mapping unit MVl. They are classified as *luvic PHAEOZEMS*, partly stony phase. A part of mapping unit RVA has non calcareous and calcareous ones which have been mapped as *haplic* and *calcaric PHAEOZEMS*. These soils are moderately deep and stony, so they have a stony and petric phase.

(k) LITHOSOLS

LITHOSOLS are soils limited in depth by continuous coherent and hard rock within 25cm of the surface. They are not abundant in the survey area and are classified as *eutric LITHOSOLS*, having a base saturation of over 50% (mapping units MUC and HUP).

(l) VERTISOLS

VERTISOLS are heavy clay soils which develop cracks from the surface downwards which are at some periods in most years at least lcm wide to a depth

of 50cm. In the survey area they show gilgai microrelief (mapping unit AA5) or intersecting slickensides (mapping unit LsV3p) and wedge-shaped structural aggregates. Except from the A-horizon, they do not have very distinct horizons. The A is followed by a B or C-horizon. The dominating clay mineral is montmorillonite which causes swelling and shrinking upon wetting and drying, respectively.

VERTISOLS are not widespread in the survey area. They have dark reddish brown colours and are therefore classified as *chromic VERTISOLS*. Where appropriate, a stony, petric, saline and sodic phase is added.

(m) NITOSOLS

NITOSOLS are soils with an ABC horizon sequence. They are characterised by an argillic B-horizon with a fine texture. The increase in clay content from the A to the B-horizon is gradual. The characteristic structure of the B-horizon is strongly developed, fine to medium angular blocky with shiny ped faces. In the survey area *eutric NITOSOLS*, having a base saturation or over 50%, are only found in mapping unit U1V1 where they occur together with *chromic* LUVISOLS*.

3.4.2 Proposed modifications in the FAO-Unesco Legend

Some remarks about soil classification and some new proposals will be made in this chapter.

(a) ARENOSOLS

The need is felt to make a further subdivision of the *cambic ARENOSOLS* in order to separate the chemically poor from the rich ones and both from the *calcaric* ones. The following additions at the third level are proposed.

- *calcaro-cambic ARENOSOLS* are calcareous at least between 20 and 50cm from the surface
- *dystro-cambic ARENOSOLS* have a base saturation of less than 50 percent, at least in some part of the soil between 20 and 50cm of the surface
- *eutro-cambic ARENOSOLS*, other *cambic ARENOSOLS* with a base saturation of over 50 percent

Calcaro-cambic ARENOSOLS and *eutro-cambic ARENOSOLS* occur in the survey area, although they have not yet been classified as such. In the same way the *luvic ARENOSOLS* could be separated into *dystro-luvic* and *eutro-luvic ARENOSOLS*.

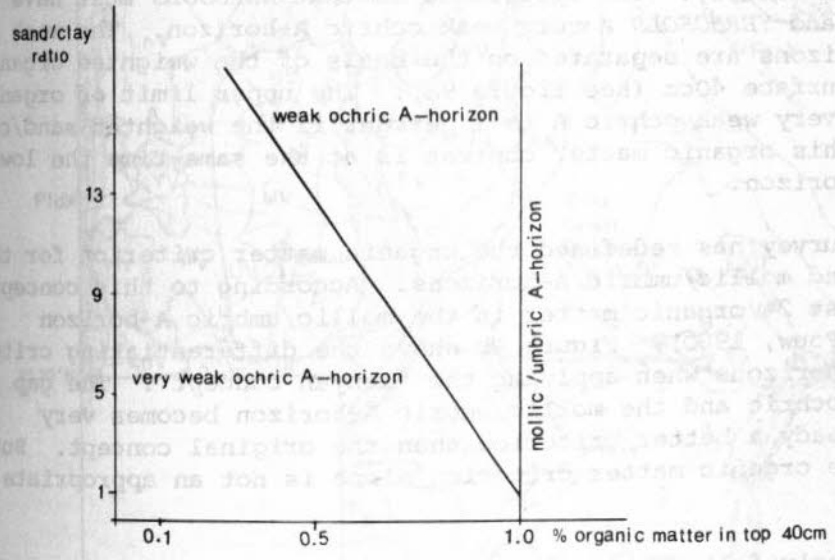
(b) YERMOSOLS-XEROSOLS

A major part of the area is occupied by *XEROSOLS*. In or close to agro-climatic zone V *XEROSOLS* occur.

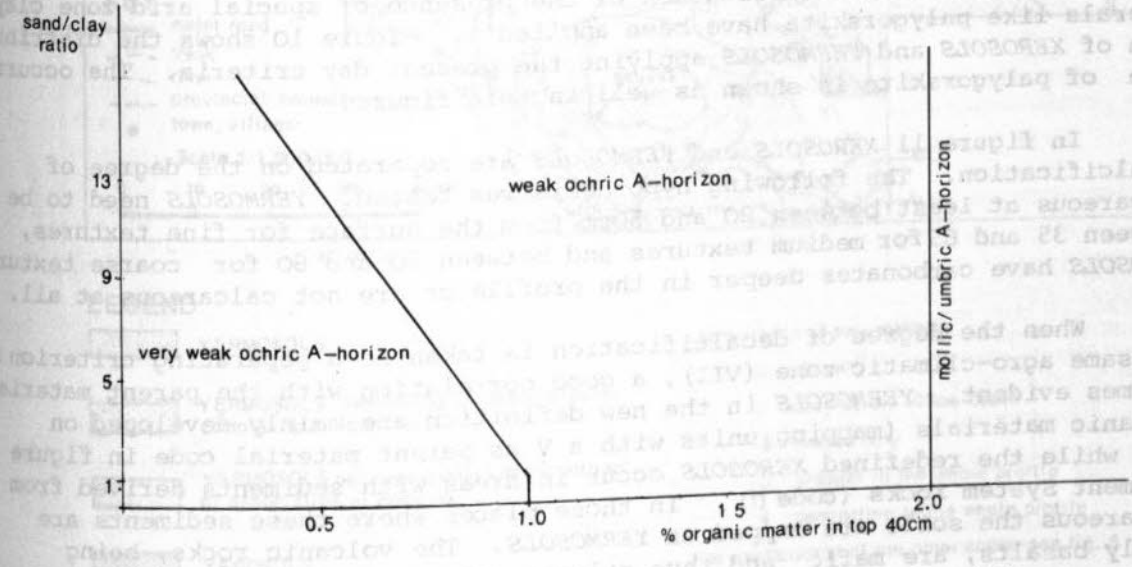
The diagnostic property to separate *XEROSOLS* and *YERMOSOLS* from other soils is the aridic moisture regime. An aridic moisture regime has no period as long as 90 consecutive days when there is moisture in some or all parts of the moisture control section while the soil temperature is continuously above 8°C.

No soil moisture measurements were carried out in the survey area but it is assumed that agro-climatic zones VII and VI have an aridic soil moisture

Fig. 9 **Differentiating criteria between a very weak ochric, a weak ochric and a mollic/umbric A–horizon in relation to organic matter content in the top 40cm of the soil.**



(a) As defined by FAO–Unesco (1974)



(b) As defined by FAO–Unesco (1974) and modified by Kenya Soil Survey (Siderius and van der Pouw, 1980)

regime. Zone V might have an aridic moisture regime as well but in this study soils occurring in zone V are regarded as having an ustic soil moisture regime.

The basis for separating *YERMOSOLS* from *XEROSOLS* as given by FAO-Unesco (1974) is not very satisfactory. The difference is that *XEROSOLS* must have a weak ochric A-horizon and *YERMOSOLS* a very weak ochric A-horizon. The weak and very weak ochric A-horizons are separated on the basis of the weighted organic matter content in the surface 40cm (see figure 9a). The upper limit of organic matter content for the very weak ochric A is 1 percent if the weighted sand/clay ratio is 1 or less. This organic matter content is at the same time the lower limit for a mollic A-horizon.

The Kenya Soil Survey has redefined the organic matter criterion for the limit between ochric and mollic/umbric A-horizons. According to this concept there should be at least 2% organic matter in the mollic/umbric A-horizon (Siderius and van der Pouw, 1980). Figure 9b shows the differentiating criteria between the various A-horizons when applying the "Kenyan concept". The gap between the very weak ochric and the mollic/umbric A-horizon becomes very apparent. This is already a better criterion than the original concept. But still it seems that the organic matter criterion alone is not an appropriate one.

It is also strongly felt that the limit of organic matter content is still far too high for a very weak ochric A-horizon. Besides this, the topsoil of *XEROSOLS* and *YERMOSOLS* is often affected by erosion and/or sedimentation processes, leading to a decline in organic matter content and thus making it inappropriate to use the organic matter as a diagnostic criterion. Other criteria have therefore been tested to separate *YERMOSOLS* from *XEROSOLS*. For example the depth of decalcification or the presence of special arid zone clay minerals like palygorskite have been applied[1)]. Figure 10 shows the distribution of *XEROSOLS* and *YERMOSOLS* applying the present day criteria. The occurrence of palygorskite is shown as well in this figure.

In figure 11 *XEROSOLS* and *YERMOSOLS* are separated on the degree of decalcification. The following hypothesis was tested. *YERMOSOLS* need to be calcareous at least between 20 and 50cm from the surface for fine textures, between 35 and 65 for medium textures and between 50 and 80 for coarse textures. *XEROSOLS* have carbonates deeper in the profile or are not calcareous at all.

When the degree of decalcification is taken as a separating criterion in the same agro-climatic zone (VII), a good correlation with the parent material becomes evident. *YERMOSOLS* in the new definition are mainly developed on volcanic materials (mapping units with a V as parent material code in figure 11), while the redefined *XEROSOLS* occur in areas with sediments derived from Basement System rocks (code U). In those places where these sediments are calcareous the soils are mapped as *YERMOSOLS*. The volcanic rocks, being mainly basalts, are mafic and thus release calcium carbonates upon weathering, whereas the Basement System rocks are felsic and do not contain much calcium. In a few places the Basement System rocks contain limestone bands. One of these was found in the hills in the western part of the survey area where it may explain the occurrence of calcareous soils. Also a few observations in the Korante plains indicated the presence of calcareous soils.

Based on these observations it seems that the influence of parent material on the speed and degree of decalcification is overruling the climatic influences. Therefore it can be concluded that the degree of decalcification is not a good criterion in this area for separating *XEROSOLS* from *YERMOSOLS*.

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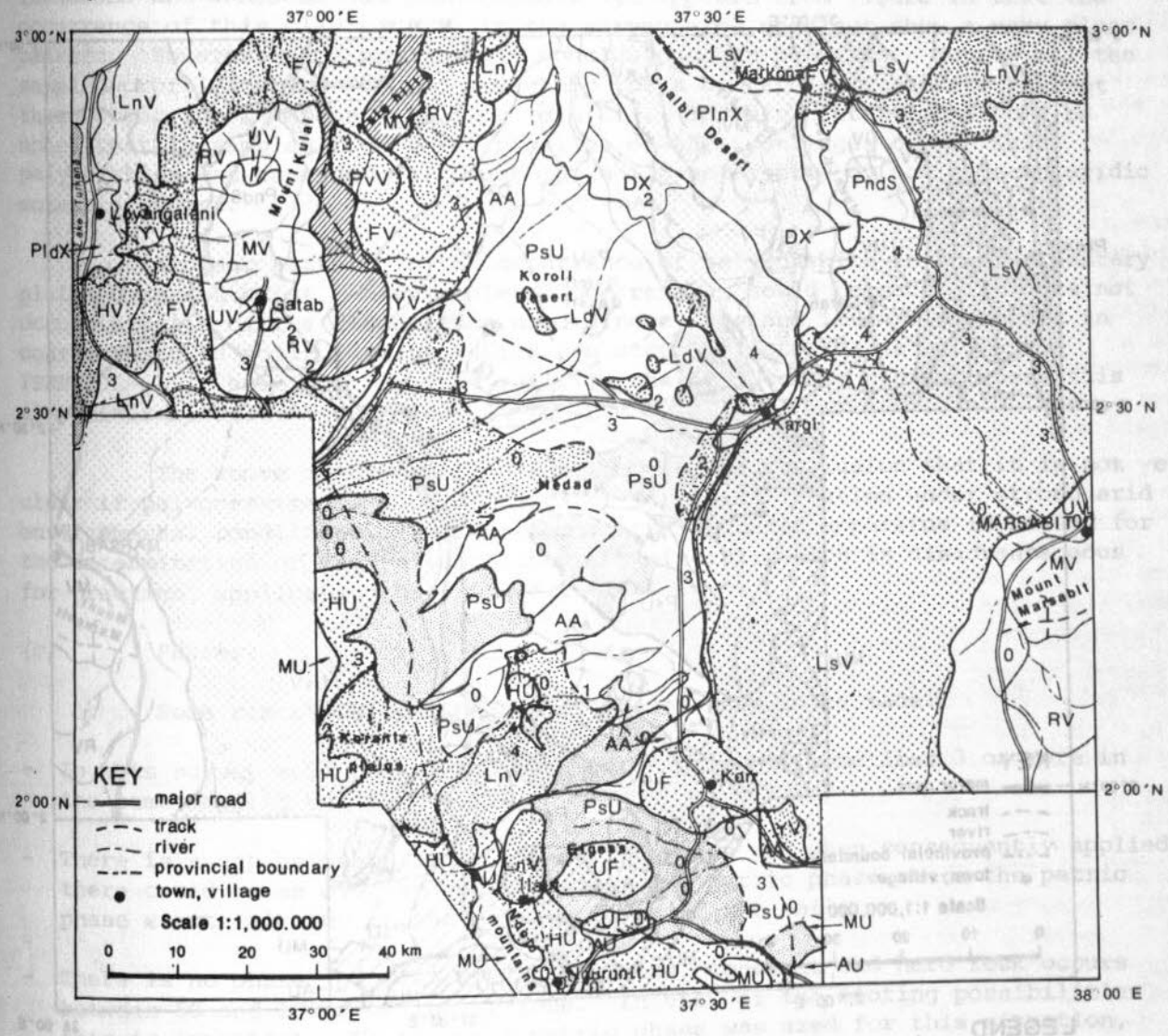
1) *The place of these soils in the key to the soil units (classification) does not change, only the weak and very weak ochric A-horizon criterion is replaced by the above described requirements.*

Fig.10 Distribution of YERMOSOLS and XEROSOLS and the occurrence of palygorskite



LEGEND

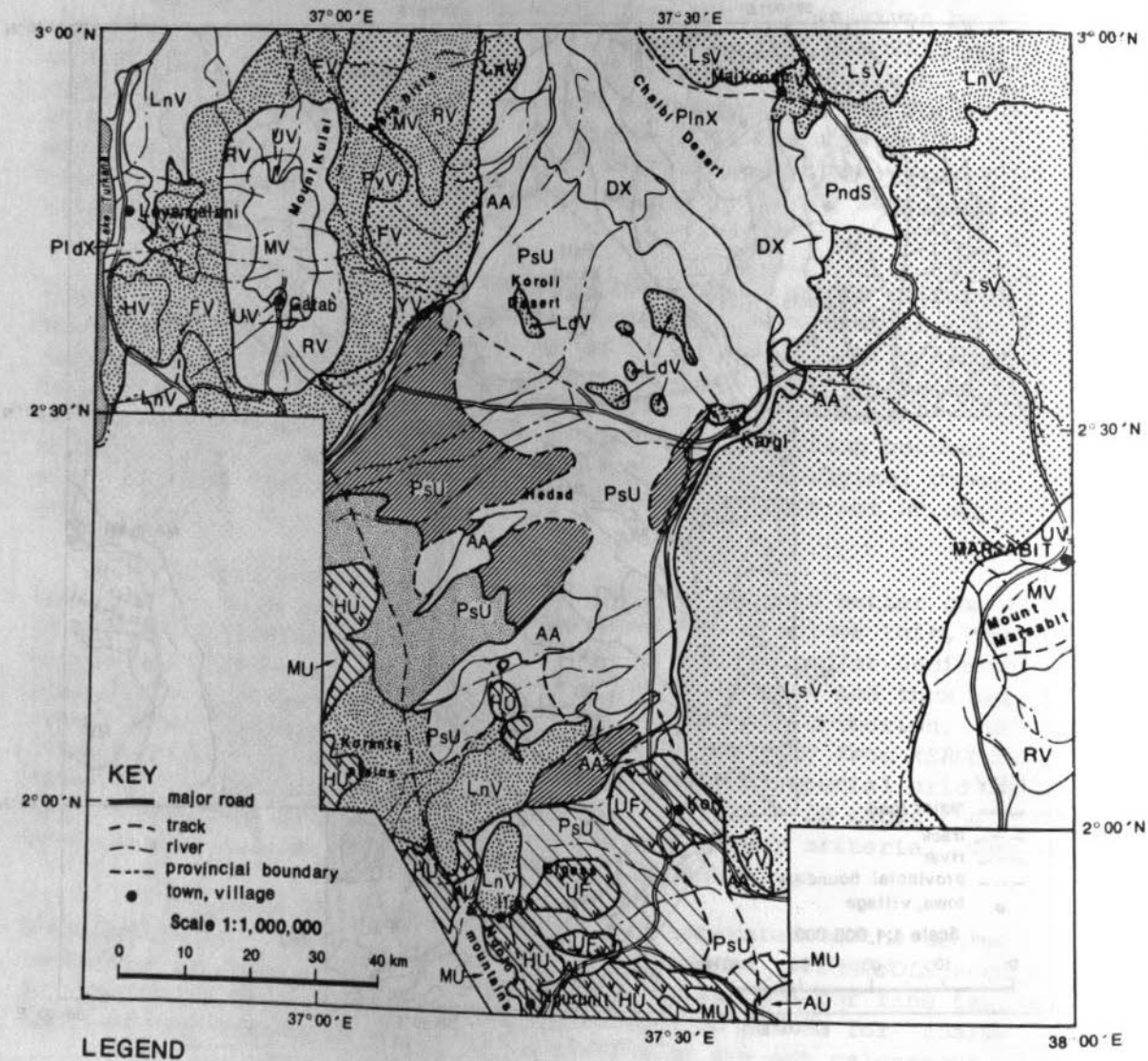
- YERMOSOLS
- YERMOSOLS dominating in association or complex with other soils
- YERMOSOLS occupying only a minor portion of association or complex
- XEROSOLS

occurrence of palygorskite

- 0 absent
- 1 only below 100cm depth
- 2 traces only
- 3 present in the whole profile
- 4 dominating in the whole profile

For explanation of the other codes see fig. 5

Fig.11 YERMOSOLS and XEROSOLS separated on the degree of decalcification



LEGEND

YERMOSOLS being calcareous at least between 20 and 50cm from the surface for fine textures, between 35 and 65cm for medium textures and between 50 and 80cm for coarse textures

- YERMOSOLS
- YERMOSOLS dominating in association or complex with other soils
- YERMOSOLS occupying a minor portion of association or complex

XEROSOLS, having calciumcarbonates deeper in the profile or being not calcareous at all

- XEROSOLS
- XEROSOLS dominating in association or complex with other soils
- XEROSOLS occupying a minor portion of association or complex

For the explanation of codes see fig. 5

The presence of palygorskite as a separating criterion between *YERMOSOLS* and *XEROSOLS* was also tested. It appears from figure 10 that the occurrence of this clay mineral in the survey area does not show a very clear pattern. However, some preliminary conclusions can be drawn. Nearly all the sampled profiles which occur on volcanic rocks contain palygorskite, except those occurring in areas with high rainfall. In this context it should be noted that in samples from three profiles on the footridges of Mt. Kulal palygorskite was recorded, although the soils apparently do not have an aridic moisture regime.

A clear pattern in the occurrence of palygorskite in the sedimentary plains does not exist. Nevertheless some remarks could be made. It does not occur in soils of the floodplains or drainage ways and it is also absent in coarse textured soils. Palygorskite can occur in *SOLONETZ* as well as in *YERMOSOLS*. In some well drained soils in the sedimentary plains, where this clay mineral could be expected, it is absent.

The above mentioned findings lead to the conclusion that it is not yet clear if palygorskite is a good indicator for soil formation under strong arid environmental conditions. Besides this, sophisticated apparatus is needed for the determination of the palygorskite clay mineral, which is disadvantageous for practical application of this criterion.

(c) Phases

Some remarks about the use of phases have to be made:

- In this survey soil phases are very often present, sometimes 3 or more in the same mapping unit.
- There is a gap between lithic and petric phase and when consequently applied, there could be an overlap between stony and petric phase where the petric phase starts already in the surface layer of the soil.
- There is no phase foreseen when continuous, coherent and hard rock occurs between 50 and 100cm of the surface. In view of the rooting possibilities this is important. Up to now a petric phase was used for this situation, but most of the petric phases are penetrable for roots. So the following new phase is proposed.

Semi-lithic phase: The semi-lithic phase marks soils where continuous coherent and hard rock occurs within 50 to 100cm of the surface. To the definition of petric phase should then be applied "the concretionary layer or the layer with coarse fragments is penetrable by roots".

3.4.3 Some aspects of soil genesis

Some apects of soil genesis in relation to time, climate, topography and slope will be dealt with. Very clear relationships between soils and parent material are not present as most of the soils are relatively young and seem to have been formed under climatic conditions not very different from the present day climate.

a) Influence of climate

Strongly weathered soils occur on the relatively moist (agro-climatic zone IV) tops of the Basement System mountains of which only the fringes of the Ndoto mountains lie within the survey area. *Ferralo*- chromic LUVISOLS* with a

CEC-clay of 23 me/100g were found here (mapping unit MUC). The soils occur on some flat parts on the tops of the Ndoto mountains which could represent rests of an old planation surface. Also on the footridges of Mt. Marsabit (agro-climatic zone V) highly weathered soils are found (*ferralic CAMBISOLS* of mapping unit RVp) with a CEC-clay of 12 me/100g in the B-horizon. The clay minerals are dominated by kaolinite, but the pH is neutral. Weathering basalt is present in the profile as well. The preponderance of kaolinite together with weathering basalts and a high pH could not be explained.

It would be expected that the soils on top of Mt. Kulal and Mt. Marsabit show properties which indicate a higher degree of weathering than elsewhere in the survey area as these soils occur higher and consequently receive more rain. The pH and base saturation follow this pattern but the soil classification differs. Only on top of Mt. Marsabit a clear argillic B-horizon is present. The soils are classified as *luvic PHAEOZEMS* with a CEC-clay of 50 me/100g, a base saturation of 50% and a pH of 4.8 (mapping unit MV1). On top of Mt. Kulal *eutric CAMBISOLS* occur with a CEC-clay of 28 me/100g, a base saturation between 60 and 80% and a pH of 6.2 (mapping unit MV2P).

A kind of toposequence is found on the high level uplands on Mt. Kulal and Mt. Marsabit. On these relatively flat parts of the mountains, which are the most stable ones, a sequence from more to less developed soils is present from high to lower altitudes. As rainfall is positively correlated with altitude, the climatic factor could have played the leading role. Table 10 gives various parameters of these soils in relation to altitude.

Table 10. Some soil characteristics of the high level uplands in relation to altitude

mapping unit	altitude (m)	agro-clim. zone	CEC-clay[1] (me/100g)	base sat.[1] (%)	C[2] (%)	pH-H2O[1]	soil classification
U1V1	1,650	IV	35	85	2.5	6.9	*eutric NITOSOLS/ chromic* LUVISOLS*
U1V2	1,320	IV-V	45	80	(1.9-(2.5	6.8	*chromic CAMBISOLS*
U1V3P	1,200	V	75	100	(0.5-(1.4	7.4	*eutric CAMBISOLS*

1) *B-horizon*

2) *A-horizon*

A very clear topo-sequence can be found when the organic matter content and the C/N quotient in the whole surey area are studied. They reflect the present day climate on soil formation. Table 11 gives the relation between the organic C-content in the A-horizon of the soil and the agro-climatic zones.

Table 11. Organic C-content and C/N quotient of the A-horizon in relation to the agro-climatic zones

Agro-climatic zone	III	IV	V	VI	VII
% C	3.0-4.0	2.0-2.9	0.6-1.9	0.5-0.8	0.1-0.4
C/N	10	10	9-10	5-8	3-8

It is obvious that there is a clear increase in the organic matter content from the low lying areas with a low rainfall to the high lying areas with a high rainfall. The range in C/N ratios is rather high in agro-climatic zones VII and VI but values of around 7 are the most common[1)]

The C/N quotient of the soil under natural conditions is mainly dependent on the microbial population and its C/N ratios. Actinomycetes have a C/N ratio of around 5. It is known that these micro-organisms occur in high amounts in arid regions with alkaline soils. Bacteria with a C/N of 10 prefer more neutral environments (Alexander, 1976). It can be concluded that in ecological zones VI and VII where slightly alkaline soils are dominating, actinomycetes form the major part of the microflora and that in ecological zones III to V, where neutral to slightly alkaline soils are found the microflora consists of bacteria.

b) Influence of parent material and hydrology

In the sedimentary plains a very clear sequence of soils from the western towards the eastern and north-eastern parts is present. They range from coarse textured *cambic ARENOSOLS*, via medium textured, *luvic YERMOSOLS* with a sodic phase to medium and fine textured *orthic SOLONETZ* and finally in the north-east to fine textured *SOLONCHAKS*.

Several factors played a role in the genesis of this sequence. The first is the distance from the source of the parent material. In the processes of transportation of the erosion products from the Basement System mountains in the west, the finer materials have been carried further away to the east and north-east. Another source for the sediments in the Chalbi desert are the volcanic rocks which provide mainly silt size and clay particles from Mt. Kulal, the Asie hills and Mt. Marsabit.

The second factor is the hydrology. Water coming from the mountains in the west carries with it the soluble weathering products of the Basement Sysytem rocks. As these rocks are mainly felsic, sodium salts will form an important constituent. Due to the general slope the water will accumulate more frequently in the north-eastern plains and by evaporation salts will accumulate. The concentration of the salts increases in the same direction as this general slope. This is now reflected in the sodicity of the soils which is increasing from west to east. It has lead to the formation of *SOLONETZ* soils in the eastern and north-eastern parts of the plains. The high amount of Na-ions in the soil leads to a high amount of exchangeable Na at the exchange complex of the clay minerals. High amounts of exchangeable Na are leading to instability of the clay minerals and they will disperse easily upon wetting. Clay evaluation from the topsoil takes place as well as illuviation into the subsoil, finally leading to an AE horizon with a coarse texture and an argillic B-horizon which can become virtually impermeable. The argillic B-horizon of the *SOLONETZ* soils has a characteristic prismatic or columnar structure. The degree of sodicity and the degree of structural formation increases from west to east/north-east. Unit PsU5 has soils with an abrupt textural change between the A and the B-horizon and shows commonly well developed, coarse columns. The latter phenomena is known as solodization and involves the destruction of clay minerals and consequently an accumulation of silicon compounds (Szabolcs, 1979).

The surface layer of the soils in mapping unit PsU5 has become so poor in clay that hardly any binding components are left. Splash and rill erosion and also locally deflation have caused an irregular mesorelief. In

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1) Values of 3 possibly indicate analytica errors due to the extreme low organic matter content of the soils.

places the top of the B-horizon is now at the surface surrounded by areas with sand accumulation. The sand can be accumulated into a kind of obstacle dunes up to 1m in height, but 50cm is more common. Closer to the Chalbi desert these pseudo-dunes become higher and gradually change into real dunes. The difference between pseudo and real dunes is arbitrarily based on the degree of sorting of the sand.

No laboratory data on sand size distribution are present and therefore field data are used. More precise research in this subject is however recommendable. The sands of the pseudo-dunes hardly show a sorting of any kind, being evidence of transport over only very short distances. The real dunes show a better sorting of the sand fraction, although a very good sorting was only occasionally present. The source of the sands could well have been derived from the eroded A-horizon of the *SOLONETZ* soils, deposited in the Chalbi and after drying of the surface blown back and redeposited by the wind into dunes. Another source could be the weathered sandstones in the east. The greater part of the dunes overlie lacustrine sediments and thus are clearly not the result of the *SOLONETZ* forming processes.

Highly saline soils, *SOLONCHAKS*, are found in low lying, rather flat places where stagnating water evaporates and the salts accumulate. The Chalbi desert is the largest area where water from various parts is collected. This basin does not have an outlet and temporarily a shallow lake forms until the water is evaporated and consequently the salts accumulate. Therefore the Chalbi desert is not a climatic but a halophytic desert. The very high salinity is inhibiting plant growth. Other places with high salinity are found south-east of Korr (Uya swamp) at the foot of the Marsabit lava and near Olturat at the foot of Mt. Kulal, as well as along the shores of Lake Turkana.

3.4.4 Correlation between the FAO-UNESCO and the Soil Taxonomy soil classifications

The FAO-Unesco system (1974) is not a classification system sensu-stricto but a legend for the soil map of the world. It can be used for classifying soils and for the sake of simplicity it is called a classification system in this paper.

The Soil Taxonomy (1975), is a morphometric system as all properties used to characterize the soils can be measured in the field or in the laboratory. Diagnostic soil horizons and properties are used to separate the higher categories. The Soil Taxonomy distinguishes six categories. In this survey the soils are classified to subgroup level (4th level) and mostly also to family level. The classification to subgroup level usually did not present difficulties as enough data were gathered during the soil survey. For the classification at family level this was not always the case as mineralogical data were often lacking, but best possible estimations have been made.

Several definitions of diagnostic horizons and properties used in the FAO/Unesco legend are drawn from the Soil Taxonomy. The two systems, although the FAO/Unesco one is much simpler, are therefore easily comparable, especially in the higher categories.

One of the major differences between the two systems is the use of the soil moisture regime (see also ch. 3.4.1). The soil moisture regime is used at the highest levels in the Soil Taxonomy for all orders while in the FAO/Unesco system it is only diagnostic for *XEROSOLS* and *YERMOSOLS*.

In appendix 4 the classification of the soils of all the mapping units together with the range of soil characteristics is given applying both systems.

For easier reference table 12 gives the correlation of the FAO/Unesco and the Soil Taxonomy soil classification. The FAO-Unesco names are put in alphabetical order. Some observations can be made:

- In general the correlation is very good. The Soil Taxonomy has no separate class for the *calcaric* subgroups as present in the FAO-Unesco system.
- *LITHOSOLS* and lithic phases have a lithic subgroup in the Soil Taxonomy.

Other phases of the FAO-Unesco system are not reflected in the higher categories of the Soil Taxonomy. They only appear at family or lower levels (e.g. stony phase - skeletal textural class).

Table 12. Correlation between the FAO-Unesco and Soil Taxonomy soil classifications

FAO-Unesco	Soil Taxonomy
cambic ARENOSOLS	Typic Torripsamments
luvic ARENOSOLS	Alfic Torripsamments
eutric CAMBISOLS	Typic Ustropepts
eutric CAMBISOLS (lithic)[1)]	Lithic Ustropepts
chromic CAMBISOLS*	Typic Ustropepts
ferralic CAMBISOLS	Oxic Ustropepts
calcaric FLUVISOLS	Typic Torrifluvents
eutric LITHOSOLS	Lithic Torriorthents
chromic LUVISOLS*	Udic Paleustalfs
chromic LUVISOLS*	Aridic Haplustalfs
ferralo-chromic LUVISOLS*	Oxic Haplustalfs
eutric NITOSOLS	Udic Paleustalfs
calcaric PHAEOZEMS	Entic Haplustolls
haplic PHAEOZEMS	Entic Haplustolls
luvic PHAEOZEMS	Udic Argiustolls
calcaric REGOSOLS	Typic Torriorthents
calcaric REGOSOLS (lithic)	Lithic Torriorthents
eutric REGOSOLS (lithic)	Lithic Ustorthents
orthic SOLONCHAKS	Typic Salorthids
takyric SOLONCHAKS	Typic Salorthids
orthic SOLONETZ	Typic Natrargids
chromic VERTISOLS	Typic Torrerts
haplic XEROSOLS	Typic Camborthids
haplic XEROSOLS (lithic)	Lithic Camborthids
calcic YERMOSOLS	Typic Calciorthids
calcic YERMOSOLS (lithic)	Lithic Calciorthids
gypsic YERMOSOLS	Cambic Gypsiorthids
haplic YERMOSOLS	Typic Camborthids
haplic YERMOSOLS (lithic)	Lithic Camborthids
luvic YERMOSOLS	Typic Haplargids
vertic YERMOSOLS*	Vertic Camborthids

1) *lithic phase*

3.5 SOIL PHYSICAL ASPECTS

3.5.1 Bulk density

The bulk density of the soil is the weight of oven dry soil per unit of volume, mostly expressed in g/cm3. Bulk density measurements were carried out at samples of 14 different soil pits. Unfortunately not enough data were collected to arrive at conclusions about the effects of soil degradation on the bulk density in areas with accelerated erosion around villages and watering points. In table 13, some bulk density figures are given in relation to soil type and parent material.

Table 13. Bulk density of some soils in relation to soil type and parent material

	No. of samples	bulk density (g/cm3)	
soils on sediments derived from Basement System		A-horizon	B-horizon
YERMOSOLS	8	1.60	1.62
SOLONETZ	5	1.67	1.61
soils on various volcanic rocks	2	1.2	

Some prelimenary conclusions can be drawn from this table:

- There is no significant difference between the bulk density of *YERMOSOLS* and *SOLONETZ*.
- There is no significant difference between the bulk density of the A and the B-horizons of the above mentioned soils.
- The bulk density of the soils developed on various volcanic rocks is low. This sugguests a major influence of volcanic ashes, which usually have a very low bulk density, on the parent material. It has to be mentioned that these data are derived from two soil profiles only, located on the northern slopes of Mt. Marsabit. Generalisation, therefore, is not possible.

3.5.2 Soil moisture

The amount of water which can be removed from the soil by drying at 105°C is generally regarded as soil moisture. The soil moisture storage capacity depends mainly on the texture although the soil structure and the organic matter play a role as well. The capacity of the soil to retain water is very important as the vegetation in the survey area has to rely solely on the amount of water stored in the soil because groundwater is hardly anywhere within reach of the root-system of the vegetation.

The precipitation, almost entirely in the form of rain, is the only source of water which can enter the soil. However, not all the rainwater falling on the surface of the soil will enter. Several loss factors or barriers may exist. If the rainfall intensity exceeds the infiltration capacity of the soil, runoff will take place. The amount of runoff is a function of

several factors of which slope, texture of the topsoil, vegetation cover and the presence of a surface crust or seal are the most important ones. Surface sealing is present in the area but is not continuous. The crust is rather soft and when moist it is very permeable for water. Slump crusts only occur in areas with a heavy textured topsoil and these are not widespread. Generally speaking no impermeable surface horizons occur. It has however to be mentioned that in places where the B-horizon of the *SOLONETZ* is at the surface, water stagnation takes place. For the nomades of the area this has a positive effect as these shallow pools serve as temporary water-points for their livestock. Mainly due to time constraints no infiltration measurements were carried out.

The amount of water retained in the soil against the force of gravity after saturation is called the field capacity, often expressed as a volume percentage. The binding force with which the water is hold is low and generally a corresponding pF value of 2.0 is accepted as the tension with which this water is hold. A pF value of 2.0 corresponds with a tension of 0.1 atmosphere (0.1 atm = 100 cm water pressure; log 100 = 2). The permanent wilting point is usually set at a pF of 4.2 (corresponding with a tension of 15 atm). The Kenya Soil Survey uses a pF value of 2.3 for field capacity and a pF of 3.7 for the upper limit of inhibited growth. The amount of water stored between pF 2.3 and 3.7 is regarded as readily available water for the plant. However, in the case of a natural vegetation which is adapted to harsh conditions, the plants may be able to extract water from the soil up to a pF of 4.2. That is the reason why the total amount of available water for this survey is based on the difference in moisture content from between pF 2.0 and 4.2. From only a few profiles in the area reliable pF data are available. Based on these data and on experience elsewhere (e.g. Braun and van de Weg, 1977), a tentative relation between texture and total available soil moisture could be established. Table 14 gives the total available moisture percentage in relation to the texture.

Table 14. Total available moisture (pF 2.0 - pF 4.2) in relation to texture

texture	total available soil moisture (volume %)
silt loam	20
clay - sandy clay	17
sandy clay loam	15
sandy loam	12
loamy sand	10
sand	6

The amount of water available for the plant depends on the quantity of water infiltrated, the soil moisture storage capacity, the soil depth and the rooting depth. The soil depth indicated on the soil map is the depth to continuous coherent bedrock. Roots may however experience other physical or chemical barriers when penetrating the soil. In this respect strong salinity or sodicity in parts of the area are inhibiting factors for root development. Calculations on soil moisture availability and length of growing season are carried out in chapter 4 (Land evaluation).

3.5.3 Soil moisture regime

Both in the FAO/Unesco Legend of the "Soil Map of the World" (1974) and in the Soil Taxonomy (Soil Survey Staff, 1975) the soil moisture regime is used for the classification of the soils. The FAO/Unesco System only uses the aridic soil moisture regime as the diagnostic criterion for the *XEROSOLS* and *YERMOSOLS* (see chapter 3.4 on the soil classification). In the Soil Taxonomy the soil moisture regime is used in defining classes in the very high categories. The moisture regime is regarded as a very important property of the soil as well as a determinant of processes that can go on in the soil. E.g. for the movement of salts, leaching of elements and the formation of an argillic horizon water moving though the soil is a pre-requisite (Soil Survey Staff, 1975). The determination of the moisture regime can best be done through long term measurements. As these data are scarce, an estimation of the soil moisture regime can be done by relating it to meteorological records.

In the survey area, no soil moisture measurements were carried out, but from the available climatic data some conclusions can be drawn. The agro-climatic zones VII and VI, receiving a low rainfall and having a high potential evapotranspiration, certainly have an aridic soil moisture regime. In the aridic moisture regime, the moisture control section in most years is (1) dry in all parts more than half the time (cumulative) that the soil temperature at a depth of 50 cm is above 5°C and (2) never moist in some or all parts as long as 90 consecutive days when the soil temperature at a depth of 50 cm is above 8° C. The moisture control section lies approximately between 10 and 30 cm for fine textured soils, between 20 and 60 cm for medium textured soils and between 30 and 90 cm for coarse textured soils.

The soils in agro-climatic zones III and IV, corresponding more or less with the Marsabit climatic data, most probably have an ustic moisture regime. The ustic moisture regime is one of limited moisture and for the survey area, where the difference between summer and winter soil temperatures is less than 5°C, defined as follows. The moisture control section in the ustic moisture regime is dry in some or all parts for 90 or more cumulative days in most years. But the moisture control section is moist in some part for more than 180 cumulative days, or it is continuously moist in some part for at least 90 consecutive days.

The soils in agro-climatic zone V are assumed to have mainly an ustic moisture regime. Calculations done in chapter 4 give results of over 100 and sometimes over 150 days with available moisture in zone V. Although these days are not always consecutive, the results approach closely the requirements for an ustic soil moisture regime.

3.5.4 Soil temperature

The temperature of the soil is an important property. Soil temperature has a considerable influence on biological, chemical and physical processes in the soil. In the survey area no soil temperature measurements were done. Van Wijngaarden and van Engelen (1975) have published extensive measurements in the Tsavo area and although the air temperature in the major parts of the survey area are higher than in Tsavo, it can be expected that their data are valid for this area as well. Therefore, some of their conclusions are given below. The vegetation has a pronounced effect of soil temperature and the daily temperature range, especially in the top 30 cm of the soil. On a bare surface, values of twice the average monthly

maximum temperature where measured, whereas under a tree cover the temperatures were 10 to 20°C lower. Below 30 cm depth the daily and monthly variations in soil temperature are relatively small. At 30 cm the soil temperature in the open is about 1° to 2°C higher than the average monthly maximum temperature. Under a tree this is comparable to the average maximum temperature or 1°C less. Rainfall has a reducing effect on the soil temperature.

The greater part of the survey area, at least agro-climatic zones VII and VI and probably zone V, has an isohyperthermic soil temperature regime. The mean annual soil temperature is 22°C or higher and the difference between the mean summer and mean winter temperature is less than 5°C. Agro-climatic zones III and IV are likely to have an isothermic soil temperature regime. The mean annual soil temperature is 15°C or higher but lower than 22°C with a difference of less than 5°C between summer and winter.

3.6 SOIL FERTILITY ASPECTS

In order to assess the soil fertility, only the chemical aspects are considered. Of the many methods for the determination of available plant nutrients, the Kenya Soil Survey currently uses the Mehlich method for the analyses of composite topsoil samples from 0-20 cm depth (see chapter 2.2). From this analysis only P, Ca, K and Mg are being considered. Available P was not always determined with the Mehlich method, but often with the Olsen method. The results of this method may be higher than those obtained from the Mehlich analyses as the Olsen method was originally developed for soils with a high pH. As a matter of fact most soils in the survey area have such a pH. The classes used to define the soil fertility status are given below in table 15 and were derived from Legger and van der Pouw (1980). The classification of available P (P-Olsen) is based on figures given by Singh (1979).

Table 15. Classes of fertility status of P, K, Ca and Mg.

class	P-Olsen (ppm)	available P (ppm)	Mass analysis (Mehlich, 1962) available K (me/100g)	available Ca (me/100g)	available Mg (me/100g)
very low)	)	)	0-0.3	0-2	0-1
)	0-5	) 0-20			
low)		)	0.3-1.0	2-6	1-3
moderate	5-10	20-80	1.0-2.0	6-10	3-6
high	10-20	80-200	2.0-3.5	10-20	6-12
very high	>20	>200	>3.5	>20	>12

These classes apply to the agricultural use of land and more in particular to the southern part of Kenya, while in other parts of the world, different criteria are used. For example for K deficiency, Kamprath gives a value of 0.1 me/100g exchangeable K (in: Mongi and Huxley, 1979). When applying this criterion, there are no soils in the survey area deficient in K. They mostly have around 0.5 me/100g K in the topsoil and 1.0-2.0 me/100g K in the subsoil. However, when using the classes from table 15 several soils

are low in K.

The requirements on the soil fertility for the natural vegetation are not known. Therefore, it is possible that the above mentioned classes are not very meaningful, but in the absence of better criteria they have been used in chapter 3.3 to assess the soil fertility status of the different mapping units.

It is assumed that in the greater part of the survey area the soil fertility is not limiting the production of the vegetation. This is based upon the following observations:

- The availability of nutrients is almost everywhere moderate or higher, especially when for available K a limit of 0.1 me/100g is used.

- The N-content especially in the dry parts of the area, is round 0.03% which can be considered as low. This nevertheless amounts to about 960 kg/ha in the top 20 cm only. At the beginning of the rainy season the mineralisation will be rapid and a flush of N will become available. Most of the herbs and bushes in the area are legumes and therefore have very low N requirements.

- From experiments in Mali, where the chemical soil fertility is even lower than in the survey area, it appeared that below an average annual rainfall of 500 mm, soil moisture and not the fertility was the first limiting factor (Penning de Vries et al., 1982). Mali has a single rainy season, whereas the survey area has a bimodal rainfall pattern. The rainfall limit may therefore be even higher in this area.

In appendix 5 a summary of the chemical fertility status of the soils is given. As the fertility in the major part of the area is not a limiting factor for the vegetation production, no extensive descriptions will be given. However, some general remarks can be made.

The organic C content in the topsoil is generally below 0.5% in those parts of the area with an aridic soil moisture regime. Towards the mountain tops a steep increase in organic matter occurs, related with a higher rainfall. On the tops of the volcanic mountains an organic C content of 4% may occur. The quality of the organic matter is high as the C/N quotient varies between 5 and 10 (see chapter 3.4).

The pH of the soils in the dry parts is neutral or higher. Near the mountain tops the lowest recorded pH is 5.5.

The CEC of the soils is generally above 15 me/100g except in the coarse textured soils and in those soils where kaolinite is the dominating clay mineral. The base saturation is mostly 100%, near the mountain tops it maybe somewhat lower but it never comes below 50%.

When looking at the P-status of the soils it is remarkable that the highest levels of available P are found in the soils developed on Basement System rock sediments, thus in the Hedad and Elgess areas. The soils in the whole northern part of the area, on and around Mt. Kulal, the Asie hills, west and east of the Chalbi and the northern and southern slopes of Mt. Marsabit have a low to moderately high content of available P. This could be due to the P fixing capacity of soils which have high volcanic ash influences.

3.7 SALINITY

From only a few profiles in the survey area the composition of the soluble salts in the saturation extract of the soil was determined. The figures give a rough idea of the composition of the salts in the soil. In table 16 the results are summarized. For the location of the profiles, see figure 8.

Table 16. The composition of the water soluble salts in the saturation extract of some saline soils

Observation No.		42-9	42-9	42-9	42-10	42-10	42-13	54-8	67-16
Depth (cm)		40-50	50-70	90-100	10-30	30-45	130-140	135-170	40-50
Conductivity (mmhos/cm)		5.0	6.5	15.5	4.5	3.5	8.5	20.5	2.5
Na^+	(me/l)	27.8	45.2	121.7	10.4	8.0	76.5	161.5	226.1
K^+	"	0.7	0.3	0.2	2.0	4.0	0.4	0.3	0.8
Ca^{++}	"	n.d	7.4	22.0	28.0	20.8	7.6	23.2	21.2
Mg^{++}	"	n.d	9.6	1.2	5.0	4.9	0.8	28.0	0.4
CO_3^{--}	"	0	0	0	0	0	2.4	3.6	2.0
HCO_3^-	"	5.6	6.0	5.6	6.4	6.4	12.4	6.8	9.6
Cl^-	"	25.6	53.4	130.0	27.4	23.4	60.0	183.0	218.0
SO_4	"	5.1	2.4	5.3	6.9	6.8	10.3	11.8	18.4

n.d = not determined

The main components present in saline soils are sodium and chloride. Calcium, bicarbonates and sulphates are of second importance.

4. INTERPRETATION OF THE SURVEY DATA

4.1 INTRODUCTION

The function of the land evaluation is "to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whilst at the same time conserving those resources for the future" (cf. FAO, 1976). The land evaluation therefore should be part of an overall land use planning process. The different surveys have provided data which can be analysed together in order to arrive at a land suitability classification for various kinds of land use.

The methodology used for the land evaluation is principally based on the "Framework for Land Evaluation" (FAO, 1976). Other useful information was obtained from various reports, published by the Kenya Soil Survey and from discussions with IPAL scientists and various staff members of KSS. The basic approach is first to define the land utilization type (LUT's) which are relevant to the survey area. The second step is to determine the requirements which are important in the evaluation for the chosen land utilization type. These are presented as conversion tables. Thirdly is the determination and rating of the land characteristics which contribute to the rating of each land quality. After that, the rating of the land qualities has to be made for each unit of land being considered. The ratings of the land qualities for each unit of land are matched with the requirements to determine the land suitability for a given LUT by using the conversion tables.

The most relevant LUT's for the survey area are:

- Pastoralism (extensive grazing and browsing by camels, cattle, sheep and goats)
- Protected forest and/or game reserve
- Smallholder, rainfed, mixed farming (agriculture with dairy farming), low technology, low input

The LUT pastoralism will be treated first as this one is the most important for the survey area. More than 90% of the area is presently occupied by this type of land use, although the intensity varies considerably from place to place. The suitability classification for pastoralism will be treated for two different situations:

(a) The current suitability

The current suitability for pastoralism which has as its main aim animal production, (secondary production) is very much determined by the land quality vegetation (primary production). The carrying capacity is based on the availability and the quality of the forage and corrected, if necessary, for the land qualities accessibility and resistance to erosion.

(b) The potential suitability

The potential suitability can be higher than the current one as it is believed that, due to poor management, the actual vegetation is not in balance with the soil and the climatic conditions. For a potential suitability, those land qualities influencing the primary production will be treated as well as those influencing the secondary production.

Other less relevant LUT's will be treated briefly in chapter 4.4 and recommendations on land use will be given. These LUT's are: forest and game reserve and smallholder rainfed mixed farming.

4.2 CURRENT SUITABILITY FOR PASTORALISM

4.2.1 Description of the land utilization type and approach to the suitability classification

The LUT pastoralism is dominant in the survey area. Pastoralism can be described as nomadic to semi-nomadic extensive grazing and browsing of the natural vegetation by camels, cattle, sheep and goats. The tribes in the area have the right to use the land but as a rule the different tribes do not use the same geographic area. Within a tribal area the people have common access to the land. Herds are often owned by families or households, rather than by individuals. Herd sizes may vary considerably; from a few camels to over one hundred. Some families or clans move around with their houses and animals (nomadism) while others are settled in a certain place and only their herds move around (semi-nomadism). The common livestock species are camels, cattle, sheep and goats. Camels are the preferred animals and their possession contributes largely to the social status of the owners. The products of the camels are milk and blood. Some castrated males are used as package animals. Cows produce milk and are sometimes also bleeded. Sheep and goats produce, besides milk, meat for local consumption. Some animal hides and skins are marketed but at very low prices, due to the absence of a good marketing system.

Capital investment per ha as well as labour and veterinary inputs per ha are very low. The present infrastrature is very poor while technology and management levels are low (traditional). As a result the family income is extremely low. The different livestock species are herded separately, except for sheep and goats which are always herded together. Often the herds are split up: the weak and the lactating animals stay around the homestead and are looked after by the small children. The main herds (camels) may go out for weeks and up to 200 km from the homestead. They are kept in satellite or "forr" camps and are herded by grown up boys and girls. The head of the family has a mangement function: he decides where and when to move herds or camp, where the animals are watered, etc. The present management needs improvement as parts of the area are over-utilized whereas other parts are under-utilized.

The primary production is the most important land quality in the determination of the land suitability. The vegetation component, quantity as well as quality, is the leading factor in the determination of the allowed maximum off-take of forage and browse in the survey area under the present circumstances. The primary production was determined by the IPAL rangeland scientists (IPAL, 1983) and is supposed to be correlated with the above-ground standing crop biomass of the dwarf shrub and herb layer. The data are only based on two wet season surveys so they should be regarded with caution. In determining the carrying capacity, based on the standing biomass, only a certain percentage of the biomass is used. The usable forage quantity of the herb and dwarf shrub species is estimated at 37.5% of the total standing crop biomass. For the dwarf shrubs the estimated usable forage biomass is 18.5% of the standing crop, while for *Duosperma eremophilum* (a particular dwarf shrub), it is estimated at 11%. Of the standing dead annual grass, only 18.5% is considered to be available as forage.

Wood and foliage production of the large shrubs and trees are obtained from growth measurements combined with destructive sampling. Tree and large shrub foliage and fruits constitute a part of a normal diet of camels and goats (about 30%), sheep (10%) and cattle (1%) (in % of dry matter intake). If it is assumed that these proportions of the total intake are required for the optimum health and productivity of the species concerned, then it follows that the total tree and large shrub browse production which is available to the livestock, can be a limiting factor affecting the carrying capacity of the range, especially with respect to goats and camels. Thus in determining the carrying capacity of each range unit, the lower value of the available fodder in the two main canopy layers is taken. To estimate the available fodder from the foliage production, half of the palatable production is taken. For sheep and goats a quarter of the palatable foliage production is taken, because of the lower availability of tree foliage to those animal species.

To calculate the carrying capacity the following intake values are used (kg dry matter): camels, 4.81 kg/day; cattle, 4.45 kg/day; sheep, 0.76 kg/day; goats, 0.84 kg/day. The calculated carrying capacity, which is thus related to the primary production, the desirability and the palatability of the vegetation are combined with the other land qualities to arrive at a final suitability classification.

The specific land factor analysis required from the soil surveyor is, in this case, related to the land qualities accessibility and resistance to erosion. The possible limitations caused by these land qualities lead to a reduction of the initially calculated carrying capacity based on the primary production and so a final carrying capacity can be obtained.

Some land qualities, like natural fertility and soil moisture availability, are believed to be reflected in the existing vegetation, as they will have a certain influence on both the quantity and the quality of the vegetation.

Hinderance of the vegetation for livestock is considered to be low and will not be considered.

There are no areas with special risks for animal diseases[1)] and no provisions were made for the inclusion of this factor in the analysis.

4.2.2 Ratings of the land qualities

The figures used for the different subratings do not have an absolute meaning: the lower the figure, the better the land characteristic. The subrating includes also a weight factor. This explains why the full scale from 1 to 5 is not always used and jumps from 1 to 3 to 5 may occur.

(a) Accessibility

The land quality accessibility is composed of the following land characteristics:

- steepness of the terrain
- stone or boulder cover of the soil surface
- occurrence of flooding

1) *Pers. comm. Dr. Field*

As the requirements vary for the different animals commonly kept in the area (camels, cattle, sheep and goats), a separate rating is given for each species. As sheep and goats are always herded together, their requirements are combined. Table 17 gives the subrating for the land characteristic steepness of the terrain.

Table 17. Subrating for the steepness of the terrain

subrating	slope class cm	ct	sg
1	A,B,C	A,B,C,D	A,B,C,D
2	D	E	E
3	-	-	>E
4	E	>E	-
5	>E	-	-

cm = camels ct = cattle sg = sheep and goats
Slope class A: 0-2% B: 2-5% C: 5-8% D: 8-16%
E: 16-30%

In table 18 the subrating for the stone or bouldery cover of the soil surface is given.

Table 18. Subrating for the stone and/or boulder cover of the soil surface

subrating	cover with stones/boulders (%) cm	ct	sg
1	0-50	0-50	0-80
2	-	-	>80
3	50-80	50-80	-
4	>80[1)]	-	-
5	>80[2)]	>80	-

cm = camels ct = cattle sg = sheep and goats
1) in case of stones 2) in case of boulders

In table 19 the subrating for the occurrence of flooding is given. Flooding is limited to a few small areas and to the Chalbi desert. The duration of flooding varies locally from a few days to a maximum of 4 to 6 weeks per year. Flooding influences the accessibility only slightly.

Table 19. Subrating for the occurrence of flooding

subrating	flooding
1	absent
2	occassionally present

The final rating for the accessibility, schematically given in table 20, is determined by the most limiting factor of any of the three subratings. So if for example the subratings are 1, 4, 1 respectively, the final rating will be 4. A combination of 4 with 4, with 1 or 2, will end up in 5.

Table 20. Final rating for the accessiblity of the terrain

final rating	degree of accessibility	subrating for steepness	cover with stones/boulders	flooding
1	excellent	1	1	1
2	good	2	2	2
3	moderately well	(2	3	2
		(3	2	2
4	poor	(3	3	2
		(4	3	2
		(3	4	2
5	very poor	4	4	2

(b) Resistance to erosion

The land quality resistance to erosion is composed of the following land characteristics:

- slope class
- texture of topsoil
- aerial cover of the vegetation

The resistance to erosion of the soil is assumed not to be directly influenced by different animal species. The mean density of the livestock population in the area is very low: 5.09 livestock units per km^2 (1 livestock unit is the equivalent of a 250 kg cow; after Field in IPAL, 1983). Consequently the extent of soil erosion influenced by the trampling activity of the livestock is very small. The effect of trampling around water points, small in extent and very localised, cannot be neglected and hence needs special attention. For example by strongly controlling the grazing in a radius of 1 km around the watering point and by closing the water point during the rainy season when surface water is available elsewhere.

The subrating for the slope class is given in table 21.

Table 21. Subrating for the slope class

subrating	slope class	slope percentage
1	A	0-2
2	AB,B	0-5, 2-5
3	C	5-8
4	D	8-16
5	E or steeper	>16

Table 22 gives the subrating for the texture of the topsoil (0-20 cm depth). The texture of the topsoil is expected to have a correlation with the infiltration capacity. The subrating will be upgraded with one class if the surface is exceedingly stony or exceedingly bouldery (protective cover).

Table 22. Subrating for the texture of the topsoil (0-20 cm depth)

subrating[1)]	texture
1	sand, loamy sand
2	sandy loam, sandy clay loam
3	loam, clay loam or finer

1) upgrade one class if exceedingly stony and bouldery

Another characteristic influencing the resistance to erosion is the aerial cover of the vegetation. In this respect the perennial grasses and the dwarf shrubs play a very important role since they are present the whole year round. The annual grasses germinate rapidly afer the first rains, but they also die off quickly due to lack of soil moisture which is enhanced by their shallow rooting depths. They may contribute to erosion control for short periods only. Large shrubs and trees have both a negative and a positive effect. The rain drops falling from the branches and leaves are large and cause a splash effect on the surface (when bare). The roots however may protect the soil from being transported. It was decided to use as vegetation cover parameter the percentage aerial cover of perennial grasses and dwarf shrubs plus 50% of the aerial cover of annual grasses and herbs. Table 23 shows the subrating for the vegetation cover.

Table 23. Subrating for the vegetation cover

subrating	vegetation cover (%)
1	>50
3	20 - 50
5	<20

The rating for the resistance to erosion is composed of the sum of the subratings for slope class, topsoil texture and vegetation cover. Table 24 shows the final rating for the resistance to erosion.

Table 24. Final rating for the resistance to erosion

rating	degree of resistance	sum of subratings (slope class, texture topsoil, vegetation cover)
1	high	3-6
2	moderate	7-10
3	slight	11-13

The ratings for accessibility and resistance to erosion can be combined into an overall rating for the different soil mapping units in the survey area. The possible combinations of the ratings of the land qualities accessibility and resistance to erosion are given in table 25.

Table 25. Combined rating for the land qualities accessibility and resistance to erosion

accessibility	resistance to erosion		
	1	2	3
1	1	2	3
2	1	2	3
3	2	2	3
4	3	3	4
5	4	4	4

4.2.3 From land qualities to carrying capacity

The aim of the suitability classification is to arrive at a realistic carrying capacity of a land unit for the different types of animals. Carrying capacity figures derived from vegetation only have been calculated by the rangeland and livestock ecologists of the IPAL project (IPAL, 1983). The accessibility of the area for the different livestock species and the erodability of the soil may influence the carrying capacity in a negative way. Poorly accessible areas will reduce the number of animals in that area, even if there is forage available. Areas which are succeptible to erosion need to be protected in such a way that the protective vegetation cover will remain and/or can be increased. Therefore the off-take by the livestock should be less than the calculated one which is based on maintaining the current vegetation potential. This can be achieved by reducing the initially calculated carrying capacity by IPAL with a percentage, related to the degree of the limitations caused by accessibility problems and erodability. This reduction factor is based on the combined rating for accessibility and resistance to erosion (table 25).

Table 26. Reduction factor for the initially calculated carrying capacity (by IPAL, 1983) based on limitations caused by accessibility and resistance to erosion

combined rating for accessibility and resistance to erosion	reduction factor for the calculated carrying capacity
1	0%
2	25%
3	50%
4	75%

In some cases extrapolation of the calculated carrying capacity was necessary as the IPAL range type mapping units do not always coincide with the soil mapping units. The carrying capacity figures have been modified according to the reduction on factors given in table 26 and can be regarded as the recommended ones under the current circumstances. The suitability class defining criteria (viz. the carrying capacities) are shown in table 27.

Table 27. Current suitability rating for pastoralism

final rating	suitability class	reduced carrying capacity (animals/km^2/year) camels	cattle	sheep	goats
1	high	6-10	16-30	31-60	11-20
2	moderate	4-5	7-15	13-30	7-10
3	marginal	2-3	3-6	5-12	3-6
4	sub-marginal	≤1	≤2	≤4	≤2

The different livestock species may occupy an area at the same time, as they mostly use different parts of the same vegetation or prefer different species. For pastoralism, in this case extensive grazing and browsing, the class "not suitable" is omitted as this one only exists if there is really nothing to graze or to browse (e.g. the Chalbi area). Therefore the class marginally suitable has been subdivided into marginally suitable and sub-marginally suitable.

4.2.4 Results of the current suitability classification

A detailed list with the subratings, ratings and the final ratings of the land qualities for every mapping unit and per livestock species is given in Appendix 6. It has to be stressed again that the given carrying capacity figures are the best possible estimations, based on IPAL data (IPAL, 1983). The figures however, need to be handled with care and may change as soon as more precise data on the primary production become available.

The results of the suitability classification are summarised in table 28 following the same order as on the legend of the soil map.

In some cases in this table especially with complex soil mapping units, a range of suitability classes has been given. In these cases the most frequently occurring class is given first, followed by the less frequent one.

Table 28. Current suitability for pastoralism per mapping unit and per livestock species

Mapping unit	suitability class				recommended carrying capacity (aminals/km^2)				extent (x 10^3 ha)
	cm	ct	sh	g	cm	ct	sh	g	
MUC	4-1	4-1	3-1	3-1		incomplete data			14.2
MV1	4-2	2	2	2		"			14.3
MV2P	4-2	3-2	2	2		"			17.2
MVC	4-3	4	4	3	0.1-1.5	2.8-1.3	2.5-3.8	2.5-3.8	8.5
MPP	4-3	3-2	2	2		incomplete data			2.5
HUP	4	4	4	4	0.1-0.3	0.1-0.3	0.5	0.5	11.7
HVP	4	4	4	4	0.3	0.3	1	1.5	9.0
HP1P	4	3-2	2	4	0.3	1.5-3.8	15-22.5	1-1.5	1.6
HP2P	4	4	4	4	<0.3	<0.3	<0.5	<0.5	11.2
U1V1	4	1	1	4	<0.1	21-28	43-57	<0.2	1.9
U1V2	4	1	1	4	<0.1	21-28	43-57	<0.2	1.6
U1V3P	4	2	2	4	<0.1	15	30	<0.2	5.5
U2F1	3	4	4	3	1.5	1.5	2.3		15.0
U2FA (top	4	4	4	3	0.8	0.8	3	4.5)	14.7
U2FA (mid	3	3	4	3	2.3	2.3	3	4.5)	
LsV1P	4	3	3	3	0.8	2.3	5	3	3.9
LsV2	3	1	1	3	2	19	40	5	6.4
LsV3p	4	1	1	4	<0.1	21	57	0.2	23.2
LsVC1	3-2	3-2	2	2	2.5-3.8	2.8-8.3	23	10	282.3
LsVC2	3-2	3-2	2	2	2.5-3.8	2.8-8.3	23	10	90.8
LsXp	4	3	3	3	0.8	3.8	11	3	4.8
LnV1	4	4	4	3	0.3	0.8	3	2.3	39.1
LnV2	3	3	2	2	1.3	2.8	23	10	24.3
LnV3p	3	3	3	3	1.5	2.3	5	5	6.9
LnV4p	4	4	4	3	0.1	0.5	1.5	2.3	41.6
LdVP	3	4	3	2	2.5	1.8	5.3	7.5	10.7
RVp	4	1	1	4	0.1	28	57	0.2	16.2
RVA (upper	4	2	2	3	0.4	7.5	19	3.8)	
RVA (m.up	3	3	4	3	0.8	15	30	1.5)	46.0
RVA (lower	3	3	4	3	1.5	2.3	3.8	3.8)	
RVC	4-3	3	4	3	1-1.5	2.3	3.8	3.8	14.8
FU1	3	3	3	3	2	3	6	5	3.5
FUA	3	3	4	3	3	3	3.8	6	38.9
FV1P	3	3	4	3	1.5	2.3	3.8	3.8	53.7
FV2p	4	4	4	4	0.1	0.3	1.5	0.8	6.4
FV3P	3	3	3	3	1.5	2.3	5	5	21.7
FVC	4-3	4	4	3	1-1.5	0.1-1.5	1.5	3	33.4
YV1p	3	4	4	3	1.5	1.5	3	5	8.2
YV2	3	4	4	3	1.5	0.4	0.8	3	1.0
YV3	3	3	3	3	1.5	6	12	3	4.8
YVC	3-4	3-4	3	3	1-1.5	0.8-2.3	5	5	16.5
PvVp	3	3	4	3	1.5	2.3	3.8	3.8	6.0
PnSP	4	4	4	4	0.6	1.5	3	1.5	6.0
PnSA	3	3	3	3	1.5	3	6	3.8	3.3
PdSP	4	4	4	4	0.4	1	2	1	8.1
PsUK	3	4	4	3	1.5	0.8	1.5	3	2.0
PsU1	1	3	3	1	7	6	12	15	119.3

Table 28. (contd.)

Mapping unit	suitability class				recommended carrying capacity (animals/km^2)				extent (x 10^3 ha)
	cm	ct	sh	g	cm	ct	sh	g	
PsU2	1	3	3	1	7	4	8	15	2.2
PsU3	2	3	2	2	4.5	6	12.8	8.3	22.8
PsU4	2	3	3	2	4.5	5.3	5.3	8	94.2
PsU5	4	3	3	3	1	3.5	7	2.5	86.1
PsUA1	1	3	3	1	7	3	6	17	37.2
PsUA2	3	3	3	3	15.2	2.3-3	4.5-6	3.8-5	38.8
PlnX1	-	-	-	-	0	0	0	0	59.6
PlnXA	-	-	-	-	0	0	0	0	10.1
PldXC	4	4	4	4	0.4	0.8	1.5	0.8	8.0
AUC	3	4	3-4	2-3	2.3-3	1.5-2	5-3.8	7-5.3	11.4
AA1	4	4	4	4	0.8	0.4	0.8	1.5	1.4
AA2	3	4	3	2	3	2	5	7	5.9
AA3	3	1	1	2	3	20	43	8	31.7
AA4	3	3	3	3	3	6	12	6	2.1
AA5	3	2	2	3	2.2	11.3	22.5	4.5	10.5
AAC	4	3	3	3	0.8-1	3.8-5	7.5-10	2.3-3	13.4
DXA	4	2	2	3	0.8	8.3	18.8	2.3	55.2

notes: cm = camels; ct = cattle; sh = sheep; g = goats

In case of a range of suitability classes, the most frequently occurring suitability class is given first. For some soil associations a subdivision is made in the soil mapping unit. For more details of the sub-units see ch. 3.3 and appendix 1.

n.d. = not determined.

It can be seen from this table that highly suitable land for camels and goats comprises units PsU1, PsU2 and PsUA1 (158,700ha). Moderately suitable for camels are unit PsU3 and PsU4 (117,000ha). Marginally suitable are 710,000ha, while the rest of the survey area is submarginally suitable.

Highly suitable for cattle and sheep are units U1V1, U1V2, LsV2, LsV3p, RVp and AA3 (81,000ha). Moderately suitable for cattle are units MV1, U1V3P, parts of RVA, AA5 and DXA (111,000ha). Marginally suitable for cattle are 1,030,600ha, while the remainder of the area is submarginally suitable.

Moderately suitable for sheep are units MV1, MV2P, MPP, HP1P, U1V3P, LsVC1, LsVC2, LnV2, parts of RVA, PsU3, AA5 and DXA (513,000ha). Marginally suitable are 500,900ha, while the rest is submarginally suitable.

Moderately suitable for goats are units MV1, MV2P, MPP, LsVC1, LsVC2, LnV2, LdVP, PsU3, PsU4, AUC, AA2 and AA3, (609,000ha). Marginally suitable are 594,000ha, while the rest is submarginally suitable.

The only area which is totally unsuitable for all livestock species the Chalbi desert (69,700ha).

4.3 POTENTIAL SUITABILITY FOR PASTORALISM

4.3.1 Description of the land utilization type and approach to the suitability classification

As stated earlier, at present the vegetation is not in equilibrium with the soil and climatic conditions. The main reason for this is the influence of the nomadic societies on their environment. One of the goals of the proposed management plan is to arrive at a situation whereby the people of the area can live in good harmony with the environment to the profit of both man and his surroundings. This kind of situation may be achieved 20 to 50 years after implementation of an adequate management system for the natural resources (IPAL, pers. comm.). An important aspect of a proper management is that the recommended carrying capacity, indicated in table 28, will not be exceeded. In the potential situation, both quantity and quality of the vegetation will be in a far better equilibrium with the soil and climatic conditions than at present. It is quite possible that the existing trends of sedentarisation will continue. However, the herds will have to remain mobile.

The LUT pastoralism (nomadic to semi-nomadic, small scale, extensive grazing and browsing of camels, cattle, sheep and goats) is basically the same as for the current situation (ch. 4.2). However, some attributes will change. The marketing structure will be improved and consequently more of the products will be sold at higher prices. The infrastructure will be improved and controlled water points will be introduced. Consequently, the capital investment per ha is higher than in the present situation, though still low. Labour input will not change very much. The family income may be somewhat higher than in the present situation, due to a better marketing structure. Veterinary input per animal will still be very low, but is higher and more efficient than in the existing situation. Some range improvements may have taken place, such as the clearing of undesirable woody species. The level of technology will be low to moderate.

4.3.2 Land qualities and their ratings.

To arrive at a potential suitability classification, those qualities influencing the primary production as well as those having an impact on the secondary production have to be considered. The following land qualities may influence the primary production:

(a) Natural fertility of the soil

(b) Resistance to erosion

(c) Soil moisture availability and flooding

(d) Presence of salinity and/or sodicity

The land quality considered that may influence the secondary production directly is the accessibility of the terrain. Other considerations are:

- High risks for endemic diseases are assumed to be absent (see ch. 4.2.1).
- Hindrance of vegetation is considered to be negligible.
- Drinking water will be available throughout the area in the form of controlled watering points or as surface water.

(a) Natural fertility of the soil

The soil fertility of the area is in general moderate to high, except for nitrogen which is low. However, many plants are leguminous so it can be expected that they fix some nitrogen.

In the major part of the area the rainfall is below 300 mm/year, falling in two seasons. Studies in Mali showed that below 300 mm rainfall the most limiting factor for plant growth is the water availability and not the chemical fertility. Between 300 and 500 mm, both factors are important and only above 500 mm annual rainfall the chemical fertility was the most limiting factor (Penning de vries et al. 1982). The Sahelian zone studied in Mali has only one rainy season. In our case as well it can be expected that the soil fertility is not limiting the productivity of the natural vegetation and hence this land quality cannot be treated as a differentiating criterion.

(b) Resistance to erosion

The rating for resistance to erosion is given in ch. 4.2.2. However, it can be assumed that in future conditions the vegetation cover percentage will be higher than at present. Therefore, the subrating for vegetation cover will be upgraded with one class except for cases where the present vegetation cover is already over 50%.

(c) Soil moisture availability and flooding

The land quality soil moisture availability for plant growth is very complicated. Since no detailed studies have been carried out, an approximate method has been devised to arrive at an indication for the soil moisture availability for the plant.

The rating for the soil moisture availability is based on the following characteristics.

- rainfall; more precisely the effective rainfall which includes the effect of runoff and the water that evaporates before entering the soil
- evapotranspiration
- soil moisture storage capacity
- flooding

(c1) Rainfall and evapotranspiration

The mean annual rainfall figures are obtained from Bake (1983). These rainfall figures are used in combination with the figures for the potential evaporation to delineate and to define the agro-climatic zones (see ch. 1.2.5).

In table 29 the figures for the annual rainfall, the potential evaporation and the actual evapotranspiration are given for each agro-climatic zone. In order to facilitate the calculations, average figures have been used. Braun assumes that the potential evapotranspiration is 80% of the potential evaporation (In: Sombroek et al. 1982). The potential evapotranspiration however is only reached when the crop or the range vegetation is in optimal growth condition with a closed groundcover. This situation may be present only in agro-climatic zone III in the study area. Stroosnijder and Kone have measured actual evapotranspiration in Mali and they found a value of 2.8 mm/day for natural rangeland with a low vegetation cover (In: Penning de Vries et al.,1982).

On the bases of the foregoing, different percentages for the actual evapotranspiration are assumed for the different agro-climatic zones occurring in the survey area (see table 29).

Table 29. Annual rainfall, potential evaporation and actual evapotranspiration for the different agro-climatic zones

agro-climatic zone	r (mm)	r (mm) average	Eo (mm)	Eo (mm) average	Estimated Ea as % of Eo	Ea mm/day	r/Eo (%)
III	900-800	930	1750-1800	1775	80	3.9	50-55
IV	750-900	825	1800-1880	1840	70	3.5	40-50
V	525-750	637	1880-2095	1988	60	3.3	25-40
VI	320-525	422	2095-2150	2122	50	2.9	15-25
VII	170-320	245	2150-2280	2215	50	3.0	<15

notes: r = mean annual rainfall (Bake, 1983)

Eo = potential evaporation (Woodhead, 1968)

Ea = actual evapotranspiration

The effective rainfall is the amount of rainwater which enters the soil. Two loss factors are being considered: the runoff and the immediate evaporation of the rain that falls on a hot and bare surface before it enters the soil. To arrive at exact figures, runoff measurements would have been necessary and figures about rainfall intensity and distribution should have been available. As this is not the case, assumptions have been made based on literature (Penning de Vries, et al., 1982; Hudson, 1981; Unesco, 1979). Runoff is, besides rainfall characteristics, mainly depending on the slope and the surface characteristics of the soil. Although some sealing was found to be present in the area, no surface horizons with a low permeability do occur. The texture of the topsoil, as well as the surface stoniness influence the infiltration capacity. For the subratings of slope and texture of topsoil, the same ratings apply as those used for the land quality resistance to erosion. So the runoff, or the effective rainfall depends mainly on the slope of the terrain and the surface texture. For the agro-climatic zones VI and VII a correction of 10% is made to account for the water which evaporates at the soil surface before entering the soil. The correction is not applied for the other zones where the air temperatures are somewhat lower (7-10°C lower) and the vegetation cover is higher. For an area with an almost closed forest it is assumed that the effective rainfall is 60% of the mean annual rainfall. Table 30 shows the effective rainfall in relation to slope class, texture of the topsoil and the agro-climatic zone. The subratings for slope class and texture of topsoil are given in tables 21 and 22 respectively.

Table 30. Effective rainfall as a function of slope class, texture of the topsoil and the agro-climatic zone (ACZ)

sum of subratings for slope class and texture of topsoil	% of mean rainfall considered as effective	
	ACZ III, IV, V	ACZ VI, VII
2-3	80	70
4-5	70	65
6	60	55
7-8	50	45

(c2) Soil moisture storage capacity

Another important characteristic is the soil mositure storage capacity and the total water available for the plant. As total available water is taken the amount of water stored between pF 2.0 and pF 4.2 (see ch. 3.5.2). This is the soil moisture storage capacity.

In table 31 the soil moisture storage capacity is given in relation to the texture of the soil.

Table 31. Soil moisture storage capacity as a function of the texture

texture	soil moisture storage capacity (vol %)
clay - sandy clay	17
sandy clay loam	15
silt loam	20
sandy loam	12
loamy sand	10
sand	6

For a soil profile, the soil moisture storage capacity over the effective soil depth can be calculated with the help of table 31. The effective soil depth is the depth to which the roots can penetrate. As the maximum effective soil depth a depth of 2 m is chosen (trees and dwarf shrubs often go deeper, annual vegetation however roots more superficially). Coherent hard rock, a soil layer with an ECe of more than 15 mmho/cm or a soil layer with an ESP of over 30 are considered as not penetrable for roots. For gravelly and stony soils a reduction of the soil moisture storage capacity of 30% is applied and for very gravelly and very stony soils a correction of 50% is used.

The soil moisture storage capacity in the arid and semi-arid zones alone is not a good indication for the amount of available water for plant

growth. Most of the time of the year the soil moisture content will be below field capacity and often even below wilting point.

A deep soil with a high soil moisture storage capacity in low rainfall areas is from this point of view hardly useful as the soil will never be moistened to a great depth. To what depth the soil will be moistened depends on the rainfall distribution, the effective rainfall, the evapotranspiration and the soil moisture storage capacity. The maximum amount of water to be stored in the soil depends on the maximum amount of rain that falls in a short period (e.g. 10 days) and varies in the different agro-climatic zones. The maximum amount of water that can infiltrate and be stored in the soil in a short period determines the soil moisture storage requirements. It is realised that this amount of precipitation occurs only once in 3 to 5 years (see ch. 2.2.1). As no exact figures are known about the rainfall intensity and its distribution a tentative classification is proposed for the maximum soil moisture storage requirements in the different agro-climatic zones (see table 32).

Table 32. Soil moisture storage requirements for the different agro-climatic zones based upon climatic data

agro-climatic zone	soil moisture storage requirements (mm)
III	200
IV	200
V	160
VI	120
VII	80

However, local run-on plays an important role throughout the area. In the run-on places the soil moisture storage capacity therefore has to be higher than the storage capacity required for that particular agro-climatic zone. So a soil moisture storage capacity higher than the required one can store more moisture and can be beneficial for the vegetation growth. Table 33 gives a subrating of the ratio of the actual soil moisture storage capacity to the required one.

Table 33. Subrating of the soil moisture storage capacity in relation to the required amount

subrating	ratio of actual soil moisture storage capacity to the required one
1	>1.5
2	0.5-1.5
3	<0.5

The ratio 1 is crucial: around this figure the soil moisture

storage capacity can be regarded as sufficient. If the soil moisture storage capacity becomes lower than half the required amount, it has a clearly negative effect on the possibilities for plant growth. If the ratio is higher than 1.5 the effect will evidently be positive.

(c3) Flooding

The occurrence of flooding has a positive effect on the soil moisture availability. The flooding is never long enough to inhibit plant growth completely. Besides, the areas which are flooded from time to time have an adapted vegetation. Flooding may occur once a year, seldom twice, but also once in two years. The duration varies from a few days to a few weeks. The Chalbi desert may be flooded up to 6 weeks. The subrating for flooding is given in table 19.

The final rating for soil moisture availability for plant growth

The availability of soil moisture is expressed in five classes of cumulative amounts of growing days. On a "growing day" there is sufficient water in the soil for the vegetation to grow. The rating for soil moisture availability, is given in table 34. The ratings given are specifically for the survey area.

Table 34. Final rating for soil moisture availability expressed in growing days

soil moisture availability	rating	growing days (cumulative) per year
very high	1	150-200
high	2	100-150
moderate	3	60-100
low	4	40-60
very low	5	<40

To determine the final rating for the soil moisture availability the following procedure is followed:

- Calculate the effective rainfall for the mapping unit/agro-climatic zone combination (tables 29 and 30). Divide the effective rainfall by the actual daily evapotranspiration belonging to the climatic zone in question. In this way the number of growing days without moisture stress is calculated and the rating can be obtained from table 34.

However, two corrections are possible: one for the soil moisture storage capacity and one for the occurrence of flooding.

- Calculate the soil moisture storage capacity. Determine the subrating using table 32 and 33. Subrating 1 upgrades the final rating (table 34) one step, subrating 2 produces no change and subrating 3 down grades the final rating one step.

- If flooding occurs (subrating 2) the final rating will be upgraded with one class.

(d) Presence of salinity and/or sodicity

The presence of salinity and/or sodicity influences in a negative way the production of the vegetation. The composition of the vegetation might show a difference as well: on saline soils halophytic plant species appear. These can be beneficial for the diet of the livestock, but even halophytic plants grow better in a non-saline environment. Only the highly tolerant halophytic plants can tolerate an ECe of more than 15 mmho/cm (Richards, 1954). It is assumed that the roots do not penetrate in a layer with an ECe of more than 15 mmho/cm. The relation between rooting depth and the occurrence of sodicity (high ESP) is less clear. Generally an ESP of 15 is used as a limit. However, in the area it was observed that roots do penetrate layers with an ESP of 20 or more. Based on these field observations, the lower limit is therefore set at an ESP of 30. The influence of very high salinity and/or sodicity is reflected in the soil moisture availability through limitations in rooting depth.

Thus the primary production is inhibited by saline and/or sodic condition, although some halophytic vegetation types even grown on strongly saline soils, but their biomass production generally is very low.

Intable 35 the subratings for the salinity and the sodicity are given. Each profile is rated for the ECe and for ESP. It is to be noted that more emphasis is laid on the topsoil than on the subsoil as most plants have the highest root development in the surface layers of the soil.

Table 35. Subratings for the salinity and the sodicity of the soil

subrating	Ece (mmho/cm)		ESP (%)	
	0-50 cm	50-100 cm	0-50 cm	50-100cm
1	<4	<8	<6	<10
2	4-8	8-15	6-10	10-30
3	>8	>15	>10	>30

Table 36. Rating of the salinity and sodicity of the soil

rating	sum of subratings for ECe and ESP
1	2, 3
2	4, 5
3	6

The final rating is obtained by the sum of the subratings for the ECe and ESP, as shown in table 36.

(e) Accessibility of the terrain

The same ratings of the accessibility of the terrain are used as in chapter 4.2.2 (table 20).

4.3.3 Potential suitability class-defining criteria

The final suitability is determined, following table 25 combining the accessibility and the resistance to erosion with the land qualities soil moisture availability and salinity/sodicity in table 37 (conversion table), (see also appendix 6).

Table 37. Conversion table for the potential land suitability classification for pastoralism

suitability class	land qualities		
	accessibility and resistance to erosion	soil moisture availability	salinity/ sodicity
1. high	2	2	1
2. moderate	3	3	2
3. marginal	3	4	2
4. sub-marginal	4	5	3

Table 37 gives the ratings of the mapping units for these land qualities which occur, leading to a certain suitability. The most limiting factor determines the suitability class.

In general the term "unsuitable" is avoided, as an animal can find almost everywhere something for food, except in the Chalbi desert.

The above mentioned land qualities influence the potential suitability of the land for pastoralism either directly through the primary production of indirectly through their effect on the secondary production. The suitability classes given in table 37 should be translated into classes of carrying capacity. Although there are not yet sufficient data available on the primary production to give reliable correlations between the suitability classes and the carrying capacity, a provisional guideline is made to give a correlation based on data provided by IPAL (1983). It is shown in table 38.

Table 38. Correlation between suitability classification and potential carrying capacity

suitability class	carrying capacity in animals /km^2			
	camels	cattle	sheep	goats
1. high	7-10	16-30	31-60	11-20
2. moderate	5-6	9-15	17-30	9-10
3. marginal	3-4	5-8	9-16	5-8
4. sub-marginal	≤2	≤4	≤8	≤4

The figures on carrying capacity in table 38 are very tentative and need to be handled carefully. The different livestock species mentioned can occupy the land unit at the same time as they use partly different forage products.

4.3.4 Results of the potential suitability classification

The rating of the land qualities of every soil mapping unit and agro-climatic zone combination are given in appendix 6. The results of the potential suitability for pastoralism are summarised in table 39.

The units which are highly suitable for all livestock species considered are U1V1, U1V2, LsV2, RVP and parts of RVA, of FUA and of AUC. Together they comprise 60,700 ha and cover 3.9% of the survey area. The highly suitable units are found in agro-climatic zones IV, V and partly in VI. Unit LnV2 (24,300 ha) is highly suitable for sheep and goats and is the only one with this suitability class found in agro-climatic zone VII. The units which are moderately suitable for all livestock species are U1V3P, U2F1, parts of U2FA and of RVA, FU1, parts of FUA, FV3P, YV2, PsU1, PsU3, PsUA1, PsUA2, parts of AUC, AA2, AA3 and AAC. Together they comprise 383,900 ha and cover 24.5% of the survey area. The greater part of these units are located in the flat and lower parts of the survey area and often fall in agro-climatic zone VII.

The units in agro-climatic zone VII, although they may have deep soils without pedological limitations, are never highly suitable for pastoralism as the available soil moisture is always the most limiting factor.

The units with a moderate suitability for two or more of the livestock groups (often cattle and sheep/goats) are: MV1, MV2P, MPP, HP1P and YVC (together 45,600 ha).

The units which are marginally suitable for all the livestock species are: MUC (partly), LsV3p, LsVC1, LsVC2, RVC, FUA (partly), FV1P, YV1p, YV3, PvVp, PsUK, PsU4, PsU5, AA1, AA4, AA5 and DXA. Together these units comprise 567,900 ha and cover 36.3% of the survey area. The units which are sub-marginally suitable for all the livestock species are: HVP, HP2P, U2FA (partly), LsV1P, LsXp, LnV2, PnSA, PdSP and P1dXC. Together they cover 83,600 ha and comprise 5.3% of the survey area.

Table 39. Potential suitability for pastoralism per land unit and per livestock species

land unit		suitability class[2]			extent	
soil mapping unit[1]	agro-climatic zone	cm	ct	sg	ha (x 10^3)	(%)
MUC	V	3	3	3	6.3	0.4
	VI	4	4	3-2	7.9	0.5
MV1	III	-	-	-	6.5	0.4
	IV	3	2	2	7.8	0.5
MV2P	III	4	3-2	2	4.0	0.3
	IV	4	3-2	2	13.2	0.8
MVC	VII	4-3	4-3	3	8.5	0.5
MPP	III-VII	4-3	3-2	2	2.5	0.2
HUP	VI	4-3	4-3	3	11.7	0.7
HVP	VII	4	4	4	9.0	0.6
HP1P	V,VI	4-3	3-2	2	1.6	0.1
HP2P	VII	4	4	4	11.2	0.7
U1V1	IV	1	1	1	1.9	0.1
U1V2	V	1	1	1	1.6	0.1
U1V3P	V	2	2	2	5.5	0.4
U2F1	VII	2	2	2	15.0	1.0
U2FA (top	VII	4	4	4	5.0	0.4
U2FA (middle	VII	2	2	2	9.7	0.6
LsV1P	VII	4	4	4	3.9	0.2
LsV2	V,VI	1	1	1	6.4	0.4
LsV3p	VI	3	3	3	23.2	1.5
LsVC1	VII	3	3	3	282.3	18.1
LsVC2	VII	3	3	3	90.8	5.8
LsXp	VII	4	4	4	4.8	0.3
LnV1	VII	4	4	3	39.1	2.5
LnV2	VII	4	4	1	24.3	1.6
LnV3p	VII	3	3	2	6.9	0.4
LnV4p	VII	4	4	3	41.6	2.7
LdVP	VII	3	4	3	10.7	0.7
RVp (crests)	V	1	1	1	16.2	1.0
(upper	V	2	2	2	9.8	0.6
RVA (middle/upper	V	1	1	1	10.0	0.6
(lower	V,VI	2	2	2	26.3	1.7
RVC	VII	3	3	3	14.8	0.9
FU1	VII	2	2	2	3.5	0.2
FUA (middle/upper	VI	2	2	2	10.2	0.7
(middle/upper	VII	3	3	3	5.0	0.3
(lower	VI	1	1	1	18.6	1.2
(lower	VII	2	2	2	5.0	0.3
FV1P	VI,VII	3	3	3	53.7	3.4
FV2p	VII	4	4	2	6.4	0.4
FV3P	VI	2	2	2	21.7	1.4
FVC	VII	3	4-3	3	33.4	2.1
YV1p	VII	3	3	3	8.2	0.5
YV2	VII	2	2	2	1.0	0.1
YV3	VII	3	3	3	4.8	0.3
YVC	VI.VII	2-3	3-4	2	16.5	1.1
PvVb	VII	3	3	3	6.0	0.4
PnSP	VII	4	4	4	6.0	0.4

Table 39. (contd).

land unit		suitability class[2]			extent	
soil mapping unit[1]	agro-climatic zone	cm	ct	sg	ha (x 10^3)	(%)
PnSA	VII	4	4	4	3.3	0.2
PdSP	VII	4	4	4	8.1	0.5
PsUK	VII	3	3	3	2.0	0.1
PsU1	VII	2	2	2	119.3	7.6
PsU2	VII	2	2	2	2.2	0.1
PsU3	VII	2	2	2	22.8	1.5
PsU4	VII	3	3	3	94.2	6.0
PsU5	VII	3	3	3	86.1	5.5
PsUA1	VII	2	2	2	37.2	2.4
PsUA2	VII	2	2	2	38.8	2.5
PlnX1	VII	-	-	-	59.6	3.8
PlnXA	VII	-	-	-	10.1	0.6
PldXC	VII	4	4	4	8.0	0.5
AUC	VI	1	1	1	6.0	0.4
	VII	2	2	2	4.4	0.3
AA1	VII	3	3	3	1.4	0.1
AA2	VII	2	2	2	5.9	0.4
AA3	VII	2	2	2	31.7	2.0
AA4	VII	3	3	3	2.1	0.1
AA5	VII	3	3	3	10.5	0.7
AAC	VII	2	2	2	13.4	0.9
DXA	VII	3	3	3	55.2	3.5

Notes: 1) *For some associations subdivisions are made to lower levels than the soil mapping units. For more details on the position of the sub-units see ch. 3.3 and appendix 1.*

2) *1 = highly suitable; 2 = moderately suitable; 3 = marginally suitable; 4 = sub-marginally suitable. When a range in suitability occurs, the most frequent or dominant one is indicated first. A preliminary carrying capacity for each suitability class per livestock species is given in table 38.*

3) *cm = camels; ct = cattle ; sg = sheep and goats*

It has to be remarked that the units PlnX1 and PlnXA, comprising the Chalbi desert, are not suitable at all for nomadism, meaning that the carrying capacity is 0. The only function they can offer for nomadism is a saltlick.

It appears from appendix 6 that some units have a varying suitability for nomadism for a specified livestock species. This is often caused by a variation in the soil moisture availability within the mapping unit (varying soil depth). As a land unit will be used for grazing and browsing as a whole unit, the final suitability given in table 39 is as far as possible expressed in a single suitability class. When a range in suitability is maintained, the most frequent or dominant one is given first.

In table 28 sheep and goats may have different suitability classes

although in table 39 they have the same ones. This is due to the different procedures to arrive at the suitability classes. In table 28, representing the current suitability, the carrying capacity data as calculated by IPAL form the base and there sheep and goats are separated. These figures were corrected according to the requirements of the species for accessiblity and the resistance to erosion of the land. For the sake of simplification, new suitability classes were made afterwards. The bases for the potential suitability (table 39) are the various land qualities mentioned before. As the influences or the requirements of the sheep and goats are believed to be similar for the various land qualities, the final suitability class is the same for both species. The proposed preliminary potential carrying capacity figures, however, are different (see table 38).

4.4 OTHER LAND UTILIZATION TYPES

4.4.1 Forest and game reserve

At present a forest and game reserve is established in Marsabit at the mountain top. Some capital is invested and tourist revenues are gained. A big part of Mt. Marsabit, the top of Mt. Kulal and the Ndoto's are gazetted as protected forest areas. The forests on Mt. Kulal and Mt. Marsabit are unique features and they play a very important role as water catchment areas (units MV1 and MV2P). They certainly need to be conserved. Preferrably the other mountain tops should also be permanently protected and used as water catchment areas (units MUC/MVC and MPP). Also all the hills should be conserved as such (units HUP, HVP, HP1P and HP2P). Game viewing is at present only practised on Mt. Marsabit (mainly buffaloes and elephants). The riverine forests, along the major drainage lines offer also opportunities for game viewing (mainly units AA2 and AA3) (reticulated giraffe, gerenuk, Grants' gazelle, oryx, dik dik, cheetah, lion).

4.4.2 Smallholder, rainfed, mixed farming

The LUT, smallholder, rainfed, mixed farming with a low to medium level of technology is actually only present around Mt. Marsabit and to a very limited extend near Gatab on Mt. Kulal. The size of the holdings is 1-2 ha. Exceptionally larger sizes upto 20 ha are found mainly outside the survey area, east of Marsabit. The livestock makes only to a very limited extend use of the agricultural residues (e.g. maize stalks). So far, no crops are being planted to serve as fodder, although this would be very beneficial for the animals (especially lactating cows). The main products are maize, beans and milk. Some potatoes, vegetables and teff are also produced locally.

It is advised to use land with slopes of less than 8%. The soils should not be too stony. A minimum of 100 consecutive growing days is required. As the final rating for soil moisture availability is expressed in cumulative growing days (table 34) only the mapping units with a rating of 1 for the soil moisture availability may be considered as suitable for this LUT. It has to be borne in mind that the rainfall in the area is not very reliable and therefore a certain risk cannot be avoided when practising rainfed agriculture. The only mapping units with a rating of 1 for soil moisture availability are U1V1 (1,900 ha) and U1V2 (1,600 ha). The soils of unit U1V1 (on Mt. Kulal) and U1V2 (around Marsabit) have excellent physical and reasonable chemical properties except for the stoniness which occurs in places. Therefore mechanisation is not possible. To reach more beneficial yields, applications of manure and N,P,K fertilizer is recommended. Irrigation could overcome the problem of drought (water stress) when the rains are not sufficient. At

present irrigation is practised only east of Marsabit. The availability of water for irrigation has to be investigated.

4.5 RECOMMENDATIONS ON LAND USE

The conservation of important water catchment areas from agricultural use should have priority. The mountain areas that should be protected are covered by the mapping units MV1, MV2P, MUC and MVC. The units MV1 and MV2P also have a unique and very fragile montane forest which should be conserved for the future. Other areas recommended for protection comprise the units: MPP, HPP, HUP, HVP and HP2P as they play also an important role as water catchment. Besides this, these units have only very limited possibilities for pastoralism at present. Unit MV1 can at the same time be used for game viewing. The soils of the units U1V1 and U1V2 should be used for rainfed mixed farming as this provides an excellent opportunity to diversify the economy. Cultivation however has some risks as the rainfall is unreliable. To reduce risks water harvesting measures should be taken and plant varieties with a short growing season be choosen. Also irrigation could solve the problem, but further studies should be undertaken to investigate the feasibility. The rest of the survey area with the exception of the Chalbi desert could be used for extensive grazing and browsing.

5. REFERENCES

Alexander, M., 1977 — Introduction to soil microbiology. 2nd ed. John Wiley, New York.

Bake, G., 1983 — An analysis of climatological data from the Marsabit District of northern Kenya. Techn. Report No. B3, Unesco-IPAL, Nairobi.

Baker, B.H., 1970 — Tectonics of the Kenya Rift Valley. Unpublished thesis.

Beckmann, G.G., 1982 — Landscape and soil history of Gondwanaland continents. Paper presented at poster session of ISSS Congress, New Delhi, 1982.

Black, C.A. (ed), 1965 — Methods of soil analysis. Part 1 and 2, Am. Soc. of Agron., Madison, Wisconsin.

Bonarius, H., 1975 — Preliminary assessment of irrigation development in the Marsabit area. Report No. P22. Kenya Soil Survey, Nairobi.

Bogerson, R.H., 1983 — A preliminary analysis of groundwater from the Marsabit District, northern Kenya. Techn. Report No. B2, Unesco-IPAL, Nairobi.

Day, P.R., 1956 — Report of the Committee on Physical Analysis, 1954-1955. Soil Sc. Soc. of America Proc. No. 20: 167-169.

Dodson, R.G., 1963 — Geology of the South Horr area. Report No. 60, Geol. Survey of Kenya, Nairobi.

Edwards, K.A., C.R. Field and I.G.G. Hogg, 1979 — A preliminary analysis of climatological data from Marsabit District of northern Kenya. Tech. Report No. B-1, Unesco-IPAL, Nairobi.

FAO, 1971 — Rangeland surveys - Kenya.Development in Marsabit District. Draft edition, AGP: SF/KEN 11, Working paper 9, FAO/UNDP, Nairobi.

FAO, 1976 — A framework for land evaluation. Soils bulletin No. 32, FAO, Rome.

FAO, 1977 — Guidelines for soil profile description. 2nd ed., FAO, Rome.

FAO-Unesco, 1974 — Soil Map of the World; Vol. I, Legend. Unesco, Paris.

Fuchs, V.E., 1939 — On the geological history of the Lake Rudolf basin, Kenya Colony. Philos. transac. of the Royal Soc. of London, Serie B, No. 560, Vol. 229.

Herlocker, D., 1979 — Vegetation of south-western Marsabit District. Techn. Report No. D1, Unesco-IPAL, Nairobi.

IPAL, 1983 Resource management plan for the Rendille area of northern Kenya. Unesco-IPAL, Nairobi.

Kamprath, E.J. 1979 Monitoring soils in agroforestry: chemical properties. In: Mongi, H.O. and P.A. Huxley (eds), Soils research in agro-foresty. Proceedings of an expert consultation. ICRAF, Nairobi.

Lusigi, W.L. 1981 Combating desertification and rehabilitating degraded production systems in northern Kenya. Techn. Report No. A4, Unesco-IPAL, Nairobi.

Mehlich, A., A. Pinkerton, W. Robertson and R. Kempton, 1962 Mass analysis methods for soil fertility evaluation. Internal publication, Ministry of Agriculture, Nairobi.

Munsell Color Co., 1975 Munsell soil color charts, Munsell Color Co., Baltimore.

Ojany, F.F., 1966 The physique of Kenya; a contribution in landscape analysis. Annals of the Assoc. of Am. Geogr., Vol. 56, No.2.

Penning de Vries, F.W.T., and M.A. Djiteye (eds), 1982 La productivite des paturages saheliennes. Une etude des sols, des vegetations et de l'exploitation de cette ressource naturelle. Pudoc, Wageningen.

Randel, R.P., 1970 Geology of the Laisamis area. Report No. 84, Geol. Survey of Kenya, Nairobi.

Rhemtulla, S., 1970 The south Turkana expedition. Scientific papers III-A, geological reconnaissance of south Turkana. Geogr. Journ., Vol. 136, part 1.

Siderius, W. and B.J.A. van der Pouw (eds), 1980 The application of the FAO-Unesco terminology of the soil map of the world legend for soil classification in Kenya. Report No. M15, Kenya Soil Survey, Nairobi.

Singh, B.R., 1979 Nutrient availability indices and optimum nutrient element levels in soils for crops under agroforestry conditions. In: Mongi, H.O. and P.A. Huxley (eds), Soils research in agro-forestry. Proceedings of an expert consultation. ICRAF, Nairobi.

Sombroek, W.G., J.P. Mbuvi and H.W. Okwaro, 1976 Soils of the semi-arid savanna zone of northeastern Kenya. Report No. M2, Kenya Soil Survey, Nairobi.

Sombroek, W.G., H.M.H. Braun and B.J.A. van der Pouw, 1982 Exploratory soil map and agro-climatic zone map of Kenya, scale 1:1,000,000. Report No. E1, Kenya Soil Survey, Nairobi.

Soil Survey Staff, 1951 Soil survey manual. Agric. handbook No. 18, U.S. Dep. Agric. U.S. Govt. Printing Office, Washington D.C. (with 1962 supplement).

Soil Survey Staff, 1975 Soil taxonomy. Agric. handbook No. 437, U.S. Dep. Agric. U.S. Govt. Printing Office, Washington D.C.

Stakman, W.P., and G.G. van der Harst, 1962 The use of the pressure membrane apparatus to determine soil moisture contents at pF 3.0 to 4.2 inclusive. Research note No. 159. Institute for Land and Water Management, Wageningen.

Szabolcs, I., 1979 A review of research on salt affected soils. Natural resources research XV, Unesco, Paris.

Theisen, A.A. and E. Bellis, 1964 Quantitative analysis of clay mineral mixtures by X-ray diffraction. Nature, 204: 1228-1230.

Theisen, A.A.and M.E. Hayward, 1962 A paste method for the preparation of slides for clay mineral identification by X-ray diffraction. Soil Sci. Soc. Am. Proc., 26: 90-91.

Touber, L., B.J.A. van der Pouw and V.W.P. van Engelen (eds), 1983 Soils and vegetation of the Amboseli-Kibwezi area. Report No. R6, Kenya Soil Survey, Nairobi.

van der Harst, G.G. and W.P. Stakman, 1965 Soil moisture retention curves, II. Directions for the use of the sand-box apparatus, range pF 0 to 2.7. Institute for Land and Water Management, Wageningen.

van Wijngaarden, W.and V.W.P. van Engelen (ed), 1985 Soils and vegetation of the Tsavo area. Report No. R7, Kenya Soil Survey, Nairobi.

Wamukoya, O.K.H., 1977 Proceedings of a seminar on land evaluation for rangeland use. Report No. M11, Kenya Soil Survey, Nairobi.

Watanabe, F.S.and S.R. Olsen, 1965 Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ - extracts from soils. Soil Sci. Soc. Am. Proc. 1965, 29: 677-678.

Woodhead, T., 1968 Studies of potential evaporation in Kenya. E. Afr. Agric. For. Res. Org. Nairobi.

Appendix 3. DETAILED DESCRIPTION AND ANALYTICAL DATA OF REPRESENTATIVE SOIL PROFILES

profile description no.	mapping unit	observation no.	page
1	MUC	66-11	163
2	MV1	55-1	165
3	MV2P	41-2	167
4	MPP	55-20	169
5	HUP	66-10	171
6	HP2P	43-14	173
7	U1V1	41-2	175
8	U1V2	55-17	177
9	U1V3P	55-14	179
10	U2F1	67-17	181
11	U2FA	54-21	183
12	LsV1P	43-12	185
13	LsV2	55-16	187
14	LsV3p	55-19	189
15	LsVC1	55-12	191
16	LsVC1	55-13	193
17	LnV1	43-19	195
18	LnV2	54-14	197
19	LnV3p	41-8	199
20	LnV4p	41-16	201
21	LdVP	42-11	203
22	RVp	55-23	205
23	RVA	41-10	207
24	RVA	41-9	209
25	FU1	54-11	211
26	FUA	66-8	213
27	FUA	67-15	215
28	FV1P	41-18	217
29	FV2p	41-26	219
30	FV3p	42-20	221
31	FVC	42-24	223
32	YV1p	41-17	225
33	YV2	42-17	227
34	PvVp	42-19	229
35	PnSA	43-16	231
36	PsUK	55-9	233
37	PsU1	54-18	235
38	PsU2	55-8	237
39	PsU3	54-20	239
40	PsU4	42-3	241
41	PsU5	54-8	243
42	PsUA1	54-4	245
43	PsUA1	54-7	247
44	PsUA2	66-4	249
45	PsUA2	66-5	251
46	PlnX1	42-16	253
47	PlnXA	43-5	255
48	AA2	42-23	257
49	AA3	54-9	259
50	AA4	43-10	261
51	AA5	55-10	263
52	DXA	43-4	265

LABORATORY DATA OF PROFILE DESCRIPTION No: 1

FIELD OBSERVATION No: 66-11 **MAPPING UNIT:** MUC **SOIL CLASSIFICATION:** /ferralo*- chromic LUVISOL

Laboratory no. ...../82	4383	4384	4385	4386		
Horizon	Ah	Bt1	Bt2	Bt3		
Depth (cm)	0-12	12-27	27-95	95-120		
pH-H_2O(1: v/v)	6.5	6.5	6.6	6.8		
pH-KCl ,,	5.4	4.8	4.9	4.6		
EC(mmho/cm) ,,	0.05	0.04	0.03	0.04		
$CaCO_3$ (%)	-	-	-	-		
$CaSO_4$ (%)						
C (%)	0.58	0.38	0.46	0.34		
N (%)						
C/N						
CEC (me/100g), pH 8.2	5.2	6.6	6.0	6.6		
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	1.5	1.7	1.5	1.8		
,, Mg ,,	0.7	1.1	1.7	2.0		
,, K ,,	0.3	0.2	0.1	0.1		
,, Na ,,	0.1	0.1	0.1	0.2		
Sum of cations	2.6	3.1	3.4	4.1		
Base sat. %, pH 8.2	51	48	57	62		
,, ,, %, pH 7.0						
ESP at pH 8.2	2	2	2	3		
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						

X-ray report: From 12-27cm kaolinite and illite are present; from 27-95cm kaolinite and a mixed layered mica are detected.

Depth (cm)	0-12	12-27	27-95	95-120		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	70	68	68	70		
Silt % 0.05–0.002mm	16	12	8	8		
Clay % 0.002–0 mm	14	20	24	22		
Texture class	SL	SCL/SL	SCL	SCL		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm) Laboratory no. 82 / 4423

			Available	Total
pH-H_2O (1:2.5v/v)	6.7			
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	0.45	K ,,	0.3	
N%	0.22	Ca ,,	1.0	
P-Olsen(ppm)	4	Mg ,,	2.1	
		Mn ,,	0.3	
		P (ppm)		

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.1

General site information

Mapping unit	: MUC
Soil classification	: ferralo*-chromic LUVISOL
Observation no./date	: 66-11; 20/3/82
Location/altitude	: Marsabit District; 37° 17' E, 1° 45'N; 1500 m
Agro-climatic zone	: V
Parent material	: Granitoid gneisses of the Basement System (Precambrian)
Physiography	: Mountain
Relief	: Mountainous
Slope at site	: 25%, facing N
Vegetation	: Very few trees and shrubs, some perennial grasses
Land use	: Heavy grazing with livestock
Erosion	: Severe splash and rillwash erosion
Surface stoniness/rockiness	: Very to extremely rocky, fairly stony
Surface sealing	: Moderately strong algea crusts present
Drainage class	: Well drained

Profile description

Ah	0-12 cm	Brown (7.5YR 5/3 dry), dark brown (7.5YR 4/3 moist); sandy loam; porous massive, breaking into weak, fine and medium, subangular blocky; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; many pores of various sizes; clear and irregular transition to: (sample no. 66-11/2)
Bt1	12-27 cm	Yellowish red (5YR 5/6 dry), reddish brown (5YR 4/4 moist); sandy loam to sandy clay loam; porous massive, moderately coherent; slightly hard when dry, very friable when moist, slightly sticky and non-plastic when wet; patchy, thin clay cutans; many fine and medium, common coarse pores; gradual and smooth transition to: (sample no. 66-11/3)
Bt2	27-95 cm	Yellowish red (5YR 5/8 dry), dark red (2.5YR 3/5 moist); sandy clay loam; porous massive, strongly coherent; hard to very hard when dry, very friable when moist, sticky and plastic when wet; thin, broken, clay cutans; many fine and medium, common coarse pores; gradual and smooth transition to: (sample no. 66-11/4)
Bt3	95-120+ cm	Yellowish red (5YR 5/8 dry), dark red (2.5YR 3/6 moist); slightly gravelly sandy clay loam; porous massive, moderately coherent; hard when dry, very friable when moist, sticky and plastic when wet; thin patchy clay cutans; many fine and medium, few coarse pores; frequent micas. (sample no. 66-11/5)

REMARK: Roots are present throughout the profile

LABORATORY DATA OF PROFILE DESCRIPTION No: 2

FIELD OBSERVATION No: 55-1 **MAPPING UNIT:** MV1 **SOIL CLASSIFICATION:** luvic PHAEOZEM

Laboratory no. ...../74	1845	1846	1847	1848	1849	
Horizon	Ah	Bt1	Bt2	Bt3	BC	
Depth (cm)	0-20	20-40	40-75	75-115	115-130	
pH-H_2O (1: v/v)	5.0	4.9	4.8	4.8	4.6	
pH-KCl "	4.5	4.2	3.8	3.6	3.6	
EC (mmho/cm) "	0.50	0.13	0.09	0.06	0.13	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	3.80					
N (%)	0.51					
C/N	7.6					
CEC (me/100g), pH 8.2						
CEC " " pH 7.0	33	30	27	27	27	
Exch. Ca (me/100g)	12.4	9.8	7.2	6.0	6.6	
" Mg "	10.2	7.5	7.6	6.7	6.6	
" K "	0.5	0.3	0.4	0.3	0.5	
" Na "	0.3	0.3	0.2	0.2	0.2	
Sum of cations	23.4	17.9	15.4	13.2	13.9	
Base sat. %, pH 8.2						
" " %, pH 7.0	71	60	57	48	51	
ESP at pH 7.0	<1	1	<1	<1	<1	

Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	16	14	12	10	12	
Silt % 0.05-0.002mm	36	22	24	26	36	
Clay % 0.002-0 mm	48	64	64	64	52	
Texture class	C	C	C	C	C	
Dispersed clay %						
Flocculation index						

Texture USDA:						
Sand % 2.0 - 1.0mm						
" " 1.0 - 0.50mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10mm						
" " 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						

Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions (me/l)						
Adj. SAR						

Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Clay mineralogy:							
SiO_2/Al_2O_3 (mol/mol)							
SiO_2/R_2O_3 "							
Fe_2O_3 (mmol%)							

X-ray report:

Fertility aspects: (0- cm) Laboratory no. /

pH-H_2O (1: v/v)			Available	Total
Exch. acidity (me/100g)		Na (me/100g)		
C%		K "		
N%		Ca "		
P-Olsen (ppm)		Mg "		
		Mn "		
		P (ppm)		

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.2

General site information

Mapping unit	: MV1
Soil classification	: luvic PHAEOZEM
Observation no./date	: 55-1; 12/2/74
Location/altitude	: Marsabit District; 37° 57'E, 2°18'N; 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	0-20 cm	Dark brown (7.5YR 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: (sample no. 55-1/1)
Bt1	20-40 cm	Dark reddish brown (5 YR 3/4, dry), dark reddish brown (5 YR 3/3 moist); clay; strong, fine to medium, subangular blocky, breaking into crumbs; slightly hard when dry, very friable when moist, very sticky and very plastic when wet; few fine and medium pores; gradual and smooth transition to: (sample no. 55-1/2)
Bt2	40-75 cm	Dark reddish brown (5 YR 3/3 dry and moist); clay; strong, fine, angular blocky; slightly hard when dry, very friable when moist, very sticky and very plastic when wet; moderately thick, continous clay cutans; few, fine and medium pores; gradual and smooth transition to: (sample no. 55-1/3)
Bt3	75-115cm	Dusky red (2.5 YR 3/2 dry and moist); clay; weak, fine and medium, subangular 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: (sample no. 55-1/4)
BC	115-130+cm	Dark reddish brown (5 YR 3/2 dry and moist); clay

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

LABORATORY DATA OF PROFILE DESCRIPTION No: 3

FIELD OBSERVATION No: 41-1 **MAPPING UNIT:** MV2P

Laboratory no. ...../76	1898	1899	1900			
Horizon	Ah	Bw1	Bw2			
Depth (cm)	0-40	40-70	70-95			
pH-H_2O(1: v/v)	6.5	6.3	6.0			
pH-KCl ,,	5.6	4.5	4.2			
EC(mmho/cm) ,,	0.2	0.4	0.2			
$CaCO_3$(%)	-	-	-			
$CaSO_4$(%)						
C (%)	2.96	1.12	0.91			
N (%)	0.37					
C/N	8.3					
CEC (me/100g), pH 8.2						
CEC ,, ,, pH 7.0	38	24	20			
Exch.Ca (me/100g)	18.5	9.4	5.7			
,, Mg ,,	10.6	8.8	6.6			
,, K ,,	0.9	0.3	0.1			
,, Na ,,	n.d	0.8	0.6			
Sum of cations		19.3	13.0			
Base sat. %, pH 8.2						
,, ,, %, pH 7.0	78	80	65			
ESP at pH 7.0		3	3			

Saturation extract:

Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						

Clay mineralogy:

SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						

X-ray report:

SOIL CLASSIFICATION: eutric CAMBISOL

Depth (cm)	0-40	40-70	70-95			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	20	24	32			
Silt % 0.05-0.002mm	22	16	8			
Clay % 0.002-0 mm	58	60	60			
Texture class	C	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0- 20cm) Laboratory no. 2126/82

			Available	Total
pH-H_2O (1:2.5 v/v)	6.3			
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	4.75	K ,,	0.5	
N%	0.50	Ca ,,	19.6	
P-Olsen(ppm)	9	Mg ,,	8.0	
		Mn ,,	0.2	
		P (ppm)	57	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 3

General site information

Mapping unit	: MV2P
Soil classification	: eutric CAMBISOL
Observation no./date	: 41-2; 31/3/76
Location/altitude	: Marsabit District; 36° 56'E 2° 42'N; 2010m
Agro-climatic zone	: III
Parent material	: Basalts and tuffs (Tertiary volcanics)
Physiography	: Mountain top
Relief	: Mountainous
Slope at site	: 5%
Vegetation	: Evergreen montane forest
Land use	: Forest reserve but illegal seasonal grazing with domestic animals takes place as well
Erosion	: Nil
Surface stoniness/rockiness	: Very rocky and stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

Ah	0-40 cm	Dark reddish brown (5 YR 3/2 moist); clay; strong, crumb to strong, fine, subangular blocky; hard when dry, friable when moist, sticky and plastic when wet; many pores of various sizes; clear and smooth transition to: (sample no. 41-1a)
Bw1	40-70 cm	Dusky red (2.5 YR 3/2 dry and moist); clay; strong, fine, angular blocky; hard when dry, friable when moist, sticky and plastic when wet; moderately thick, broken clay cutans; common pores; gradual and smooth transition to: (sample no. 41-1b)
Bw2	70-95 cm	Reddish brown (5 YR 4/3 dry), dark reddish brown (5 YR 3/3 moist); clay; strong, fine, angular blocky; hard when dry, friable when moist; moderately thick, patchy, clay cutans; gradual and smooth transition to: (sample no.41-1c)
C	95^{+} cm	Weathering tuff

REMARK: Roots penetrate deep into the soil

LABORATORY DATA OF PROFILE DESCRIPTION No: 4

FIELD OBSERVATION No: 55-20 **MAPPING UNIT:** MPP **SOIL CLASSIFICATION:** eutric REGOSOL, stony and lithic phase

Laboratory no. ...../82	7201					
Horizon	Ah					
Depth (cm)	0-13					
pH-H_2O(1:2.5 v/v)	8.6					
pH-KCl ,,	7.6					
EC(mmho/cm) ,,	0.12					
$CaCO_3$(%)	-					
$CaSO_4$(%)						
C (%)	2.1					
N (%)	0.25					
C/N	8					
CEC (me/100g), pH 8.2	29.7					
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	24.0					
,, Mg ,,	1.2					
,, K ,,	1.0					
,, Na ,,	0.5					
Sum of cations	26.7					
Base sat. %, pH 8.2	90					
,, ,, %, pH 7.0						
ESP at pH 8.2	2					
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-13					
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	48					
Silt % 0.05-0.002mm	22					
Clay % 0.002-0 mm	30					
Texture class	SCL					
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 7137/ 82

			Available	Total
pH-H_2O (1:2.5 v/v)	7.1			
Exch. acidity (me/100g)		Na (me/100g)	0.2	
C%	1.97	K ,,	0.3	
N%	0.27	Ca ,,	10.7	
P-Olsen (ppm)	2	Mg ,,	10.0	
		Mn ,,		
		P (ppm)		

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.4

General site information

Mapping unit	: MPP
Soil classification	: eutric REGOSOL, stony and lithic phase
Observation no./date	: 55-20; 2/6/82
Location/altitude	: Marsabit District; 37°57'E, 2°20'N; 1500m
Agro-climatic zone	: V
Parent material	: Pyroclastic rocks; mainly tuffs (Quaternary volcanics)
Physiography	: Cinder cones within mountain area
Relief	: Mountainous
Slope at site	: 10%
Vegetation	: Perennial grassland with shrubs
Land use	: Partly used for grazing; partly under forest in forest reserve
Erosion	: Slight gully erosion
Surface stoniness/rockiness	: Fairly rocky and stony to extremely stony
Surface sealing	: Nil
Drainage class	: Somewhat excessively drained

Profile description

Ah	0-13 cm	Dark brown (7.5 YR 3/4 moist); slightly stony and gravelly sandy clay loam; strong, medium, granular; friable when moist, sticky and plastic when wet; very few small and medium pores; gravel and stones consist of tuff and pumice; abrupt and smooth transition to: (sample no. 55-20/1)
C	13-40 cm	Dark yellowish brown (10 YR 4/6 moist); extremely stony loamy sand (weathering tuff); irregular transition to:
R	40^{+} cm	Tuffs and pumice

REMARK: Roots are present throughout the profile to a depth of 40-50cm

LABORATORY DATA OF PROFILE DESCRIPTION No: 5

FIELD OBSERVATION No: 66-10 **MAPPING UNIT:** HUP **SOIL CLASSIFICATION:** eutric LITHOSOL

Laboratory no. ..... /81	7917						
Horizon	AC						
Depth (cm)	0-20						
pH–H_2O(1: v/v)	7.9						
pH–KCl ,,	6.9						
EC(mmho/cm) ,,	0.10						
$CaCO_3$(%)							
$CaSO_4$(%)							
C (%)	0,38						
N (%)	0,08						
C/N	5						
CEC (me/100g), pH 8.2	7.2						
CEC ,, ,, pH 7.0							
Exch.Ca (me/100g)	8.4						
,, Mg ,,	1.4						
,, K ,,	0,7						
,, Na ,,	0.2						
Sum of cations	10.7						
Base sat. %, pH 8.2	100						
,, ,, %, pH 7.0							
ESP at pH 8.2	2						
Saturation extract:							
Moisture %							
pH–paste							
ECe (mmho/cm)							
Na(me/l)							
K ,,							
Ca ,,							
Mg ,,							
Sum of cations(me/l)							
CO_3(me/l)							
HCO_3 ,,							
Cl ,,							
SO_4 ,,							
Sum of anions(me/l)							
Adj. SAR							
Clay mineralogy:							
SiO_2/Al_2O_3(mol/mol)							
SiO_2/R_2O_3 ,,							
Fe_2O_3(mmol%)							
X-ray report:							

Depth (cm)	0-15					
Gravel %	n.d					
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	80					
Silt % 0.05–0.002mm	10					
Clay % 0.002–0 mm	10					
Texture class	LS/SL					
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm) Laboratory no. /

			Available	Total
pH–H_2O (1:2.5v/v)				
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	0.27	K ,,	0.4	
N%	0.08	Ca ,,	5.8	
P–Olsen(ppm)	16	Mg ,,	1.9	
		Mn ,,	0.5	
		P (ppm)		

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 5

General site information

Mapping unit	: HUP
Soil classification	: eutric LITHOSOL
Observation no./date	: 66-10; 11/7/81
Location/altitude	: Marsabit District; 37° 20'E, 1° 46'N; 660m
Agro-climatic zone	: VI
Parent material	: Undifferentiated Basement System rocks
Physiography	: Hill
Relief	: Hilly, with slopes from 8 to over 30%
Slope at site	: 10%
Vegetation	: The greater part is bare, the rest has annual grasses and Commiphora shrubs
Land use	: Heavy grazing
Erosion	: Severe splash and rill wash erosion
Surface stoniness/rockiness	: Extremely rocky and very stony
Surface sealing	: Nil
Drainage class	: Excessively drained

Profile description

AC	0-15/30 cm	Strong brown (7.5 YR 5/6 dry), dark brown (7.5 YR 3/4 moist); stony and gravelly loamy sand to sandy loam; weak, coarse, subangular blocky; hard when dry, very friable when moist, non-sticky and non-plastic when wet; many large, few medium and few fine pores; few, small micas and feldspars; clear and smooth transition to: (sample no. 66-10/1)
R	15/30+ cm	Slightly weathered hard rock

LABORATORY DATA OF PROFILE DESCRIPTION No: 6

FIELD OBSERVATION No: 43-14 **MAPPING UNIT:** HP2P

SOIL CLASSIFICATION: calcaric REGOSOL, stony, lithic and sodic phase

Laboratory no. ...../82	7176					
Horizon	AC					
Depth (cm)	0-20					
pH-H_2O(1:2.5 v/v)	7.6					
pH-KCl ,,	7.0					
EC(mmho/cm) ,,	0.45					
$CaCO_3$(%)	+++					
$CaSO_4$(%)						
C (%)	0.17					
N (%)						
C/N						
CEC (me/100g), pH 8.2	31.0					
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	36.5					
,, Mg ,,	6.5					
,, K ,,	1.6					
,, Na ,,	2.5					
Sum of cations	47.1					
Base sat. %, pH 8.2	100					
,, ,, %, pH 7.0						
ESP at pH 8.2	8					
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0.15					
Gravel %	n.d					
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	22					
Silt % 0.05-0.002mm	24					
Clay % 0.002-0 mm	54					
Texture class	C					
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20cm) Laboratory no. 7128/82

			Available	Total
pH-H_2O (1:2.5v/v)	8.6			
Exch. acidity (me/100g)		Na (me/100g)	0.5	
C%	0.3	K ,,	0.5	
N%	0.04	Ca ,,	37.0	
P-Olsen (ppm)	7	Mg ,,	4.0	
		Mn ,,	tr	
		P (ppm)	47	

Various:

Remarks: pH values do not correspond

Kenya Soil Survey

PROFILE DESCRIPTION NO. 6

General site information

Mapping unit	: HP2P
Soil classification	: calcaric REGOSOL, stony, lithic and sodic phase
Observation No./date	: 43-14; 4/6/82
Location/altitude	: Marsabit District; 37° 49'E, 2° 38'N; 550m
Agro-climatic zone	: VII
Parent material	: Tuffs (Quaternary pyroclastics)
Physiography	: Hill
Relief	: Hilly, with slopes from 8 up to over 30%
Slope at site	: 20%
Vegetation	: Very few annual grasses and shrubs
Land use	: Game reserve
Erosion	: Not present
Surface stoniness/rockiness	: Rocky and extremely stony
Surface sealing	: Nil
Drainage class	: Excessively drained

Profile description

AC	0-15 cm	Strong brown (7.5 YR 5/6 dry), brown (7.5 YR 4/4 moist); exceeedingly stony and gravelly clay; weak, fine to medium, subangular blocky; soft when dry, very friable when moist, slightly sticky and plastic when wet; strongly calcareous; stones and gravel consist of tuff and pumice; gradual and smooth transition to: (sample no. 43-14/2)
C	15-40 cm	Basically the same as above, but higher stone content; irregular transition to:
R	40^{+}cm	Tuffs and pumice

REMARK: The soil is non-saline and slightly sodic

LABORATORY DATA OF PROFILE DESCRIPTION No: 7

FIELD OBSERVATION No: 41-2 **MAPPING UNIT:** U1V1

SOIL CLASSIFICATION: chromic* LUVISOL

Laboratory no. ....√76	1902	1903	1904	1905		
Horizon	Ah	Bt1	Bt2	Bt3		
Depth (cm)	0-14	14-50	50-90	90-110		
pH-H_2O(1: v/v)	6.6	6.8	7.0	6.9		
pH-KCl ,,	5.1	5.3	5.6	5.7		
EC(mmho/cm) ,,	0.24	0.14	0.30	0.60		
$CaCO_3$(%)	-	-	-	-		
$CaSO_4$(%)						
C (%)	2.9	1.6	1.5	1.1		
N (%)	0.22	0.14				
C/N	13	11				
CEC (me/100g), pH 8.2						
CEC ,, ,, pH 7.0	30	27	26	24		
Exch.Ca (me/100g)	12.5	12.6	11.4	9.8		
,, Mg ,,	12.0	10.0	10.5	9.6		
,, K ,,	0.3	0.2	0.2	0.1		
,, Na ,,	0.4	0.4	0.7	1.1		
Sum of cations	25.2	23.2	22.8	20.6		
Base sat. %, pH 8.2						
,, ,, %, pH 7.0	84	86	88	86		
ESP at pH 8.2 7.0	1	1	3	5		
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-14	14-50	50-90	90-110		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	20	20	20	38		
Silt % 0.05–0.002mm	26	12	8	12		
Clay % 0.002–0 mm	54	68	72	50		
Texture class	C	C	C	C		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– 20cm) Laboratory no. 2124 / 81

			Available	Total
pH-H_2O (1: 2.5 v/v)	5.7			
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	2.30	K ,,	0.4	
N%	0.21	Ca ,,	8.7	
P-Olsen(ppm)		Mg ,,	8.0	
		Mn ,,	0.4	
		P (ppm)	10	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 7

General site information

Mapping unit	: U1V1
Soil classification	: chromic* LUVISOL
Observation no./date	: 41-2; 1/4/76
Location/altitude	: Marsabit District, 36°56'E, 2°39'N; 1650m
Agro-climatic zone	: IV
Parent material	: Basalts (Tertiary/Quaternary)
Physiography	: High level uplands
Relief	: Gently sloping (slope class B)
Slope at site	: 2%
Vegetation	: Bushed perennial grassland
Land use	: Heavy grazing is practised
Erosion	: Nil
Surface stoniness/rockiness	: None to fairly stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

Ah	0-14 cm	Dark reddish brown (2.5 YR 3/4 dry), dark reddish brown (2.5 YR 2.5/4 moist); clay; strong, fine to medium, subangular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; common fine to coarse pores; clear and smooth transition to: (sample no. 41-2a)
Bt1	14-50 cm	Reddish brown (2.5 YR 4/4 dry), dark reddish brown (2.5 YR 3/4 moist); clay; moderate, medium, subangular to angular blocky; hard when dry, friable when moist, sticky and plastic when wet; broken, moderately thick, clay cutans; common fine pores; gradual and smooth transition to: (sample no. 41-2b)
Bt2	50-90cm	Red (2.5 YR 4/6 dry), dark reddish brown (2.5 YR 3/4 moist); clay; strong, fine to medium angular blocky; hard when dry, friable when moist, sticky and plastic when wet; moderately thick, continous, shiny clay cutans; common fine pores; gradual and smooth transition to: (sample no. 41-2c)
Bt3	90-110^{+}cm	Reddish brown (5 YR 4/4 dry), reddish brown (5 YR 4/3 moist); clay; moderate, medium, angular blocky;hard when dry, friable when moist, sticky and plastic when wet; moderately thick, continuous, shiny clay cutans; common fine pores; few, small Mn concretions (sample no. 41-2d)
	REMARK:	Roots are present throughout the profile to a depth of more than 110 cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 8

FIELD OBSERVATION No: 55-17 **MAPPING UNIT:** U1V2

Laboratory no. ...../ 82	4335	4336	4379			
Horizon	Ah	Bw1	Bw2			
Depth (cm)	0-20	20-50	50-90			
pH-H_2O (1:2.5 v/v)	6.6	6.4	6.7			
pH-KCl ,,	5.6	5.4	5.4			
EC (mmho/cm) ,,	0.08	0.09	0.09			
$CaCO_3$ (%)	-	-	-			
$CaSO_4$ (%)						
C (%)	1.9	0.8	0.7			
N (%)	0.19					
C/N	10					
CEC (me/100g), pH 8.2	23.3	23.1	21.4			
CEC ,, ,, pH 7.0						
Exch. Ca (me/100g)	3.2	10.6	6.7			
,, Mg ,,	5.3	6.9	6.2			
,, K ,,	0.8	1.9	1.0			
,, Na ,,	0.2	0.2	0.2			
Sum of cations	12.5	19.6	14.1			
Base sat. %, pH 8.2	49	85	66			
,, ,, %, pH 7.0						
ESP at pH 8.2	<1	<1	<1			
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						
X-ray report:						

SOIL CLASSIFICATION: chromic CAMBISOL

Depth (cm)	0-20	20-50	50-90			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	14	14	14			
Silt % 0.05-0.002mm	24	24	28			
Clay % 0.002-0 mm	62	62	58			
Texture class	C	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 4418 / 82

			Available	Total
pH-H_2O (1:2.5 v/v)	6.8			
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	1.96	K ,,	1.1	
N%	0.19	Ca ,,	11.0	
P-Olsen (ppm)	4	Mg ,,	7.2	
		Mn ,,	0.8	
		P (ppm)		

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 8

General site information

Mapping unit	: U1V2
Soil classification	: chromic CAMBISOL
Observation no./date	: 55-17; 24/3/82
Location/altitude	: Marsabit District; 37° 58'E, 2° 21'N; 1320 m
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	0-20 cm	Dark reddish brown (2.5 YR 3/4 dry), reddish brown (5 YR 4/4 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: (sample no. 55-17/2)
Bw1	20-50 cm	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: (sample no. 55-17/3)
Bw2	50-90 cm	Dark red (2.5 YR 3/6 dry), dark reddish brown (2.5 YR 3/5 moist); stony clay; weak, coarse primatic, 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: (sample no. 55-17/4)
C	90-140 cm	Soft, rotten basalt with Fe and Mn mottles; irregular transition to: (sample no. 55-17/4)
R	140+cm	Coherent basalt
	REMARK:	Roots are present to a depth of over 100 cm

LABORATORY DATA OF PROFILE DESCRIPTION No: 9

FIELD OBSERVATION No: 75-14 **MAPPING UNIT:** U1V3P

SOIL CLASSIFICATION: eutric CAMBISOL, stony and petric phase

Laboratory no. .../82	4329	4330				
Horizon	Ah	Bw				
Depth (cm)	0-20	20-60				
pH-H_2O (1:2.5 v/v)	6.6	7.4				
pH-KCl ,,	5.8	6.5				
EC (mmho/cm) ,,	0.10	0.06				
$CaCO_3$ (%)		++				
$CaSO_4$ (%)						
C (%)	1.4	0.4				
N (%)	0.14					
C/N	10					
CEC (me/100g), pH 8.2	20.7	28.3				
CEC ,, ,, pH 7.0						
Exch. Ca (me/100g)	8.6	17.5				
,, Mg ,,	6.2	10.7				
,, K ,,	2.6	0.4				
,, Na ,,	0.2	0.4				
Sum of cations	17.6	29.0				
Base sat. %, pH 8.2	85	100				
,, ,, %, pH 7.0						
ESP at pH 8.2	<1	1				
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						
X-ray report:						

Depth (cm)	0-20	20-60				
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	22	40				
Silt % 0.05-0.002mm	30	26				
Clay % 0.002-0 mm	48	34				
Texture class	C	CL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 4416 / 82

			Available	Total
pH-H_2O (1: 2.5 v/v)	7.5			
Exch. acidity (me/100g)		Na (me/100g)	0.2	
C%	1.39	K ,,	1.4	
N%	0.17	Ca ,,	14.0	
P-Olsen (ppm)	13	Mg ,,	6.0	
		Mn ,,	0.5	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 9

General site information

Mapping unit	: U1V3P
Soil classification	: eutric CAMBISOL, stony and petric phase
Observation no./date	: 55-14; 27/3/82
Location/altitude	: Marsabit District; 38°00'E, 2°24'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 shrubland 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: (sample no. 55-14/2)
Bw	20-60 cm	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: (sample no. 55-14/3)
Cmk	60-62 cm	Platy petrocalcic material; abrupt and smooth transition to:
CR	62^{+} cm	Tuffs
	REMARKS:	Many fine and common roots from 0-60 cm

LABORATORY DATA OF PROFILE DESCRIPTION No: 10

FIELD OBSERVATION No: 67-17 **MAPPING UNIT:** U2F1

Laboratory no. ...../82	4387	4388	4389	4390		
Horizon	Ah	AB	Bt	BC		
Depth (cm)	0-8	8-28	28-70	70-80		
pH-H_2O (1:2.5 v/v)	7.8	8.1	7.5	6.9		
pH-KCl ,,	6.6	6.4	6.0	6.0		
EC (mmho/cm) ,,	0.10	0.11	0.19	0.70		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.20	0.20	0.17	0.20		
N (%)						
C/N						
CEC (me/100g), pH 8.2	15.8	16.0	23.8	24.8		
CEC . ,, pH 7.0						
Exch. Ca (me/100g)	10.3	12.2	16.9	11.7		
,, Mg ,,	2.2	3.7	3.7	4.9		
,, K ,,	1.7	1.4	0.8	0.5		
,, Na ,,	0.1	0.1	0.1	0.4		
Sum of cations	14.3	17.4	21.5	17.5		
Base sat. %, pH 8.2	90	100	91	71		
,, ,, %, pH 7.0						
ESP at pH 8.2	<1	<1	<1	3		
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						
X-ray report:						

SOIL CLASSIFICATION: luvic YERMOSOL

Depth (cm)	0-8	8-28	28-70	70-80		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	68	68	56	54		
Silt % 0.05–0.002 mm	14	12	18	14		
Clay % 0.002–0 mm	18	20	26	32		
Texture class	SL	SL/SCL	SCL	SCL		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
,, ,, 1.0 – 0.50 mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10 mm						
,, ,, 0.10 – 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 4424 / 82

			Available	Total
pH-H_2O (1: 2.5 v/v)	6.9			
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	0.35	K ,,	1.0	
N%	0.04	Ca ,,	8.2	
P-Olsen (ppm)	15	Mg ,,	4.4	
		Mn ,,	0.5	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 10

General site information

Mapping unit	: U2F1
Soil classification	: luvic YERMOSOL
Observation no./date	: 67-17; 23/3/82
Location/altitude	: Marsabit District; 37°31'E, 1°59'N; 550 m
Agro-climatic zone	: VII
Parent material	: Gneisses rich in ferro-magnesian minerals (Basement System rocks)
Physiography	: Low level uplands
Relief	: Gently undulating
Slope at site	: 1.5%
Vegetation	: Grassland *(Cenchrus ciliaris)* with dwarf shrubs *(Duosperma eremophilum)*
Land use	: Intensively used for grazing and cutting of the woody vegetation
Erosion	: Strong splash, severe sheetwash, moderate rill, severe deflation. Obstacle dunes (about 50 cm) are present
Surface rockiness/stoniness	: Nil to very few rock outcrops
Surface sealing	: Slight sealing
Drainage class	: Well drained

Profile description

Ah	0-8 cm	Reddish brown (7.5 YR 6/6 dry), reddish brown (7.5 YR 4/4 moist); sandy loam; weak, fine to coarse, angular and subangular blocky; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; common fine and medium, few coarse pores; few small micas and dark minerals; clear and smooth transition to: (sample no. 67-17/2)
AB	8-28 cm	Yellowish red (5 YR 5/6 dry), red (2.5 YR 4/6 moist); slightly gravelly, sandy loam to sandy clay loam; porous massive, moderately coherent, breaking into weak, fine to medium, angular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; many fine and medium, common, coarse pores; fine gravel consists of sub-angular quartz and feldspars; few fine micas and dark minerals; clear and smooth transition to: (sample no. 67-17/3)
Bt	28-70 cm	Red (2.5 YR 4/6 dry), reddish brown (2.5 YR 4/4 moist); slightly gravelly sandy clay loam; strong, coarse prismatic, breaking into moderate to weak, coarse angular blocky; very to extremely hard when dry; very friable when moist, sticky and plastic when wet; moderately thick, continous, clay cutans; common fine and medium, few fine micas and dark minerals; from 60 cm depth very few, small, soft $CaCO_3$ concretions; clear and smooth transition to: (sample no. 67-17/4)
BC	70-80 cm	Yellowish red (5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); slightly gravelly sandy clay loam; moderate, fine to coarse, subangular blocky; slightly hard when dry, very friable when moist,sticky and plastic when wet; many fine and medium, few coarse pores; very few, small, soft $CaCO_3$ concretions; gravel consists of rock fragments; few, small micas and dark minerals; abrupt and smooth transition to: (sample no. 67-17/5)
C	80-110+cm	Rotten rock, gneiss with biotite and amphibolite, calcareous; with depth merging into coherent hard rock
	REMARKS:	Roots are present throughout the profile up to 100 cm depth. The top 70 cm of the soil shows a positive reaction with the NaF test.

LABORATORY DATA OF PROFILE DESCRIPTION No: 11

FIELD OBSERVATION No: 54-12 **MAPPING UNIT:** U2FA

SOIL CLASSIFICATION: haplic YERMOSOL, stony and petric phase

Laboratory no. ...../82	4312	4313				
Horizon	A	Bw				
Depth (cm)	0-10	10-50				
pH-H_2O (1:2.5 v/v)	7.8	7.6				
pH-KCl ,,	6.8	6.7				
EC (mmho/cm) ,,	0.11	0.11				
$CaCO_3$ (%)	-	-				
$CaSO_4$ (%)						
C (%)	0.09	0.06				
N (%)						
C/N						
CEC (me/100g), pH 8.2	14.3	13.7				
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	9.6	11.0				
,, Mg ,,	3.9	3.8				
,, K ,,	1.3	0.5				
,, Na ,,	0.2	0.4				
Sum of cations	15.0	15.7				
Base sat. %, pH 8.2	100	100				
,, ,, %, pH 7.0						
ESP at pH 8.2	1	3				
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						
X-ray report:						

Depth (cm)	0-10	10-50				
Gravel %	38	47				
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	64	72				
Silt % 0.05-0.002 mm	18	10				
Clay % 0.002-0 mm	18	18				
Texture class	SL	SL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm						
,, ,, 1.0 - 0.50 mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10 mm						
,, ,, 0.10 - 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 4403 / 82

			Available	Total
pH-H_2O (1:2.5 v/v)	7.8			
Exch. acidity (me/100g)		Na (me/100g)	0.08	
C%	0.35	K ,,	1.1	
N%	0.06	Ca ,,	5.2	
P-Olsen (ppm)	25	Mg ,,	3.7	
		Mn ,,	0.5	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 11

General site information

Mapping unit	: U2FA
Soil classification	: haplic YERMOSOL, stony and petric phase
Observation no./date	: 54-21; 22/3/82
Location/altitude	: Marsabit District; 37°30'E, 2°1'N; 600 m
Agro-climatic zone	: VII
Parent material	: Gneisses rich in ferromagnesian minerals (Basement System rocks)
Physiography	: Low level uplands (middle slopes)
Relief	: Undulating
Slope at site	: 5-7%
Vegetation	: Virtually bare with some annual grasses and a few shrubs (e.g. *Diatropa*)
Land use	: Over grazing takes place
Erosion	: Strong splash and rillwash erosion
Surface rockiness/stoniness	: Rocky and exceedingly stony
Surface sealing	: Nil
Drainage class	: Somewhat excessively drained

Profile description

A	0-10 cm	Reddish yellow (5 YR 6/6 dry), dark red (2.5 YR 3/6 moist); very gravelly and slightly stony sandy loam; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; common fine, medium and coarse pores; gravel and stones consist mainly of quartz; few, small micas; clear and smooth transition to: (sample no. 54-21/2)
Bw1	10-22 cm	Yellowish red (5 YR 5/6 dry), dark reddish brown (2.5 YR 3/5 moist); very stony and very gravelly sandy loam; slightly hard when dry, very friable when moist, sticky and plastic when wet; angular and subangular gravel and stones consist mainly of quartz; few small micas; gradual and smooth transition to: (sample no. 54-21/3)
Bw2	22-45 cm	Essentially the same as above but different colours: red (2.5 YR 4/6 dry and moist); clear and smooth transition to:
C	45-70^{+}cm	Mainly rotten rock (gneiss)
	REMARK:	Roots are present up to 70cm depth

LABORATORY DATA OF PROFILE DESCRIPTION No: 12

FIELD OBSERVATION No: 43-12 **MAPPING UNIT:** LsV1P

SOIL CLASSIFICATION: calcaric REGOSOL, stony, sodic and petric phase

Laboratory no. ...../82	7172					
Horizon	AC					
Depth (cm)	0-40					
pH-H_2O (1:2.5 v/v)	8.8					
pH-KCl ,,	7.6					
EC (mmho/cm) ,,	0.07					
$CaCO_3$ (%)	+++					
$CaSO_4$ (%)						
C (%)	0.11					
N (%)						
C/N						
CEC (me/100g), pH 8.2	9.1					
CEC ,, ,, pH 7.0						
Exch. Ca (me/100g)	18.0					
,, Mg ,,	1.7					
,, K ,,	3.0					
,, Na ,,	1.0					
Sum of cations	23.7					
Base sat. %, pH 8.2	100					
,, ,, %, pH 7.0						
ESP at pH 8.2	11					
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						
X-ray report:						

Depth (cm)	0-40					
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	68					
Silt % 0.05–0.002 mm	18					
Clay % 0.002–0 mm	14					
Texture class	SL					
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
,, ,, 1.0 – 0.50 mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10 mm						
,, ,, 0.10 – 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–40cm) Laboratory no. 7126 /82

			Available	Total
pH-H_2O (1:2.5 v/v)	8.0			
Exch. acidity (me/100g)		Na (me/100g)	0.9	
C%	0.08	K ,,	1.3	
N%	0.02	Ca ,,	19.0	
P-Olsen (ppm)	12	Mg ,,	6.0	
		Mn ,,	0.4	
		P (ppm)	218	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 12

General site information

Mapping unit	: LsV1P
Soil classification	: calcaric REGOSOL, stony, sodic and petric phase
Observation no./date	: 43-12; 3/6/82
Location/altitude	: Marsabit District; 37°56'E, 2°43'N; 580m
Parent material	: Basalts and pyroclastics (Tertiary/Quaternary volcanics)
Physiography	: Stepped plateau
Relief	: Almost flat to gently sloping with slopes from 0-2% (slope class A)
Slope at site	: 2%
Vegetation	: Very low cover with annual grasses and dwarf shrubs
Land use	: Seasonal grazing
Erosion	: A desert pavement protects the soil from erosion
Surface stoniness/rockiness	: Extremely stony and gravelly
Surface sealing	: Nil
Drainage class	: Somewhat excessively drained

Profile description

AC	0-40 cm	Strong brown (7.5 YR 5/6 dry), yellowish red (5 YR 4/6 moist); extremely stony and gravelly sandy loam; massive, slightly coherent; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; strongly calcareous; stones and gravel consist of lava fragments; gradual transition to: (sample no. 43-12/2)
CR	40^{+}cm	More than 90% stones in the soil
	REMARKS:	The soil is moderately sodic from the top downwards. Due to the very stony character of the soil separate sampling from 0-10 and 10-40cm was not possible.

LABORATORY DATA OF PROFILE DESCRIPTION No: 13

FIELD OBSERVATION No: 55-16 **MAPPING UNIT:** LsV2

Laboratory no. ...../ 82	4332	4333	4334			
Horizon	Ah	Bt1	Bt2			
Depth (cm)	0-20	20-50	50-90			
pH-H_2O(1:2.5 v/v)	7.3	6.5	6.7			
pH-KCl ,,	6.4	5.8	6.0			
EC(mmho/cm) ,,	0.11	0.24	0.19			
$CaCO_3$(%)	+	-	-			
$CaSO_4$(%)						
C (%)	0.88	0.33	0.29			
N (%)	0.14					
C/N	6					
CEC (me/100g), pH 8.2	27.1	17.7	15.3			
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	24.2	7.4	5.6			
,, Mg ,,	9.2	5.3	5.4			
,, K ,,	1.6	0.7	0.5			
,, Na ,,	0.8	0.2	0.2			
Sum of cations	35.8	13.6	11.7			
Base sat. %, pH 8.2	100	77	76			
,, ,, %, pH 7.0						
ESP at pH 8.2	3	1	1			
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: chromic LUVISOL

Depth (cm)	0-20	20-50	50-90			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	42	18	16			
Silt % 0.05-0.002mm	26	22	30			
Clay % 0.002-0 mm	32	60	54			
Texture class	CL	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at: depth	10-15		70-75			
pF 0						
pF 2.0	45.0		45.8			
pF 2.3	29.6		32.8			
pF 2.7	28.0		31.2			
pF 3.0						
pF 3.7	25.2		28.4			
pF 4.2	22.9		25.7			

Fertility aspects: (0-20 cm) Laboratory no. 4418 /82

			Available	Total
pH-H_2O (1:2.5 v/v)	6.8			
Exch. acidity (me/100g)		Na (me/100g)	0.08	
C%	1.2	K ,,	1.0	
N%	0.14	Ca ,,	6.6	
P-Olsen (ppm)	4	Mg ,,	4.6	
		Mn ,,	0.8	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.13

General site information

Mapping unit	: LsV2
Soil classification	: chromic LUVISOL
Observation no./date	: 55-16; 29/3/82
Location/altitude	: Marsabit District; 37°53'E, 2°11'N; 1050 m
Agro-climatic zone	: V
Parent material	: Basalts and pyroclastics (Tertiary/Quaternary volcanics)
Physiography	: Stepped plateau
Slope at site	: 1%
Vegetation	: Shrubland 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	0-20 cm	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: (sample no. 55-16/2)
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: (sample no. 55-16/3)
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 (sample no. 55-16/4)
	REMARK:	Throughout the profile, common, fine and few, large roots occur.

LABORATORY DATA OF PROFILE DESCRIPTION No: 14

FIELD OBSERVATION No: 55-19 **MAPPING UNIT:** LsV3p **SOIL CLASSIFICATION:** chromic VERTISOL, stony phase

Laboratory no. ...../82	7199	7200				
Horizon	Bw	Bwk				
Depth (cm)	5-30	20-70				
pH-H_2O (1:2.5 v/v)	8.8	8.4				
pH-KCl "	7.6	7.2				
EC (mmho/cm) "	0.35	0.30				
$CaCO_3$ (%)	++	++				
$CaSO_4$ (%)						
C (%)	0.8	0.6				
N (%)						
C/N						
CEC (me/100g), pH 8.2	37.5	34.5				
CEC " " pH 7.0						
Exch. Ca (me/100g)	46.0	46.0				
" Mg "	9.1	14.7				
" K "	0.8	0.4				
" Na "	0.6	0.7				
Sum of cations	56.5	61.8				
Base sat. %, pH 8.2	100	100				
" " %, pH 7.0						
ESP at pH 8.2	2	2				
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3 (mmol%)						
X-ray report:						

Depth (cm)	5-30	30-70				
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	22	20				
Silt % 0.05–0.002 mm	22	24				
Clay % 0.002–0 mm	56	56				
Texture class	C	C				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
" " 1.0 – 0.50 mm						
" " 0.50 – 0.25 mm						
" " 0.25 – 0.10 mm						
" " 0.10 – 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 7136/82

			Available	Total
pH-H_2O (1:2.5 v/v)	7.4			
Exch. acidity (me/100g)		Na (me/100g)	0.32	
C%	0.4	K "	0.2	
N%	0.13	Ca "	34.0	
P-Olsen (ppm)	2	Mg "	7.6	
		Mn "	0.1	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 14

General site information

Mapping unit	: LsV3p
Soil classification	: chromic VERTISOL, stony and petric phase
Observation no./date	: 55-19; 2/6/82
Location/altitude	: Marsabit District; 37°54'E, 2°7'N; 850 m
Agro-climatic zone	: V
Parent material	: Basalts and pyroclastics (Tertiary/Quaternary volcanics)
Physiography	: Stepped plateau
Relief	: Gently sloping
Slope at site	: 4%
Vegetation	: Deciduous shrubland (*Acacia mellifora* as dominant species) with herbs as understory
Land use	: Heavy grazing
Erosion	: Slight splash and rillwash erosion
Surface stoniness/rockiness	: Extremely stony
Surface cracking	: 2 to 4 cm wide cracks, which go deeper than 50 cm
Drainage class	: Imperfectly drained

Profile description

A	0-5 cm	Dark reddish brown (5 YR 2.5/3 moist); extremely bouldery and stony clay; strong, fine crumbs; friable when moist, sticky and plastic when wet; slightly calcareous; boulders and stones consist of basalt; abrupt and smooth transition to: (sample no. 55-19/1)
Bw	5-30 cm	Dark reddish brown (5 YR 2.5/2 moist); very stony and slightly gravelly clay; moderate, coarse, angular and subangular blocky; very hard when dry, friable to firm when moist, sticky and plastic when wet; moderately developed slickensides, wedge shaped planes with axes tilted 45°; very few fine pores; slightly calcareous; very few, small, carbonate concretions; boulders and stones consist of basalt; clear and smooth transition to: (sample no. 55-19/2)
Bwk	30-70 cm	Dark reddish brown (2.5 YR 2.5/2 moist); very bouldery and very stony clay; weak, medium to coarse, angular blocky; very hard when dry, friable to firm when moist, sticky and plastic when wet; moderately well developed slickensides; wedge shaped planes at 45° angle; very few fine pores; moderately calcareous; very few, small, carbonate concretions; clear and smooth boundary to: (sample no. 55-19/3)
C	70+ cm	Tuff
	REMARK:	Roots are present to a depth of more than 70 cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 15

FIELD OBSERVATION No: 55-12 **MAPPING UNIT:** LsVC1 **SOIL CLASSIFICATION:** calcaric REGOSOL, stony phase

Laboratory no. ..../82	4324
Horizon	AB
Depth (cm)	0-40
pH–H_2O(1:2.5v/v)	7.9
pH–KCl / ..	6.9
EC(mmho/cm) ..	0.11
$CaCO_3$(%)	
$CaSO_4$(%)	
C (%)	0.09
N (%)	
C/N	
CEC (me/100g), pH 8.2	28.2
CEC .. .. pH 7.0	
Exch.Ca (me/100g)	28.0
.. Mg ..	11.0
.. K ..	1.5
.. Na ..	0.6
Sum of cations	41.1
Base sat. %, pH 8.2	100
.. .. %, pH 7.0	
ESP at pH 8.2	2

Saturation extract:

Moisture %	
pH–paste	
ECe (mmho/cm)	
Na(me/l)	
K ..	
Ca ..	
Mg ..	
Sum of cations(me/l)	
CO_3(me/l)	
HCO_3 ..	
Cl ..	
SO_4 ..	
Sum of anions(me/l)	
Adj. SAR	

Clay mineralogy:

SiO_2/Al_2O_3(mol/mol)	
SiO_2/R_2O_3 ..	
Fe_2O_3(mmol%)	

X–ray report:

Depth (cm)	0-40
Gravel %	41
Texture, limited pretreatment:	
Sand % 2.0 – 0.05 mm	52
Silt % 0.05–0.002mm	18
Clay % 0.002–0 mm	30
Texture class	SCL
Dispersed clay %	
Flocculation index	
Texture USDA:	
Sand % 2.0 – 1.0mm	
.. .. 1.0 – 0.50mm	
.. .. 0.50 – 0.25mm	
.. .. 0.25 – 0.10mm	
.. .. 0.10 – 0.05mm	
Total sand %	
Silt %	
Clay %	
Texture class	
Bulk density	
Moisture % w/v at:	
pF 0	
pF 2.0	
pF 2.3	
pF 2.7	
pF 3.0	
pF 3.7	
pF 4.2	

Fertility aspects: (0– 40cm) Laboratory no. 4414/82

pH–H_2O (1:2.5v/v)	8.2		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.4	
C%	0.14	K ..	0.6	
N%	0.04	Ca ..	19.6	
P–Olsen (ppm)	12	Mg ..	8.1	
		Mn ..	0.4	
		P (ppm)	–	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 15

General site information

Mapping unit	: LsVC1
Soil classification	: calcaric REGOSOL, stony and petric phase
Observation no./date	: 55-12; 25/3/82
Location/altitude	: Marsabit District; 37°51'E, 2°24'N; 840 m
Agro-climatic zone	: VII
Parent material	: Basalts and pyroclastics (Tertiary/Quaternary volcanics)
Physiography	: Stepped plateau
Relief	: Gently sloping
Slope at site	: 1.5%
Vegetation	: Annual grassland with dwarf shrubs and shrubs
Land use	: Seasonal grazing
Erosion	: Strong splash and rillwash erosion, partly prevented by a stone mantle
Surface rockiness/stoniness	: Extremely stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

AB	0-40 cm	Yellowish red (5 YR 4/6 dry), reddish brown (5 YR 4/4 moist); very stony and gravelly sandy clay loam; weak, fine to medium, subangular blocky; soft when dry, very friable when moist; slightly sticky and slightly plastic when wet; strongly calcareous; stones and gravel consist of lava; gradual transition to: (sample no. 55-12/2)
C	40^{+} cm	More than 80% stones and gravel (lava)

LABORATORY DATA OF PROFILE DESCRIPTION No: 16

FIELD OBSERVATION No: 55-13 **MAPPING UNIT:** LsVC1

SOIL CLASSIFICATION: haplic YERMOSOL, boulder-mantle*, saline and sodic phase

Laboratory no. ..../82	4325	4326	4327	4328		
Horizon	A	Bw1	Bw2	Bw2		
Depth (cm)	0-20	20-60	60-90	110-150		
pH-H_2O(1:2.5 v/v)	8.1	8.5	8.1	7.8		
pH-KCl ,,	7.0	7.1	7.1	7.2		
EC(mmho/cm) ,,	0.17	0.24	0.85	3.00		
$CaCO_3$(%)	+++	+++	+++	+++		
$CaSO_4$(%)						
C (%)	0.11	0.12	0.07	0.11		
N (%)						
C/N						
CEC (me/100g), pH 8.2	28.3	28.5	29.8	28.4		
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	43.5	30.5	44.6	44.5		
,, Mg ,,	4.0	11.5	6.6	8.2		
,, K ,,	0.5	1.3	1.3	1.2		
,, Na ,,	0.3	3.1	2.0	1.8		
Sum of cations	48.3	46.4	54.5	55.7		
Base sat. %, pH 8.2	100	100	100	100		
,, ,, %, pH 7.0						
ESP at pH 8.2	1	11	7	6		
Saturation extract:						
Moisture %			48.0	50.0		
pH-paste			7.7	7.4		
ECe (mmho/cm)			6.0	8.5		
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						
From 20-60cm palygorskite, illite and kaolinite occur, from 60-90cm the same but with traces of montmorillonite.						

Depth (cm)	0-20	20-60	60-90	110-150		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	44	36	38	40		
Silt % 0.05–0.002mm	20	24	22	16		
Clay % 0.002–0 mm	36	40	40	44		
Texture class	CL	CL/C	CL/C	C		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 4415/82

			Available	Total
pH-H_2O (1:2.5 v/v)	8.3			
Exch. acidity (me/100g)		Na (me/100g)	0.5	
C%	0.2	K ,,	0.6	
N%	0.06	Ca ,,	35.0	
P-Olsen (ppm)	8	Mg ,,	4.4	
		Mn ,,	0.02	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.16

General site information

Mapping unit	: LsVC1
Soil classification	: haplic YERMOSOL, boulder-mantle*, saline and sodic phase
Observation no./date	: 55-13; 6/3/83
Location/altitude	: Marsabit District; 37°50'E, 2°29'N; 840 m
Agro-climatic zone	: VII
Parent material	: Basalts and pyroclastics (Tertiary/Quaternary volcanics)
Physiography	: Stepped plateau
Relief	: Gently sloping
Slope at site	: 3%
Vegetation	: Annual grassland with some shrubs
Land use	: Seasonal grazing
Erosion	: Very limited, due to boulder mantle
Surface rockiness/stoniness	: Rocky and exceedingly bouldery or stony
Surface crusting	: Slight crust
Drainage class	: Well drained

Profile description

A	0-20 cm	Yellowish red (5 YR 4/6 dry), dark reddish brown (5 YR 3/4 moist); very stony clay loam; moderate fine to medium, granular; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; common fine and medium, few coarse pores; strongly calcareous; stones consist of basalt; gradual and smooth transition to: (sample no. 55-13/2)
Bw1	20-60 cm	Reddish brown (5 YR 4/4 dry), dark reddish brown (5 YR 3/4 moist); clay loam to clay; moderate, coarse, angular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; common fine and medium, few coarse pores; strongly calcareous; gradual and smooth transition to: (sample no. 55-13/3)
Bw2	60-150^{+}cm	Yellowish red (5 YR 4/6 dry), dark reddish brown (5 YR 3/3 moist); clay loam to clay; massive, moderately coherent; slightly hard when dry, very friable when moist, sticky and plastic when wet; thin, patchy, clay cutans; few fine and medium pores; strongly calcareous; few, very small, soft carbonate concretions (sample nos. 55-13/4 from 60-90 cm and 5 from 110-150cm)
	REMARKS:	Slightly saline from 60 cm, moderately sodic from 20 cm depth. Many roots in top 20 cm, common fine roots up to 100 cm depth.

LABORATORY DATA OF PROFILE DESCRIPTION No: 17

FIELD OBSERVATION No: 43-19 **MAPPING UNIT:** LnVl

Laboratory no. ...../82	7188	7189	7190			
Horizon	A	Bw1	Bw2			
Depth (cm)	0-15	15-30	30-70			
pH–H_2O(1:2.5v/v)	8.8	9.1	8.1			
pH–KCl ,,	7.6	8.0	6.9			
EC(mmho/cm) ,,	0.35	0.55	3.0			
$CaCO_3$(%)	+++	+++	+++			
$CaSO_4$(%)						
C (%)	0.11	0.17	0.14			
N (%)						
C/N						
CEC (me/100g), pH 8.2	11.0	10.5	11.8			
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	24.0	28.5	24.0			
,, Mg ,,	1.5	1.9	0.9			
,, K ,,	2.4	2.4	1.6			
,, Na ,,	2.0	3.7	5.4			
Sum of cations	29.9	35.5	31.9			
Base sat. %, pH 8.2	100	100	100			
,, ,, %, pH 7.0						
ESP at pH 8.2	18	35	46			
Saturation extract:						
Moisture %			44.6			
pH–paste			7.6			
ECe (mmho/cm)			8.5			
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: haplic YERMOSOL, boulder-mantle*, saline and sodic phase

Depth (cm)	0-15	15-30	30-70			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	36	34	32			
Silt % 0.05–0.002mm	38	36	42			
Clay % 0.002–0 mm	26	30	26			
Texture class	CL	CL	CL			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm) Laboratory no. 7136/82

			Available	Total
pH–H_2O (1:2.5v/v)	7.4			
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	0.4	K ,,	0.2	
N%	0.13	Ca ,,	34.0	
P–Olsen(ppm)	2	Mg ,,	7.6	
		Mn ,,	0.02	
		P (ppm)	43	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 17

General site information

Mapping unit	: LnVI
Soil classification	: haplic YERMOSOL, boulder-mantle*, saline and sodic phase
Observation no./date	: 43-19; 5/6/82
Location/altitude	: Marsabit District; 37°46'E, 2°52'N; 550 m
Agro-climatic zone	: VII
Parent material	: Basalts mixed with ashes (Quaternary volcanics)
Physiography	: Non-dissected plateau
Relief	: Nearly flat
Slope at site	: 1%
Vegetation	: Few annual grasses
Land use	: Occasionally seasonal grazing
Erosion	: None
Surface rockiness/stoniness	: Non to fairly rocky; exceedingly bouldery or stony
Surface crusting	: Slight crust
Drainage class	: Well drained

Profile description

A	0-15 cm	Yellowish red (5 YR 5/6 dry), dark reddish brown (5 YR 3/4 moist); very stony clay loam; strong, fine to medium crumb; soft when dry, very friable when moist, sticky and slightly plastic when wet; many fine to medium pores; strongly calcareous; stones consist of basalt; gradual and smooth transition to: (sample no. 43-19/2)
Bw1	15-30 cm	Colour and texture as above; strong fine to medium subangular to angular blocky; soft when dry, very friable when moist, sticky and plastic when wet; many fine and medium, common coarse pores; strongly calcareous, gradual and smooth transition to: (sample no. 43-19/3)
Bw2	30-70^{+}cm	Colour as above; clay loam;porous massive, weakly coherent breaking into weak, fine to coarse angular blocky; many fine to coarse pores; strongly calcareous (sample no. 43-19/4)
	REMARKS:	Slightly saline from 30 cm downwards, strongly sodic thoughout. Mainly roots from 0-50cm, but some are going deeper.

LABORATORY DATA OF PROFILE DESCRIPTION No: 18

FIELD OBSERVATION No: 54-14 **MAPPING UNIT:** LnV2

SOIL CLASSIFICATION: haplic YERMOSOL, boulder-mantle* phase

Laboratory no. ...../82	4364	4365	4366			
Horizon	A	AB	Bw1			
Depth (cm)	0-10	10-30	30-50			
pH-H_2O(1:2.5 v/v)	8.2	8.3	8.3			
pH-KCl ,,	6.9	6.8	6.8			
EC(mmho/cm) ,,	0.30	0.25	0.25			
$CaCO_3$(%)	+++	+++	+++			
$CaSO_4$(%)						
C (%)	0.04	0.09	0.07			
N (%)						
C/N						
CEC (me/100g), pH 8.2	30.5	22.1	27,0			
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	48.2	38.5	46.5			
,, Mg ,,	3.7	2.9	2.9			
,, K ,,	4.1	2.8	1.9			
,, Na ,,	0.7	0.7	1.0			
Sum of cations	56.7	44.9	52.3			
Base sat. %, pH 8.2	100	100	100			
,, ,, %, pH 7.0						
ESP at pH 8.2	2	3	4			
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						

X-ray report: From 10 to 50 cm:
Palygorskite is the dominating clay mineral.
Illite occurs as well with traces of kaolinite.

Depth (cm)	0-10	10-30	30-50			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	40	40	40			
Silt % 0.05–0.002mm	34	30	30			
Clay % 0.002–0 mm	26	30	30			
Texture class	L	CL	CL			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 4396 /82

			Available	Total
pH-H_2O (1:2.5 v/v)	8.1			
Exch. acidity (me/100g)		Na (me/100g)	0.07	
C%	0.35	K ,,	1.1	
N%	0.05	Ca ,,	32.0	
P-Olsen(ppm)	7	Mg ,,	7.2	
		Mn ,,	0.3	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 18

General site information

Mapping unit	: LnV2
Soil classification	: haplic YERMOSOL, boulder-mantle* phase
Observation no./date	: 54-14; 12/3/82
Location/altitude	: Marsabit District; 37°15'E, 2°5'N; 650 m
Agro-climatic zone	: VII
Parent material	: Basalts with ashes (Quaternary volcanics)
Physiography	: Non dissected plateau
Relief	: Nearly flat
Slope at site	: 0.5-1%, sloping towards the east
Vegetation	: Shrubland with annual and perennial grasses as understory
Land use	: Occasionally seasonal grazing
Erosion	: Nil
Surface stoniness	: Exceedingly bouldery to exceedingly stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

A	0-10 cm	Yellowish red (5 YR 5/6 dry), dark reddish brown (5 YR 3/4 moist); stony loam; moderate, fine to medium, subangular blocky; loose when dry, very friable when moist, sticky and plastic when wet; few fine to medium pores; strongly calcareous; very few, medium to large, hard, $CaCO_3$ concretions; clear and smooth transition to: (sample no. 54-14/2)
AB	10-30 cm	Yellowish red (5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); clay loam; moderate, fine to medium, angular to subangular blocky; soft when dry, very friable when moist, sticky and plastic when wet; few fine to medium pores; strongly calcareous; very few, medium to large $CaCO_3$ concretions; abrupt and smooth transition to: (sample no. 54-14/3)
Bw1	30-50 cm	Dark brown (7.5 YR 4/4 dry), dark reddish brown (5 YR 3/4 moist); clay loam; weak, coarse primatic, breaking into weak, medium to coarse, angular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; few fine pores; strongly calcareous; very few, medium to large, $CaCO_3$ concretions; clear and smooth transition to: (sample no. 54-14/4)
Bw2	50-90 cm	Strong brown (7.5 YR 5/6 dry), dark reddish brown (5YR 3/4 moist); clay loam; weak, medium to coarse, angular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; few fine pores; strongly calcareous; very few, medium to large $CaCO_3$ concretions; abrupt and smooth transition to:
Ck	90^+ cm	Basalt stones and gravel, covered with $CaCO_3$ and $CaCO_3$ concretions.
	REMARK:	Roots only present up to 50 cm depth.

LABORATORY DATA OF PROFILE DESCRIPTION No: 19

FIELD OBSERVATION No: 41-8 **MAPPING UNIT:** LnV3p

SOIL CLASSIFICATION: haplic YERMOSOL, stony petric and sodic phase

Laboratory no. ..../ 81	2131	2132				
Horizon	A	Bw				
Depth (cm)	0-10	10-50				
pH–H_2O(1:2.5 v/v)	8.2	8.4				
pH–KCl "	6.9	6.8				
EC(mmho/cm) "	0.26	0.35				
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.26					
N (%)						
C/N						
CEC (me/100g), pH 8.2	36.5	40.5				
CEC " " pH 7.0						
Exch.Ca (me/100g)	29.8	44.3				
" Mg "	5.2	5.7				
" K "	1.5	0.3				
" Na "	0.9	2.7				
Sum of cations	37.4	53.0				
Base sat. %, pH 8.2	100	100				
" " %, pH 7.0						
ESP at pH 8.2	2.5	6.7				
Saturation extract:						
Moisture %						
pH–paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3(mmol%)						
X-ray report:						

Smectite, traces of kaolinite and few traces of palygorskite were found.

Depth (cm)	0-10	10-50				
Gravel %	49	n.d.				
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	46	38				
Silt % 0.05–0.002mm	26	32				
Clay % 0.002–0 mm	28	30				
Texture class	SCL	CL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
" " 1.0 – 0.50mm						
" " 0.50 – 0.25mm						
" " 0.25 – 0.10mm						
" " 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 81 / 2130

			Available	Total
pH–H_2O (1:2.5 v/v)	7.7			
Exch. acidity (me/100g)		Na (me/100g)	0.8	
C%	0.29	K "	0.5	
N%	0.05	Ca "	35.0	
P–Olsen (ppm)	8	Mg "	4.5	
		Mn "	0.1	
		P (ppm)	41	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.19

General site information

Mapping unit	: LnV3p
Soil classification	: halpic YERMOSOL, stony, petric and sodic phase
Observation no./date	: 41-8; 2/2/81
Location/altitude	: Marsabit District; 36°51'E, 2°32'N; 800 m
Agro-climatic zone	: VII
Parent material	: Basalts and pyroclastics (Quatenary volcanics)
Physiography	: Non-dissected plateau
Slope at site	: 2%
Vegetation	: Bushed annual grassland with a low vegetation cover
Land use	: Occasionally seasonal grazing
Erosion	: Slight splash and rill wash erosion
Surface rockiness/stoniness	: Fairly rocky and exceedingly gravelly and stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

A	0-10 cm	Light reddish brown (5 YR 6/4 dry), dark reddish brown (5 YR 3/3 moist); very stony and very gravelly sandy clay loam; moderate, fine to medium subangular blocky; slightly hard when dry, very friable when moist, slightly sticky and slightly calcareous; stones and gravel consist of basalt; gradual and smooth transition to: (sample no. 41-8/1)
Bw	10-40 cm	Reddish brown (5 YR 4/3 dry), dark reddish brown (5 YR 3/2 moist); slightly stony and gravelly clay loam; moderate, fine to medium, subangular blocky; slightly hard when dry, very friable when moist, slightly sticky and plastic when wet; very few pores; strongly calcareous; stones and gravel consist of basalt; clear and smooth transition to: (sample no. 41-8/2)
CR	50^{+}cm	More than 90% stones, basalt. The stones are covered with a thin layer of $CaCO_3$.
	REMARKS:	Roots are present throughout the profile. From 15 cm downwards, the soil is slightly sodic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 20

FIELD OBSERVATION No: 41-16 **MAPPING UNIT:** LnV4p

SOIL CLASSIFICATION: orthic SOLONETZ, boulder-mantle* phase

Laboratory no. ...../81	4328	4329	4330	4331		
Horizon	A	Bt	Btn	Btn		
Depth (cm)	0-10	10-40	40-60	60-120		
pH-H_2O(1:2.5 v/v)	8.1	8.5	8.6	8.8		
pH-KCl ,,	6.1	6.9	7.1	7.4		
EC(mmho/cm) ,,	0.25	0.11	0.24	1.00		
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.20					
N (%)	0.04					
C/N						
CEC (me/100g), pH 8.2	8.0	26.0	39.0	44.0		
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	17.3	31.5	30.5	39.5		
,, Mg ,,	3.5	9.5	14.5	18.0		
,, K ,,	0.8	1.1	0.8	1.5		
,, Na ,,	0.3	1.9	11.3	13.0		
Sum of cations	21.9	44.0	57.1	72.0		
Base sat. %, pH 8.2	100	100	100	100		
,, ,, %, pH 7.0						
ESP at pH 8.2	4	7	29	30		
Saturation extract:						
Moisture %				62.0		
pH-paste				8.5		
ECe (mmho/cm)				1.15		
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						

X-ray report:

Small amounts of smectite, mixed layer and palygorskite clay minerals were detected with traces of kaolinite.

Depth (cm)	0-10	10-40	40-60	60-120		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	84	56	44	34		
Silt % 0.05–0.002mm	6	10	12	16		
Clay % 0.002–0 mm	10	34	44	50		
Texture class	LS	SCL	C	C		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm) Laboratory no. 81 / 4361

			Available	Total
pH-H_2O (1:2.5 v/v)	8.2			
Exch. acidity (me/100g)		Na (me/100g)	1.8	
C%	n.d.	K ,,	0.2	
N%	n.d.	Ca ,,	7.3	
P-Olsen (ppm)	2	Mg ,,	8.9	
		Mn ,,	0.02	
		P (ppm)	22	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.20

General site information

Mapping unit	: LnV4p
Soil classification	: orthic SOLONETZ, boulder-mantle* phase
Observation no./date	: 41-16; 20/3/83
Location/altitude	: Marsabit District; 36°45'E, 2°34'N; 600 m
Agro-climatic zone	: VII
Parent material	: Basalts and pyroclastics (Quaternary volcanics)
Physiography	: Non-dissected plateau
Relief	: Nearly flat, interrupted with cinder cones
Slope at site	: 1%
Vegetation	: Annual grassland with a very low vegetation cover
Land use	: Seasonal grazing
Surface stoniness	: Exceedingly bouldery to exceedingly stony
Surface sealing	: Nil
Drainage class	: Moderately well drained

Profile description

A	0-10 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/4 moist); very bouldery, very stony, gravelly, loamy sand; massive, weakly coherent; soft when dry, very friable when moist, non-sticky and non-plastic when wet; strongly calcareous; coarse fragments consist of various lava parts; sharp and smooth transition to: (sample no. 41-16/1)
Bt	10-40 cm	Reddish brown (5 YR 4/4 dry and moist); slightly gravelly, sandy clay loam; moderate, coarse prismatic, breaking into weak, coarse, angular to subangular blocky; slightly hard when dry; friable when moist, sticky and plastic when wet; thin, patchy, clay cutans; few fine and very few, coarse pores; strongly calcareous; very few, medium, soft $CaCO_3$ concretions; gravel consists of small basalt fragments; gradual and smooth transition to: (sample no. 41-16/2)
Btn	40-120$^+$cm	Reddish brown (5 YR 4/4 dry and moist); slightly gravelly clay; weak, coarse prismatic breaking into weak, coarse angular and subangular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; moderately thick, broken, clay cutans common, fine, pores; strongly calcareous, few to frequent, medium, soft $CaCO_3$ concretions; gravel consists of basalt fragments (sample nos. 41-16/ 3 from 40-60 cm and 41-16/ 4 from 100-120 cm)
	REMARKS:	Non saline; strongly sodic from 40 cm downwards. Roots mainly present in top 50 cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 21

FIELD OBSERVATION No: 42-11 **MAPPING UNIT:** LdVP

SOIL CLASSIFICATION: haplic YERMOSOL, stony and petric phase

Laboratory no. ...../81	7901	7902				
Horizon	A	Bw				
Depth (cm)	0-20	20-50				
pH-H_2O (1:2.5 v/v)	7.5	8.5				
pH-KCl "	6.8	7.4				
EC (mmho/cm) "	0.20	0.30				
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.44	0.18				
N (%)						
C/N						
CEC (me/100g), pH 8.2	35.2	44.0				
CEC " " pH 7.0						
Exch. Ca (me/100g)	36.4	42.9				
" Mg "	7.7	6.2				
" K "	1.7	0.9				
" Na "	0.6	1.1				
Sum of cations	46.4	51.1				
Base sat. %, pH 8.2	100	100				
" " %, pH 7.0						
ESP at pH 8.2	2	3				
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3 (mmol%)						
X-ray report:						
Smectite is dominant with traces of kaolinite, palygorskite and mixed layer clay minerals.						

Depth (cm)	0-20	20-50				
Gravel %	20	n.d.				
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	28	32				
Silt % 0.05-0.002 mm	30	30				
Clay % 0.002-0 mm	42	38				
Texture class	C	CL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm						
" " 1.0 - 0.50 mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10 mm						
" " 0.10 - 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20cm) Laboratory no. 81/7889

pH-H_2O (1:2.5 v/v)	7.1		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.7	
C%	0.30	K "	0.5	
N%	0.05	Ca "	14.0	
P-Olsen (ppm)	17	Mg "	7.4	
		Mn "	1.5	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 21

General site information

Mapping unit	: LdVP
Soil classification	: haplic YERMOSOL, stony and petric phase
Observation no./date	: 42-11; 20/7/81
Location/altitude	: Marsabit District; 37° 24'E, 2°32'N; 550 m
Agro-climatic zone	: VII
Parent material	: Basalts, mixed with some tuffs and ashes
Physiography	: Dissected plateau
Relief	: Undulating to rolling
Slope at site	: 2%
Vegetation	: Shrubland *(Acacia senegal, A. horrida)* with annual grasses *(Aristida sp.)*
Land use	: Grazing
Erosion	: Slight gully at edges of the plateau
Surface rockiness/stoniness	: Non to fairly rocky, exceedingly stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

A	0-20/30 cm	Dark reddish brown (5 YR 3/3 dry and 5 YR 3/4 moist); very stony clay; strong, medium, granular, with depth merging into strong, medium and coarse, subangular blocky; slightly hard when dry, very friable when moist, very sticky and plastic when wet; patchy pressure faces; few, fine to medium pores; slightly calcareous; stones (10-20 cm) consist of angular basalt; gradual and wavy transition to: (sample no. 42-11/1)
Bw	20/30-50 cm	Dark reddish brown (5YR 3/3 dry and 5 YR 3/4 moist); very stony loam; strong, coarse prismatic, breaking into weak, coarse, subangular blocky; very hard when dry, very friable when moist, very sticky and plastic when wet; few pressure faces; few pores of various sizes; moderately calcareous; stones consist of angular basalt; abrupt and smooth transition to: (sample no. 42-11/2)
CR	50^{+}cm	Fractured basalt stones and boulders, 20 to 40 cm in dimension, which are covered with $CaCO_3$ spots.
	REMARKS:	The surface is very soft. Roots are present throughout the profile.

LABORATORY DATA OF PROFILE DESCRIPTION No: 22

FIELD OBSERVATION No: 55-22 **MAPPING UNIT:** RVp

SOIL CLASSIFICATION: ferralic CAMBISOL, bouldery and partly petric phase

Laboratory no. ...../83	823	824	835			
Horizon	A	Bw1	Bw2			
Depth (cm)	0-20	20-40	40-60			
pH–H_2O (1:2.5 v/v)	7.9	7.2	7.2			
pH–KCl "	6.6	6.2	6.0			
EC (mmho/cm) "	0.14	0.10	0.10			
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.02	0.74	0.56			
N (%)						
C/N						
CEC (me/100g), pH 8.2	14.6	18.9	14.3			
CEC " " pH 7.0						
Exch. Ca (me/100g)	10.1	8.8	8.0			
" Mg "	5.1	6.2	5.3			
" K "	1.7	1.5	1.1			
" Na "	0.6	0.5	0.5			
Sum of cations	17.8	17.0	14.9			
Base sat. %, pH 8.2	100	90	100			
" " %, pH 7.0						
ESP at pH 8.2	4	3	3			
Saturation extract:						
Moisture %						
pH–paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3 (mmol%)						
X-ray report:						

Depth (cm)	0-20	20-40	40-60		petric phase	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	26	16	20			
Silt % 0.05–0.002 mm	46	38	32			
Clay % 0.002–0 mm	28	46	48			
Texture class	CL	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
" " 1.0 – 0.50 mm						
" " 0.50 – 0.25 mm						
" " 0.25 – 0.10 mm						
" " 0.10 – 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 826/83

			Available	Total
pH–H_2O (1:2.5 v/v)	8.2			
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	0.99	K "	1.2	
N%	0.10	Ca "	9.4	
P–Olsen (ppm)		Mg "	8.4	
		Mn "	0.9	
		P (ppm)	48	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.22

General site information

Mapping unit	: RVp
Soil classification	: ferralic CAMBISOL, bouldery and partly petric phase
Observation no./date	: 55-23; 17/1/83
Location/altitude	: Marsabit District; 37°53'E, 2°8'N; 840 m
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 sheetwash, slight gully
Surface rockiness/stoniness	: In places stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

A	0-20 cm	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; clear and smooth transition to; (sample no. 55-22/1)
Bw1	20-40 cm	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: (sample no. 55-22/2)
Bw2	40-65 cm	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: (sample no. 55-22/3)
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.

LABORATORY DATA OF PROFILE DESCRIPTION No: 23

FIELD OBSERVATION No: 41-10 **MAPPING UNIT:** RVA

SOIL CLASSIFICATION: eutric CAMBISOL, stony phase

Laboratory no. ...../81	4315	4316	4317			
Horizon	A	Bw	Bw			
Depth (cm)	0-15	30-60	70-80			
pH-H_2O(1:2.5v/v)	6.7	6.8	7.4			
pH-KCl "	5.5	5.4	6.0			
EC(mmho/cm) "	0.15	0.13	0.15			
$CaCO_3$(%)	-	-	-			
$CaSO_4$(%)						
C (%)	1.13	0.87	0.84			
N (%)	0.13					
C/N	8					
CEC (me/100g), pH 8.2	34.0	25.0	24.0			
CEC " " pH 7.0						
Exch.Ca (me/100g)	15.6	13.6	13.6			
" Mg "	6.4	6.4	7.0			
" K "	5.3	1.7	1.8			
" Na "	0.6	0.3	0.6			
Sum of cations	27.9	22.0	23.0			
Base sat. %, pH 8.2	82	88	95			
" " %, pH 7.0						
ESP at pH 8.2	2	2				
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K "						
Ca "						
Mg "						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3(mmol%)						

X-ray report:

Kaolinite, illite and traces of mixed layer and palygorskite.

Depth (cm)	0-15	30-60	70-80			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	38	38	40			
Silt % 0.05-0.002mm	28	34	34			
Clay % 0.002-0 mm	34	28	26			
Texture class	CL	CL	L			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
" " 1.0 - 0.50mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10mm						
" " 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 81 / 4355

			Available	Total
pH-H_2O (12.5v/v)	7.0			
Exch. acidity (me/100g)		Na(me/100g)	0.14	
C%	n.d.	K "	2.0	
N%		Ca "	7.9	
P-Olsen(ppm)	6	Mg "	6.2	
		Mn "	0.8	
		P (ppm)	33	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 23

General site information

Mapping unit	: RVA
Soil classification	: chromic CAMBISOL, stony phase
Observation no./date	: 41-10; 5/3/81
Location/altitude	: Marsabit District; 36°58'E, 2°35'N; 1060 m
Agro-climatic zone	: V
Parent material	: Basalts and ashes
Physiography	: Footridge, crest
Relief	: Gently undulating (crest) to steep slopes (valley side)
Slope at site	: 5%
Vegetation	: Woodland with *Acacia etbaica* and *nilotica* as the dominant species. Dwarf shrubs and perennial grasses form the understory
Land use	: Seasonal grazing
Erosion	: Moderate splash and rillwash
Surface stoniness	: Very to exceedingly stony and/or bouldery
Surface crusting	: Strong crust
Drainage class	: Well drained

Profile description

A	0-15 cm	Reddish brown (5 YR 4/5 dry), dark reddish brown (5 YR 3/4 moist); slightly stony clay loam; moderate, fine to coarse, subangular blocky; slightly hard when dry, very friable when moist, slightly sticky and plastic when wet; many fine, common medium, few coarse pores; stones consist of basalt; gradual and smooth transition to: (sample no. 41-10/I)
Bw	15-50/90 cm	Yellowish red (5 YR 4/6 dry), dark reddish brown (5 YR 3/4 moist); very bouldery clay loam to loam; moderate, medium to coarse, subangular blocky; slightly hard when dry, very friable when moist; slightly sticky and plastic when wet; very few, thin, clay cutans; many fine, many medium pores; boulders consist of basalt; irregular transition to: (sample nos. 41-10/II from 40-50 cm and 41-10/III from 70-80 cm)
CR	50/90^{+}cm	Mainly basalt boulders, rounded and slightly weathered on the outside
	REMARK:	Roots are abundant throughout the profile

LABORATORY DATA OF PROFILE DESCRIPTION No: 24

FIELD OBSERVATION No: 41-9 **MAPPING UNIT:** RVA

SOIL CLASSIFICATION: haplic PHAEOZEM, stony and petric phase

Laboratory no. ...../81	4314
Horizon	Ah1
Depth (cm)	0-20
pH–H_2O(1:2.5 v/v)	6.1
pH–KCl ,,	5.4
EC(mmho/cm) ,,	0.25
$CaCO_3$(%)	-
$CaSO_4$(%)	
C (%)	2.34
N (%)	
C/N	
CEC (me/100g), pH 8.2	30.0
CEC ,, ,, pH 7.0	
Exch.Ca (me/100g)	19.5
,, Mg ,,	11.3
,, K ,,	0.9
,, Na ,,	0.6
Sum of cations	32.3
Base sat. %, pH 8.2	100
,, ,, %, pH 7.0	
ESP at pH 8.2	2

Saturation extract:

Moisture %	
pH–paste	
ECe (mmho/cm)	
Na(me/l)	
K ,,	
Ca ,,	
Mg ,,	
Sum of cations(me/l)	
CO_3(me/l)	
HCO_3 ,,	
Cl ,,	
SO_4 ,,	
Sum of anions(me/l)	
Adj. SAR	

Clay mineralogy:

SiO_2/Al_2O_3(mol/mol)	
SiO_2/R_2O_3 ,,	
Fe_2O_3(mmol%)	

X-ray report:

Depth (cm)	0-20
Gravel %	
Texture, limited pretreatment:	
Sand % 2.0 – 0.05 mm	44
Silt % 0.05–0.002mm	26
Clay % 0.002–0 mm	30
Texture class	CL
Dispersed clay %	
Flocculation index	
Texture USDA:	
Sand % 2.0 – 1.0mm	
,, ,, 1.0 – 0.50mm	
,, ,, 0.50 – 0.25mm	
,, ,, 0.25 – 0.10mm	
,, ,, 0.10 – 0.05mm	
Total sand %	
Silt %	
Clay %	
Texture class	
Bulk density	
Moisture % w/v at:	
pF 0	
pF 2.0	
pF 2.3	
pF 2.7	
pF 3.0	
pF 3.7	
pF 4.2	

Fertility aspects: (0–20cm) Laboratory no. 81 /4354

pH–H_2O (1:2.5 v/v)	6.4		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	1.95	K ,,	0.2	
N%	0.31	Ca ,,	14.3	
P–Olsen(ppm)	-	Mg ,,	10.0	
		Mn ,,	0.5	
		P (ppm)	216	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 24

General site information

Mapping unit	: RVA
Soil classification	: haplic PHAEOZEM, stony and petric phase
Observation no./date	: 41-9; 5/3/81
Location/altitude	: Marsabit District; 36°56'E, 2°37'N; 1350 m
Agro-climatic zone	: V
Parent material	: Basalts
Physiography	: Footridge
Relief	: The crest is undulating with very steep slopes to the valley side
Slope at site	: 10%
Vegetation	: Woodland with *Acacia drepanolobium* as dominant species. Dwarf shrubs and perennial grasses form the understory.
Land use	: Grazing
Erosion	: Slight sheetwash
Surface stoniness	: Exceedingly stony (basalts)
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

Ah1	0-20 cm	Dark brown (7.5 YR 3/2 dry and moist); stony and gravelly, clay loam; strong, fine to medium, granular and subangular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; very few, medium and coarse pores; gravel and stones consist of basalt, gradual and irregular transition to: (sample no. 41-9/I)
Ah2	20-40 cm	As above, but very stony and bouldery; gradual and irregular transition to:
CR	40^{+} cm	Partly weathered, grey basalt

LABORATORY DATA OF PROFILE DESCRIPTION No: 25

FIELD OBSERVATION No: 54-11 **MAPPING UNIT:** FU1

SOIL CLASSIFICATION: luvic YERMOSOL, sodic phase

Laboratory no. ...../82	4350	4351	4352	4353	4354	4355
Horizon	A	Bw	Bt1	Bt2	BC1	BC2
Depth (cm)	0-15	15-45	50-80	90-110	110-130	130-150
pH-H_2O (1:2.5 v/v)	8.2	7.8	7.4	7.5	7.7	8.0
pH-KCl ,,	7.0	5.8	5.5	6.0	6.4	6.4
EC (mmho/cm) ,,	0.10	0.05	0.18	0.60	1.30	1.80
$CaCO_3$ (%)	-	-	-	-	-	-
$CaSO_4$ (%)						
C (%)	0.09	0.04	0.06	0.04	0.04	0.06
N (%)						
C/N						
CEC (me/100g), pH 8.2	4.7	5.3	7.1	10.3	13.8	13.0
CEC ,, ,, pH 7.0						
Exch. Ca (me/100g)	4.6	6.2	4.6	6.5	4.2	4.2
,, Mg ,,	2.7	3.3	3.7	4.5	2.2	1.5
,, K ,,	0.6	0.8	0.9	1.1	1.0	0.8
,, Na ,,	0.2	0.2	0.7	2.0	0.5	1.1
Sum of cations	8.1	10.5	9.9	14.1	7.9	7.6
Base sat. %, pH 8.2	100	100	100	100	57	58
,, ,, %, pH 7.0						
ESP at pH 8.2	4	4	10	20	4	9
Saturation extract:						
Moisture %					23.0	23.0
pH-paste					7.4	7.2
ECe (mmho/cm)					7.0	10.0
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						

X-ray report: Between 15 and 80cm, illite, kaolinite and a mixed layer mineral where detected in about equal quantities

Depth (cm)	0-15	15-45	59-80	90-110	110-130	130-150
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	86	80	78	68	68	70
Silt % 0.05-0.002mm	6	8	6	12	14	16
Clay % 0.002-0 mm	8	12	16	20	18	14
Texture class	LS	SL	SL	SL/SCL	SL	SL
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density	1.58	1.73	1.64			
Moisture % w/v at: depth	7-12	30-35	65-70			
pF 0	23.6	18.4	21.6			
pF 2.0	8.8	9.3	10.5			
pF 2.3	7.9	8.8	9.7			
pF 2.7						
pF 3.0						
pF 3.7	5.1	7.4	9.2			
pF 4.2	4.7	7.4	8.5			

Fertility aspects: (0-20 cm) Laboratory no. 82 / 4394

			Available	Total
pH-H_2O (1: 2.5 v/v)	7.9			
Exch. acidity (me/100g)		Na (me/100g)	0.04	
C%	0.23	K ,,	0.5	
N%	0.03	Ca ,,	2.6	
P-Olsen (ppm)	10	Mg ,,	2.7	
		Mn ,,	0.4	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO.25

General site information

Mapping unit	: FU1
Soil classification	: luvic YERMOSOL, sodic phase
Observation no./date	: 54-11; 10/3/82
Location/altitude	: Marsabit District; 37°16'E, 2°9'N; 600 m
Agro-climatic zone	: VII
Parent material	: Sediments derived from undifferentiated Basement System rocks
Physiography	: Footslope
Relief	: Almost flat to very gently sloping
Vegetation	: Bushed dwarf shrubland with grasses as understory (*Indigofera spinosa, Acacia tortillis, Salvadora persica, Aristida mutabilis* and *Dactylanium*)
Land use	: Grazing, moderately heavy
Erosion	: Strong splash and rillwash, slight gully erosion
Surface rockiness/stoniness	: Nil
Surface sealing	: Weak, soft sealing, thin, extensive algae crusts
Drainage class	: Well drained

Profile description

A	0-15 cm	Light brown (7.5 YR 6/4 dry), yellowish red (5 YR 4/6 moist); loamy sand; strong, fine to medium, subangular blocky; soft when dry, very friable when moist, non-sticky and non-plastic when wet; common fine and medium, few coarse pores; very few, small, dark minerals; gradual and smooth transition to: (sample no. 54-11/2)
Bw	15-47 cm	Strong brown (7.5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); sandy loam; weak, fine to medium subangular blocky; slightly hard when dry; very friable when moist, slightly sticky and non-plastic when wet; common fine and medium, few coarse pores; very few, small, dark minerals; clear and smooth transition to: (sample no. 54-11/3)
Bt1	47-90 cm	Yellowish red (5 YR 4/6 dry), reddish brown (5 YR 4/4 moist); sandy loam; porous massive, strongly coherent, breaking into weak, fine to medium, angular blocky; hard to very hard when dry, friable when moist; sticky and plastic when wet; thin, broken, clay cutans in 1 to 3 cm wide bands; common fine and medium, few coarse pores; very few, very small, iron/manganese concretions (in bands); very few, small, dark minerals; gradual and smooth transition to: (sample no. 54-11/4)
Bt2	90-110 cm	Yellowish red (5 YR 5/8 dry and 5 YR 4/6 moist); sandy clay loam to sandy loam; weak, fine to medium, subangular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; thin patchy clay cutans; common fine and medium, few coarse pores; very few, very small, iron/manganese concretions; clear and smooth transition to: (sample no. 54-11/5)
BC1	110-130 cm	Yellowish red (5 YR 5/6 dry and 5 YR 4/6 moist); sandy loam; weak, fine to medium subangular blocky; soft when dry; friable when moist; sticky and plastic when wet; common fine and medium pores; very few, very small, iron/manganese concretions; gradual and smooth transition to: (sample no. 54-11/6)
BC2	130-150^{+}cm	Reddish yellow (7.5 YR 7/6 dry)and yellowish red (5 YR 5/6 moist); sandy loam; weak, fine to medium, subangular blocky; soft when dry, friable when moist, sticky and plastic when wet; few fine and medium pores; frequent, large, very hard, reddish brown (5 YR 4/4 moist) nodules (clay and iron concentrations). (sample no. 54-11/7)
	REMARKS:	Roots are present to a depth of more than 120 cm. The soil is slightly to moderately sodic from 50 cm downwards.

LABORATORY DATA OF PROFILE DESCRIPTION No: 26

FIELD OBSERVATION No: 66-8 **MAPPING UNIT:** FUA

SOIL CLASSIFICATION: cambic ARENOSOL

Laboratory no. ...../80	12410	12411	12412	12413		
Horizon	A	AB	Bw	BC		
Depth (cm)	0-10	10-25	25-150	150-200		
pH-H_2O (1:2.5 v/v)	8.3	8.1	6.9	6.7		
pH-KCl "	7.4	6.8	5.3	5.2		
EC (mmho/cm) "	0.10	0.06	0.09	0.25		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.28	0.17	0.11	0.08		
N (%)	0.05					
C/N	5.6					
CEC (me/100g), pH 8.2	5.7	6.8	5.0	10.7		
CEC " " pH 7.0	3.6	5.8	6.2	8.2		
Exch. Ca (me/100g) 1)	6.3/1.6	5.2/19.0	3.4/18.0	12.6/26.0		
" Mg " 1)	1.3/0.04	1.4/1.4	1.1/1.7	11.4/3.3		
" K " 1)	0.9/0.4	0.7/0.6	0.3/0.4	2.4/0.2		
" Na " 1)	0.1/0.6	0.1/0.6	Tr/3.9	0.1/0.7		
Sum of cations						
Base sat. %, pH 8.2	100	100	100	100		
" " %, pH 7.0	73	100	100	100		
ESP at pH 8.2	2	1	<1	<1		
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3 (mmol%)						

X-ray report: Kaolinite, illite, mixed-layer and traces of smectite and palygorskite are present as clay minerals.

Depth (cm)	0-10	10-25	25-150	150-200		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	84	84	82	70		
Silt % 0.05-0.002 mm	10	6	8	10		
Clay % 0.002-0 mm	6	10	10	14		
Texture class	LS	LS	LS	LS		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm						
" " 1.0 - 0.50 mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10 mm						
" " 0.10 - 0.05 mm						
Total sand %	82	82	81	76		
Silt %	4	7	4	11		
Clay %	11	11	15	13		
Texture class	LS	LS/SL	SL	SL		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) **Laboratory no.** 80/12424

			Available	Total
pH-H_2O (1:2.5 v/v)	7.9			
Exch. acidity (me/100g)		Na (me/100g)	0.2	
C%	0.39	K "	0.6	
N%	0.05	Ca "	4.5	
P-Olsen (ppm)		Mg "	2.2	
		Mn "	0.3	
		P (ppm)	26	

Various:

Remarks: 1) Data from survey (top) and special analysis (bottom)

Kenya Soil Survey

PROFILE DESCRIPTION NO. 26

General site information

Mapping unit	: FUA
Soil classification	: cambic ARENOSOL
Observation no./date	: 66-8; 20/10/80
Location/altitude	: Marsabit District; 37°18'E, 1°45'N; 900 m
Agro-climatic zone	: VI
Parent material	: Sediments derived from undifferentiated Basement System rocks
Physiography	: Footslope
Relief	: Undulating
Slope at site	: 6%
Erosion	: Moderate gully
Surface rockiness/stoniness	: None to fairly rocky
Surface sealing	: Moderately strong sealing
Drainage class	: Somewhat excessively drained

Profile description

A	0-10 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/4 moist); loamy sand; massive, weakly coherent, breaking into very weak, fine to medium, subangular blocky; soft when dry, very friable when moist, non-sticky and non-plastic when wet; few fine pores; clear and smooth transition to: (sample no. 66-8/1)
AB	10-25 cm	Yellowish red (5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); loamy sand; porous massive, weakly coherent; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; few fine pores; gradual and smooth transition to: (sample no. 66-8/2)
Bw	25-150 cm	Yellowish red (5 YR 5/6 dry), red (2.5 YR 4/6 moist); loamy sand; porous massive, moderately coherent; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; few fine, few medium pores; diffuse and smooth transition to: (sample no. 66-8/3)
BC	150-200^{+}cm	Reddish yellow (7.5 YR 6/6 dry), red (2.5 YR 4/6 moist); loamy sand; porous massive, breaking into weak, medium to coarse, subangular blocky; hard when dry, very friable when moist, slightly sticky and slightly plastic when wet (sample no. 66-8/4)

LABORATORY DATA OF PROFILE DESCRIPTION No: 27

FIELD OBSERVATION No: 67-15 **MAPPING UNIT:** FUA **SOIL CLASSIFICATION:** luvic YERMOSOL, saline phase

Laboratory no. ..../80	12414	12415	12416	12417		
Horizon	A	Bw	Bt	BC		
Depth (cm)	0-25	25-65	65-125	125-170		
pH–H_2O (1:2.5 v/v)	6.9	7.3	7.4	7.8		
pH–KCl ,,	5.5	5.9	6.4	6.5		
EC (mmho/cm) ,,	0.08	0.14	1.05	1.25		
$CaCO_3$ (%)			0.07	0.09		
$CaSO_4$ (%)			5.10^{-4}	5.10^{-4}		
C (%)	0.03	0.03	0.11	0.06		
N (%)						
C/N						
CEC (me/100g), pH 8.2	7.2	7.8	15.5	7.0		
CEC ,, ,, pH 7.0	7.2	7.0	10.0	14.8		
Exch. Ca (me/100g) 1)	4.9/24.0	4.8/16.0	4.8/8.0	3.6/7.0		
,, Mg ,, 1)	2.5/2.6	1.5/2.2	1.4/0.2	2.7/3.8		
,, K ,, 1)	0.2/1.7	1.3/0.3	1.3/0.5	0.7/0.7		
,, Na ,, 1)	0.2/0.8	??/0.5	0.1/1.0	0.6/2.0		
Sum of cations						
Base sat. %, pH 8.2	100	100	50?	100		
,, ,, %, pH 7.0	100	100	97	91		
ESP at pH 8.2	3	<1	<1	9		
Saturation extract:						
Moisture %			23.5	28.0		
pH–paste			7.5	7.0		
ECe (mmho/cm)			8.0	9.5		
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						
X-ray report:						

Depth (cm)	0-25	25-65	65-125	125-170		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	78	78	72	72		
Silt % 0.05–0.002 mm	8	12	8	12		
Clay % 0.002–0 mm	14	10	20	10		
Texture class	SL	SL	SL/SCL	SL		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
,, ,, 1.0 – 0.50 mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10 mm						
,, ,, 0.10 – 0.05 mm						
Total sand %	78	76	73	82		
Silt %	13	9	16	12		
Clay %	9	15	11	7		
Texture class	SL	SL	SL	LS		
Bulk density	1.65	1.62	1.56	1.58		
Moisture % w/v at: depth	2-7	10-15	48-53	75-80 cm		
pF 0	29.9	34.3	35.4	36.4		
pF 2.0	18.9	21.3	20.8	23.3		
pF 2.3	12.7	12.5	11.2	16.8		
pF 2.7	9.6	9.5	8.5	12.7		
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 80 / 12425

			Available	Total
pH–H_2O (1:2.5 v/v)	7.6			
Exch. acidity (me/100g)		Na (me/100g)	0.2	
C%	0.06	K ,,	0.7	
N%	0.04	Ca ,,	5.4	
P–Olsen (ppm)		Mg ,,	2.0	
		Mn ,,	0.4	
		P (ppm)	37	

Various:

Remarks: 1) Data from survey (top) and special analysis (bottom)

Kenya Soil Survey

PROFILE DESCRIPTION NO.27

General site information

Mapping unit	: FUA
Soil classification	: luvic YERMOSOL, saline phase
Observation no./date	: 67-15; 18/10/80
Location/altitude	: Marsabit District; 37°32'E, 1°49'N; 550 m
Agro-climatic zone	: VII
Physiography	: Footslope
Relief	: Almost flat
Slope at site	: 2%
Vegetation	: Dwarf shrubland with annual grassland and bushes (*Indigofera spinosa*, *Aristida spp.* and *Commiphora spp*)
Land use	: Heavy, seasonal grazing
Erosion	: Severe splash and rillwash erosion and slight deflation
Surface stoniness	: Non-stony
Surface sealing	: Moderate, soft sealing
Drainage class	: Well drained

Profile description

A	0-25 cm	Brown (7.5 YR 4/5 dry), dark reddish brown (2.5 YR 3/4 moist); sandy loam; porous massive, breaking into weak, fine to medium subangular blocky; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; many fine pores; very few, small soft $CaCO_3$ concretions; very few, small micas; gradual and smooth transition to: (sample no. 67-15/1)
Bw	25-65 cm	Yellowish red (5 YR 5/8 dry), dark red (2.5 YR 3/6 moist); sandy loam; porous massive, breaking into fine to medium subangular blocky; hard when dry, friable when moist, slightly sticky and non-plastic when wet; many fine pores; very few, small, soft $CaCO_3$ concretions; very few, small, micas; gradual and smooth transition to: (sample no. 67-15/2)
Bt	65-125 cm	Yellowish red (5 YR 5/8 dry), red (2.5 YR 4/6 moist); sandy loam to sandy clay loam;porous massive, breaking into very weak, coarse, subangular blocky; hard when dry, friable when moist, slightly sticky and plastic when wet; many fine pores; thin, patchy, clay cutans; very few, small, soft, $CaCO_3$ concretions; very few, small micas; gradual and smooth transition to: (sample no. 67-15/3)
BC	125-170$^+$cm	Reddish yellow (7.5 YR 7/6 dry), yellowish red (5 YR 5/8 moist); sandy loam; massive, strongly coherent; hard when dry; friable when moist, slightly sticky and slightly plastic when wet; common, fine pores; very frequent, large, dark red (2.5 YR 3/6 moist), extremely hard when dry, extremely firm when moist, iron/manganese concretions; very few, small, micas (sample no. 67-15/4)
	REMARKS:	From 65 cm downwards the soil is slightly saline with a maximum ECe value of 9.5 mmho/cm between 125 and 170 cm. The majority of the soils however, are non-saline within 100 cm depth. Below 125cm the soil is slightly sodic. Roots are present up to 1 m depth.

LABORATORY DATA OF PROFILE DESCRIPTION No: 28

FIELD OBSERVATION No: 41-18 **MAPPING UNIT:** FV1P

SOIL CLASSIFICATION: calcic YERMOSOL, stony, sodic and lithic phase

Laboratory no. ..../82	7138
Horizon	A
Depth (cm)	0-20
pH-H_2O (1:2.5 v/v)	9.1
pH-KCl ,,	7.9
EC (mmho/cm) ,,	0.35
$CaCO_3$ (%)	
$CaSO_4$ (%)	
C (%)	0.18
N (%)	
C/N	
CEC (me/100g), pH 8.2	27.1
CEC ,, ,, pH 7.0	
Exch. Ca (me/100g)	24.0
,, Mg ,,	1.7
,, K ,,	2.3
,, Na ,,	2.7
Sum of cations	30.7
Base sat. %, pH 8.2	100
,, ,, %, pH 7.0	
ESP at pH 8.2	10

Saturation extract:

Moisture %	
pH-paste	
ECe (mmho/cm)	
Na (me/l)	
K ,,	
Ca ,,	
Mg ,,	
Sum of cations (me/l)	
CO_3 (me/l)	
HCO_3 ,,	
Cl ,,	
SO_4 ,,	
Sum of anions (me/l)	
Adj. SAR	

Clay mineralogy:

SiO_2/Al_2O_3 (mol/mol)	
SiO_2/R_2O_3 ,,	
Fe_2O_3 (mmol%)	

X-ray report:

Depth (cm)	0-20					phase
Gravel %	39					
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	42					
Silt % 0.05–0.002 mm	30					
Clay % 0.002–0 mm	28					
Texture class	CL					
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
,, ,, 1.0 – 0.50 mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10 mm						
,, ,, 0.10 – 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. /

pH-H_2O (1:2.5 v/v)	8.3		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	1.0	
C%	0.3	K ,,	0.6	
N%	0.04	Ca ,,	38.0	
P-Olsen (ppm)	6	Mg ,,	3.1	
		Mn ,,	tr	
		P (ppm)	32	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRITPION NO. 28

General site information

Mapping unit	: FV1P
Soil classification	: calcic YERMOSOL, stony, sodic and lithic phase
Observation no./date	: 41-18; 8/6/82
Location/altitude	: Marsabit District; 36°58'E, 3°58'N; 570 m
Agro-climatic zone	: VII
Parent material	: Basalts, mixed with pyroclastic material
Physiography	: Footslope
Relief	: Very gently undulating
Slope at site	: 2%
Vegetation	: Bushed annual grassland
Land use	: Occasionally seasonal grazing
Erosion	: Nil
Surface rockiness/stoniness	: Fairly rocky, stony and exceedingly gravelly
Surface sealing	: Nil
Drainage class	: Somewhat excessively drained

Profile description

A	0-20 cm	Brown (7.5 YR 5/4 dry), reddish brown (5 YR 4/4 moist); stony and very gravelly, clay loam; moderate, fine to medium, subangular blocky; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; many fine and medium pores; strongly calcareous; frequent, small and medium, hard $CaCO_3$ concretions; stones consist of basalt, gravel of basalt or $CaCO_3$; gradual and smooth transition to: (sample no. 41-18/2)
BC	20-40 cm	Essentially the same as above but extremely stony and gravelly; gradual and smooth transition to:
CR	40^{+} cm	More than 90% basalt stones, covered with carbonates

LABORATORY DATA OF PROFILE DESCRIPTION No: 29

FIELD OBSERVATION No: 41-26 **MAPPING UNIT:** FV2p

SOIL CLASSIFICATION: haplic YERMOSOL, boulder-mantle* and sodic phase

Laboratory no. ...../82	7145	7146	7147			
Horizon	A	Bw1	Bw2			
Depth (cm)	0-20	20-50	50-70			
pH-H_2O(1:2.5v/v)	8.6	8.4	8.2			
pH-KCl ,,	7.4	7.4	7.3			
EC(mmho/cm) ,,	0.55	0.37	1.70			
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.26	0.18	0.21			
N (%)						
C/N						
CEC (me/100g), pH 8.2	33.9	28.1	3n.0			
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	33.0	24.0	33.0			
,, Mg ,,	6.1	2.4	5.7			
,, K ,,	3.6	3.1	1.7			
,, Na ,,	1.4	0.8	3.3			
Sum of cations	44.1	30.3	43.7			
Base sat. %, pH 8.2	100	100	100			
,, ,, %, pH 7.0						
ESP at pH 8.2	4	3	9			
Saturation extract:						
Moisture %			55.8			
pH-paste			7.8			
ECe (mmho/cm)			4.0			
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-20	20-50	50-70			phase
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	26	30	24			
Silt % 0.05–0.002mm	28	20	24			
Clay % 0.002–0 mm	46	50	52			
Texture class	C	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 82 / 7116

			Available	Total
pH-H_2O (1:2.5v/v)	8.8			
Exch. acidity (me/100g)		Na (me/100g)	0.8	
C%	0.2	K ,,	0.4	
N%	0.04	Ca ,,	29.0	
P-Olsen (ppm)	3	Mg ,,	8.4	
		Mn ,,	0.3	
		P (ppm)	146	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRITPION NO.29

General site information

Mapping unit	: FV2p
Soil classification	: haplic YERMOSOL, boulder-mantle* and sodic phase
Observation no./date	: 41-26; 15/6/82
Location/altitude	: Marsabit District; 36°47'E, 2°40'N; 600 m
Agro-climatic zone	: VII
Parent material	: Basalts, mixed with ashes
Physiography	: Footslope
Relief	: Gently undulating
Slope at site	: 5%
Vegetation	: Annual grassland and with few dwarf shrubs
Land use	: Occasionally seasonal grazing
Erosion	: Nil
Surface rockiness/stoniness	: Very rocky and extremely bouldery
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

A	0-20 cm	Dark brown (7.5 YR 3/4 dry), dark reddish brown (5 YR 3/4 moist); extremely stony clay; moderate, fine to medium, subangular blocky; soft when dry, very friable when moist, sticky and plastic when wet; common, fine to medium pores; strongly calcareous; clear and smooth transition to: (sample no. 41-26/2)
Bw1	20-50 cm	Dark brown (7.5 YR 3/4 dry), dark reddish brown (5 YR 3/4 moist); extremely stony clay; moderate, fine to medium, subangular blocky; soft when dry, very friable when moist, sticky and plastic when wet; common, fine to medium pores; strongly calcareous; clear and smooth transition to; (sample no. 41-26/3)
Bw2	50-70^{+}cm	Essentially the same as above except for structure and consistence when dry; massive, strongly coherent, breaking into weak, coarse, angular blocky; very hard when dry (sample no. 41-26/4)

LABORATORY DATA OF PROFILE DESCRIPTION No: 30

FIELD OBSERVATION No: 42-20 **MAPPING UNIT:** FV3P

SOIL CLASSIFICATION: haplic XEROSOL, stony and petric phase

Laboratory no. ...../82	7152	7153				
Horizon	A	Bw				
Depth (cm)	0-10	10-30				
pH-H_2O (1: 2.5 v/v)	8.9	8.5				
pH-KCl ,,	7.8	7.4				
EC (mmho/cm) ,,	0.40	0.30				
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.64	0.49				
N (%)						
C/N						
CEC (me/100g), pH 8.2	11.5	33.9				
CEC ,, ,, pH 7.0						
Exch. Ca (me/100g)	22.5	38.0				
,, Mg ,,	1.8	4.4				
,, K ,,	2.5	2.8				
,, Na ,,	0.7	0.6				
Sum of cations	27.5	45.8				
Base sat. %, pH 8.2	100	100				
,, ,, %, pH 7.0						
ESP at pH 8.2	6	2				

Depth (cm)	0-10	10-30				
Gravel %	n.d.	n.d.				
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	68	20				
Silt % 0.05–0.002 mm	16	42				
Clay % 0.002–0 mm	16	38				
Texture class	SL	CL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
,, ,, 1.0 – 0.50 mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10 mm						
,, ,, 0.10 – 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Saturation extract:

Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						

Clay mineralogy:

SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						

X-ray report:

Fertility aspects: (0–20 cm) Laboratory no. 82 / 7118

pH-H_2O (1: 2.5 v/v)	8.7		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.6	
C%	0.5	K ,,	1.0	
N%	0.11	Ca ,,	34.0	
P-Olsen (ppm)	10	Mg ,,	6.8	
		Mn ,,	0.1	
		P (ppm)	174	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 30

General site information

Mapping unit	: FV3p
Soil classification	: haplic XEROSOL, stony and petric phase
Observation no./date	: 42-20; 9/6/82
Location/altitude	: Marsabit District; 37°1'E, 2°48'N; 810 m
Agro-climatic zone	: VI
Parent material	: Basalts, mixed with pyroclastic material
Physiography	: Footslope
Relief	: Gently undulating
Slope at site	: 3%
Vegetation	: Deciduous shrubland with dwarf shrubs and annual grasses as understory. Main species are: *Acacia mellifora, A. reficiens, Duosperma eremophilum* and *Aristida spp.*
Land use	: Seasonal grazing
Erosion	: Slight splash and rillwash erosion
Surface stoniness	: Very stony
Surface sealing	: Slight crusting
Drainage class	: Well drained

Profile description

A	0-10 cm	Dark reddish grey (5 YR 4/2 dry), dark reddish brown (5 YR 3/2 moist); very stony sandy loam; moderate, fine, angular blocky to subangular blocky; hard when dry, friable when moist, sticky and plastic when wet; many, fine and medium pores; strongly calcareous; very few, medium $CaCO_3$ concretions; stones consist of basalt; clear and smooth transition to: (sample no. 42-20/2)
Bw	10-30 cm	Dark reddish brown (5 YR 3/2 dry and moist); very stony clay loam; strong, fine, angular blocky; hard when dry, friable when moist; sticky and plastic when wet; thin, patchy, clay cutans; many, fine and medium pores; strongly calcareous; stones consist of basalt; gradual and smooth transition to: (sample no. 42-20/3)
CR	30-50$^+$ cm	More than 90% basalt stones, covered with about 2 mm of $CaCO_3$

LABORATORY DATA OF PROFILE DESCRIPTION No: 31

FIELD OBSERVATION No: 42-24 **MAPPING UNIT:** FVC

SOIL CLASSIFICATION: orthic SOLONCHAK, stone-mantle* and sodic

Laboratory no. ...../ 82	7162	7163	7164			
Horizon	A	Bwk	Bwz			
Depth (cm)	0-18	18-55	55-80			
pH-H_2O(1:2.5 v/v)	9.2	9.6	8.9			
pH-KCl ,,	8.2	8.4	7.6			
EC(mmho/cm) ,,	0.08	0.50	2.60			
$CaCO_3$(%)	+++	+++	+++			
$CaSO_4$(%)						
C (%)	0.17	0.23	0.20			
N (%)						
C/N						
CEC (me/100g), pH 8.2	33.3	28.5	27.3			
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	34.0	33.0	40.0			
,, Mg ,,	2.7	4.7	5.9			
,, K ,,	2.2	1.6	1.8			
,, Na ,,	5.9	9.7	9.5			
Sum of cations	44.8	49.0	57.2			
Base sat. %, pH 8.2	100	100	100			
,, ,, %, pH 7.0						
ESP at pH 8.2	18	34	35			
Saturation extract:						
Moisture %			45.4			
pH-paste			7.2			
ECe (mmho/cm)			17.5			
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-18	18-55	55-80			phase
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	50	42	40			
Silt % 0.05–0.002mm	16	20	26			
Clay % 0.002–0 mm	34	38	34			
Texture class	SCL	CL	CL			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– 20cm) Laboratory no. 82 / 7122

			Available	Total
pH-H_2O (1:2.5v/v)	8.8			
Exch. acidity (me/100g)		Na (me/100g)	4.3	
C%	0.08	K ,,	0.2	
N%	0.03	Ca ,,	35.0	
P-Olsen(ppm)	3	Mg ,,	3.6	
		Mn ,,	tr.	
		P (ppm)	36	

Various:

Remarks:

Kenya Soil Survey

FILE DESCRIPTION NO.31

eral site information

ping unit	: FVC
l classification	: orthic SOLONCHAK, stone-mantle* and sodic phase
ervation no./date	: 42-24; 10/6/82
ation/altitude	: Marsabit District; 37°12'E, 3°47'N; 530 m
o-climatic zone	: VII
ent material	: Basalts, mixed with ashes
siography	: Footslope
lief	: Gently undulating
pe at site	: 2%
getation	: Shrubland with dwarf shrubs and annual grasses as understory
nd use	: Occasionally seasonal grazing
sion	: Nil
face stoniness	: Exceedingly stony
face crusting	: Slight
ainage class	: Well drained

ofile description

	0-18 cm	Dark brown (7.5 YR 4/4 dry), dark reddish brown (5 YR 3/4 moist); very stony sandy clay loam; strong, fine, subangular blocky; slightly hard when dry, friable when moist, slightly sticky and plastic when wet; many, fine to medium pores; strongly calcareous; stones consist of basalt; clear and smooth transition to: (sample no. 42-24/2)
ok	18-55 cm	Dark reddish brown (5 YR 3/4 dry and 5 YR 3/3 moist); fine gravelly clay loam; weak, fine to medium, angular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; many fine pores; strongly calcareous; gravel consist of lava parts; clear and smooth transition to: (sample no. 42-24/3)
wz	55-100^{+}cm	Colour and texture as above; porous massive, moderately coherent; hard when moist, sticky and plastic when wet; thin, broken clay cutans; many fine pores; strongly calcareous; few, small pockets of salt crystals (sample no. 42-24/4)
	REMARKS:	Roots present to about 50 cm depth. From 55 cm the soil is strongly saline. The soil is strongly sodic from the top. On top of the profile a thin layer of wind blown sand is present (coming from the Balesa river).

LABORATORY DATA OF PROFILE DESCRIPTION No: 32

FIELD OBSERVATION No: 41-17 **MAPPING UNIT:** VVlp

SOIL CLASSIFICATION: calcic YERMOSOL, stony, saline and sodic phase

Laboratory no. ...../	82	4332	4333				
Horizon		A	Bk				
Depth (cm)		0-15	15-55				
pH–H_2O(12.5v/v)		8.3	8.5				
pH–KCl ,,		7.1	7.4				
EC(mmho/cm) ,,		0.55	0.14				
$CaCO_3$(%)		+++	+++				
$CaSO_4$(%)							
C (%)		0.35					
N (%)							
C/N							
CEC (me/100g), pH 8.2		19.0	25.0				
CEC ,, ,, pH 7.0							
Exch.Ca (me/100g)		38.6	49.0				
,, Mg ,,		5.0	6.5				
,, K ,,		2.4	3.4				
,, Na ,,		2.3	0.6				
Sum of cations		48.3	59.5				
Base sat. %, pH 8.2		100	100				
,, ,, %, pH 7.0							
ESP at pH 8.2		12	2				
Saturation extract:							
Moisture %							
pH–paste							
ECe (mmho/cm)							
Na(me/l)							
K ,,							
Ca ,,							
Mg ,,							
Sum of cations(me/l)							
CO_3(me/l)							
HCO_3 ,,							
Cl ,,							
SO_4 ,,							
Sum of anions(me/l)							
Adj. SAR							
Clay mineralogy:							
SiO_2/Al_2O_3(mol/mol)							
SiO_2/R_2O_3 ,,							
Fe_2O_3(mmol%)							
X-ray report:							

Palygorskite, a mixed layer mineral and traces of kaolinite and illite were shown with X-ray analysis.

Depth (cm)	0-15	15-55				
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	56	46				
Silt % 0.05–0.002mm	22	26				
Clay % 0.002–0 mm	22	28				
Texture class	SCL	SCL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm) Laboratory no. 82 / 4362

pH–H_2O (12.5v/v)	8.2		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	0.23	K ,,	0.5	
N%	0.08	Ca ,,	41.5	
P–Olsen (ppm)	6	Mg ,,	5.0	
		Mn ,,	tr.	
		P (ppm)	39	

Various:

Remarks:

PROFILE DESCRIPTION NO. 32

General site information

Mapping unit	: YV1p
Soil classification	: calcic YERMOSOL, stony, saline and sodic phase
Observation no./date	: 41-17; 21/3/81
Location/altitude	: Marsabit District; 36°46'E, 2°43'N; 480 m
Agro-climatic zone	: VII
Parent material	: Colluvium and alluvium derived from basalts and pyroclastics
Physiography	: Piedmont plain
Relief	: Almost flat
Slope at site	: 2%
Vegetation	: Wooded dwarf shrubland with annual grasses as understory. *Acacia tortillis, Indigofera spinosa* and *Aristida spp.* are the main species
Land use	: Seasonal grazing
Erosion	: Slight splash and rillwash erosion, slight deflation; however limited due to the desert pavement
Surface stoniness	: Very to exceedingly stony
Surface sealing	: Nil
Drainage class	: Well drained

Profile description

A	0-15 cm	Dark brown (8.75 YR 4/4 moist); very gravelly sandy clay loam; strong, fine, subangular blocky, very friable when moist, slightly sticky and slightly plastic when wet; few, fine pores; strongly calcareous; few, medium $CaCO_3$ concretions; gravel consists of basalt; gradual and smooth transition to: (sample no. 41-17/I)
Bk	15-55 cm	Pinkish grey (7.5 YR 6/2 dry), dark brown (7.5 YR 4/4 moist); very gravelly sandy clay loam; massive, weakly coherent; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; few, fine pores; strongly calcareous; few to frequent, medium $CaCO_3$ concretions; gravel consists of angular basalt; clear and smooth transition to: (sample no. 41-17/II)
BCk	55-65 cm	Essentially the same as above but very stony and very gravelly sandy clay loam and few $CaCO_3$ concretions; clear and smooth transition to:
Ck	65-80$^+$cm	Over 80% hard, medium to large, $CaCO_3$ concretions
	REMARKS:	Roots are present throughout the profile. From 70cm downwards, the soil is slightly saline. The topsoil is moderately sodic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 33

FIELD OBSERVATION No: 42-17 MAPPING UNIT: YV2

SOIL CLASSIFICATION: orthic SOLONCHAK, sodic phase

Laboratory no. ...../81	12282	12283	12284	12285	12286	
Horizon	A	Bwk	Btkl	Btk2	2Ck	
Depth (cm)	0-20	20-32	32-55	55-80	85-100	
pH-H_2O(1:2.5v/v)	8.6	8.6	8.2	8.5	8.0	
pH-KCl ,,	7.0	7.1	7.0	7.1	7.2	
EC(mmho/cm) ,,	0.40	0.30	1.70	5.0	5.5	
$CaCO_3$(%)	12.5	12.4	10.9	9.4	35.0	
$CaSO_4$(%)						
C (%)						
N (%)						
C/N						
CEC (me/100g), pH 8.2	29.6	21.8	34.6	36.0	29.4	
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	56.0	45.0	42.0	37.0	27.0	
,, Mg ,,	8.8	6.7	9.6	6.4	4.0	
,, K ,,	2.6	2.0	1.9	0.4	0.6	
,, Na ,,	2.0	1.3	4.9	6.7	4.0	
Sum of cations	69.4	55.0	58.4	50.5	35.6	
Base sat. %, pH 8.2	100	100	100	100	100	
,, ,, %, pH 7.0						
ESP at pH 8.2	6	6	14	19	14	
Saturation extract:						
Moisture %			50.5	55.5	61.5	
pH-paste			8.9	8.2	6.7	
ECe (mmho/cm)			7.0	25.5	26.0	
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-20	20-32	32-55	55-80	85-100	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	48	60	42	40	36	
Silt % 0.05-0.002mm	40	22	24	30	16	
Clay % 0.002-0 mm	12	18	34	30	48	
Texture class	L	SL	CL	CL	C	
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 81 / 12281

			Available	Total
pH-H_2O (1:2.5v/v)	8.2			
Exch. acidity (me/100g)		Na(me/100g)	1.6	
C%		K ,,	0.6	
N%		Ca ,,	37.0	
P-Olsen(ppm)		Mg ,,	7.0	
		Mn ,,	tr.	
		P (ppm)	23	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 33

General site information

Mapping unit	: YV2
Soil classification	: orthic SOLONCHAK, sodic phase
Observation no./date	: 42-17; 11/11/81
Location/altitude	: Marsabit District; 37° 5'E, 2° 36'N; 550 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated alluvial and colluvial sediments
Physiography	: Piedmont plain
Relief	: Flat to almost flat
Slope at site	: 0%
Vegetation	: Wooded, perennial grassland to woodland
Land use	: Heavy grazing
Erosion	: Moderate rill and slight deflation
Surface stoniness	: Nil
Surface sealing	: Slightly hard sealing
Drainage class	: Moderately well drained

Profile description

A	0-20 cm	Brown (7.5 YR 5/3 dry), dark brown (7.5 YR 3/3 moist); loam; porous massive, slightly layered, weakly coherent, breaking into weak medium crumb; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many pores of various sizes; strongly calcareous; clear and smooth transition to: (sample no. 42-17/1)
Bwk	20-32 cm	Dark brown (7.5 YR 4/3 dry), dark reddish brown (5 YR 3/4 moist); sandy loam; porous massive, moderately coherent, breaking into weak, to coarse,angular blocky; hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many pores or various sizes; strongly calcareous; clear and smooth transition to: (sample no. 42-17/2)
Btk	32-84 cm	Reddish brown (5 YR 4/3 dry), dark reddish brown (5 YR 3/3 moist); clay loam; moderate, coarse, angular blocky; very hard when dry, friable when moist, slightly sticky and slightly plastic when wet; thin, broken,cutans or pressure faces; few, fine, few coarse pores; 2 cm wide cracks; strongly calcareous; abrupt and smooth transition to: (sample nos.42- 17/3 and 4 from 32-55 cm and from 55-80 cm respectively)
2Ck	84-150^{+}cm	Light gray (10 YR 7/2 dry and moist); soft lime with a clay texture and a strong, fine to coarse, granular structure (sample no. 42-17/5)
	REMARKS:	At 7 cm depth a fine gravelly layer (1-2 cm) of carbonate concretions occur. Roots are present to a depth of 70 cm. From 55 downwards the soil is strongly saline and strongly sodic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 34

FIELD OBSERVATION No: 42-19 MAPPING UNIT: PvVp

SOIL CLASSIFICATION: luvic VERMOSOL, stony, sodic and petric phase

Laboratory no. ...../82	7149	7150	7151			
Horizon	A	Bt	Bk			
Depth (cm)	0-20	20-50	50-90			
pH-H_2O(1:2.5 v/v)	8.5	8.7	9.1			
pH-KCl ,,	7.6	7.6	7.8			
EC(mmho/cm) ,,	0.45	0.30	0.60			
$CaCO_3$(%)	+++	+++	+++			
$CaSO_4$(%)						
C (%)	0.44	0.35	0.32			
N (%)						
C/N						
CEC (me/100g), pH 8.2	30.7	25.5	28.7			
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	27.5	31.0	25.0			
,, Mg ,,	5.7	7.5	7.5			
,, K ,,	3.1	2.0	1.4			
,, Na ,,	0.4	4.9	7.9			
Sum of cations	36.7	45.4	41.8			
Base sat. %, pH 8.2	100	100	100			
,, ,, %, pH 7.0						
ESP at pH 8.2	1	19	28			

Saturation extract:

Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						

Clay mineralogy:

SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						

X-ray report: The dominating clay mineral is montmorillonite. Palygorskite and kaolinite occur as well in small amounts.

Depth (cm)	0-20	20-50	50-90			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	50	44	32			
Silt % 0.05–0.002mm	18	14	24			
Clay % 0.002–0 mm	32	42	44			
Texture class	SCL	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						

Moisture % w/v at:

pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm) Laboratory no. 82 / 7117

pH-H_2O (1:2.5 v/v)	9.0		Available	Total
Exch.acidity (me/100g)		Na (me/100g)	1.3	
C%	0.5	K ,,	0.5	
N%	0.06	Ca ,,	35.0	
P-Olsen(ppm)	5	Mg ,,	6.0	
		Mn ,,	tr.	
		P (ppm)	34	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 34

General site information

Mapping unit	: PvVp
Soil classification	: luvic YERMOSOL, stony, sodic and petric phase
Observation no./date	: 42-19; 9/6/82
Location/altitude	: Marsabit District; 37°2'E, 2° 53'N; 750 m
Agro-climatic zone	: VII
Parent material	: Basalts, mixed with pyroclastics (Quaternary volcanics)
Physiography	: Volcanic plain
Relief	: Almost flat
Slope at site	: 0%
Vegetation	: Annual grassland with dwarf shrubs and shrubs. Some perennial grasses occur as well
Land use	: Occasionally seasonal grazing
Erosion	: Slight splash and rillwash erosion
Surface stoniness	: Stony and very gravelly
Surface crusting	: Slight crust
Drainage class	: Well drained

Profile description

A	0-20 cm	Dark brown (7.5 YR 4/4 dry), dark reddish brown (5 YR 3/3 moist) stony and gravelly, sandy clay loam; moderate, fine to medium, subangular blocky; soft when dry, very friable when moist, sticky and plastic when wet; many fine and medium pores; strongly calcareous; stones and gravel consist of basalt; clear and smooth transition to: (sample no. 42-19/2)
Bt	20-50 cm	Dark reddish brown (5 YR 3/4 dry and 5 YR 3/3 moist); slightly gravelly clay; strong, fine to coarse, subangular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; thin, patchy, clay cutans; very few, fine pores, strongly calcareous; few, medium, carbonate concretions; gravel consists of basalt; gradual and smooth transition to: (sample no. 42-19/3)
Bk	50-90 cm	Dark brown (7.5 YR 4/4 dry), dark reddish brown (5 YR 3/5 moist); slightly gravelly clay; massive, breaking into weak, coarse, angular blocky; very hard when dry, friable when moist, sticky and plastic when wet; very few, fine pores; slightly calcareous; few to frequent, medium and large, $CaCO_3$ concretions; gravel consists of lava fragments; clear and smooth transition to: (sample no. 42-19/4)
C	90-110+cm	Stony and gravelly, weathering tuffs, strongly calcareous
	REMARKS:	The soilshows some cracking and piping, in places. Roots are mainly present from 0 to 30 cm, some go deeper to about 60 cm. The soil is non-saline but strongly sodic from 20 cm downwards, with ESP values up to 50.

LABORATORY DATA OF PROFILE DESCRIPTION No: 35

FIELD OBSERVATION No: 43-16 MAPPING UNIT: PnSA

SOIL CLASSIFICATION: orthic SOLONETZ, saline phase

Laboratory no. ...../ 82	7183	7184	7185	7186		
Horizon	AE	Btn1	Btn2	Btn3		
Depth (cm)	0-10	10-20	20-60	60-100		
pH-H_2O(1:2.5v/v)	8.0	8.8	7.9	8.0		
pH-KCl ,,	6.9	7.6	7.0	7.0		
EC(mmho/cm) ,,	0.05	0.06	1.30	2.60		
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.26	0.06	0.14	0.06		
N (%)						
C/N						
CEC (me/100g), pH 8.2	3.8	3.3	8.5	8.1		
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	13.0	9.5	12.5	15.0		
,, Mg ,,	0.2	0.2	1.5	3.2		
,, K ,,	0.1	0.1	0.2	0.3		
,, Na ,,	2.1	1.0	1.0	2.7		
Sum of cations	15.4	10.8	14.7	21.2		
Base sat. %, pH 8.2	100	100	100	100		
,, ,, %, pH 7.0						
ESP at pH 8.2	55	30	12	39		

Saturation extract:

Moisture %			30.2	29.8		
pH-paste			7.7	7.3		
ECe (mmho/cm)			7.5	9.5		
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						

Clay mineralogy:

SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						

X-ray report:

Depth (cm)	0-10	10-20	20-60	60-100		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	90	86	64	66		
Silt % 0.05-0.002mm	4	2	6	4		
Clay % 0.002-0 mm	6	12	30	30		
Texture class	S	LS	SCL	SCL		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0- 20cm) Laboratory no. 82 / 7131

pH-H_2O (1:2.5v/v)	8.5		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	6.1	
C%	0.2	K ,,	0.5	
N%	0.02	Ca ,,	7.8	
P-Olsen(ppm)	2	Mg ,,	9.2	
		Mn ,,	0.3	
		P (ppm)	76	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 35

General site information

Mapping unit	: PnSA
Soil classification	: orthic SOLONETZ, saline phase
Observation no./date	: 43-16; 5/6/82
Location/altitude	: Marsabit District; 37°43'E, 2°52'N; 530 m
Agro-climatic zone	: VII
Parent material	: Quartzitic sandstones
Physiography	: Non- dissected erosional plain
Relief	: Almost flat with a gently undulating meso relief
Slope at site	: 1% (Profile located in slight depression)
Vegetation	: Almost bare, with a few grasses
Land use	: Seasonal grazing
Erosion	: Strong splash and rillwash erosion, with deposition in the depressions. Deflation occurs as well
Surface stoniness/rockiness	: Nil
Surface sealing	: Moderate crust
Drainage class	: Imperfectly drained

Profile description

AE	0-10 cm	Yellowish red (5 YR 4/6 dry), dark reddish brown (2.5 YR 3/4 moist); coarse sand; massive, slightly coherent to single grain; soft when dry, loose when moist, non-sticky and non-plastic when wet; few, fine pores; abrupt and smooth with 10 cm long, thin tongues transition to: (sample no. 43-16/3)
Btn1	10-20 cm	Red (2.5 YR 4/6 dry), dark reddish brown (2.5 YR 3/4 moist); coarse loamy sand; moderate, coarse, columnar with bleached caps; very hard when dry, very friable when moist, sticky and slightly plastic when wet; clay bridges between sand grains; few, fine pores; abrupt and smooth transition to: (sample no. 43-16/4)
Btn2	20-60 cm	Dark reddish brown (2.4 YR 3/4 dry and moist); sandy clay loam; strong, medium to coarse, angular blocky; hard when dry, friable when moist, sticky and plastic when wet; moderately thick, continous, clay cutans; few, fine pores; common, soft, black, iron manganese spots on ped faces; clear and smooth transition to: (sample no. 43-16/5)
Btn3	60-100^{+}cm	Dark red (2.5 YR 3/6 dry and moist); sandy clay loam; massive, coherent; slightly hard when dry, friable when moist, sticky and plastic when wet; clay bridges between grains; few, fine to medium pores; strongly calcareous (sample no. 43-16/6)

LABORATORY DATA OF PROFILE DESCRIPTION No: 36

FIELD OBSERVATION No: 55-9 MAPPING UNIT: PsHK

SOIL CLASSIFICATION: cambic ARENOSOL, petrocalcic phase

Laboratory no. ..... /82	4318	4319
Horizon	A	Bw
Depth (cm)	0-10	10-30
pH-H_2O (1:2.5 v/v)	8.3	8.2
pH-KCl ,,	6.9	7.3
EC (mmho/cm) ,,	0.07	0.10
$CaCO_3$ (%)		+++
$CaSO_4$ (%)		
C (%)	0.04	0.03
N (%)		
C/N		
CEC (me/100g), pH 8.2	4.3	6.0
CEC ,, ,, pH 7.0		
Exch. Ca (me/100g)	7.0	12.6
,, Mg ,,	2.1	2.7
,, K ,,	1.5	1.0
,, Na ,,	0.2	0.2
Sum of cations	10.8	16.5
Base sat. %, pH 8.2	100	100
,, ,, %, pH 7.0		
ESP at pH 8.2	4	3

Saturation extract:

Moisture %		
pH-paste		
ECe (mmho/cm)		
Na (me/l)		
K ,,		
Ca ,,		
Mg ,,		
Sum of cations (me/l)		
CO_3 (me/l)		
HCO_3 ,,		
Cl ,,		
SO4 ,,		
Sum of anions (me/l)		
Ca. SAR		

Clay mineralogy:

SiO_2/Al_2O_3 (mol/mol)		
SiO_2/R_2O_3 ,,		
R_2O_3 (mmol%)		

Clay report:

Depth (cm)	0-10	10-30				
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	84	80				
Silt % 0.05-0.002 mm	6	10				
Clay % 0.002-0 mm	10	10				
Texture class	LS	LS/SL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm						
,, ,, 1.0 - 0.50 mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10 mm						
,, ,, 0.10 - 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 82 / 4411

pH-H_2O (1:2.5 v/v)	8.5		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.2	
C%	0.13	K ,,	0.8	
N%	0.03	Ca ,,	21.5	
P-Olsen (ppm)	12	Mg ,,	4.8	
		Mn ,,	0.3	
		P (ppm)		

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 36

General site information

Mapping unit	: PsUK
Soil classification	: cambic ARENOSOL, petrocalcic phase
Observation no./date	: 55-9; 17/3/82
Location/altitude	: Marsabit District; 37°32'E, 2°28'N; 420 m
Agro-climatic zone	: VII
Parent materials	: Sediments derived from Basement System rocks, enriched with volcanic ashes
Physiography	: Sedimentary plain
Relief	: Almost flat
Slope at site	: 0.5%
Vegetation	: Almost bare to bushed grassland
Land use	: Severe overgrazing
Erosion	: Severe splash and rillwash erosion and severe deflation
Surface stoniness	: Fine gravelly
Surface sealing	: Slight
Drainage class	: Somewhat excessively drained

Profile description

A	0-10 cm	Reddish yellow (7.5 YR 6/6 dry), yellowish red (5 YR 4/6 moist); slightly gravelly loamy sand; weak, fine to medium, subangular blocky; soft when dry, very friable when moist, non-sticky and non-plastic when wet; few, fine and medium pores; few, medium hard, $CaCO_3$ concretions; very few, small, dark minerals; clear and smooth transition to: (sample no. 55-9/2)
Bw	10-30/50 cm	Yellowish red (5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); slightly gravelly, loamy sand to sandy loam; porous massive, breaking into weak, fine to medium subangular blocky; soft when dry, very friable when moist, non sticky and non plastic when wet; common, fine and medium pores; strongly calcareous; few, medium $CaCO_3$ concretions; very few, small, dark minerals; smooth and irregular transition to: (sample no. 55-9/3)
Cmk	$30/50^{+}$ cm	Petrocalcic material, continuous, coherent

LABORATORY DATA OF PROFILE DESCRIPTION No: 37

FIELD OBSERVATION No: 54-18 **MAPPING UNIT:** PsU1

SOIL CLASSIFICATION: luvic YERMOSOL, sodic phase

Laboratory no. ..../82	4378	4297	4298	4299	4300	
Horizon	A	BA	Bt1	Bt2	BC	
Depth (cm)	0-17	17-45	45-70	70-90	110-140	
pH-H_2O(1:2.5v/v)	8.3	6.8	6.3	6.3	7.4	
pH-KCl ,,	7.0	5.9	5.5	5.2	6.6	
EC(mmho/cm) ,,	0.10	0.05	0.30	0.29	1.10	
$CaCO_3$(%)					++	
$CaSO_4$(%)						
C (%)	0.03	0.02	0.09	0.07	0.06	
N (%)						
C/N						
CEC (me/100g), pH 8.2	6.5	9.7	15.3	17.0	8.3	
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	6.2	7.4	8.8	10.6	8.2	
,, Mg ,,	2.9	3.2	5.2	5.8	3.2	
,, K ,,	1.0	1.5	1.9	1.9	1.6	
,, Na ,,	0.2	0.5	1.0	1.7	0.7	
Sum of cations	10.3	12.6	16.9	20.0	13.7	
Base sat. %, pH 8.2	100	100	100	100	100	
,, ,, %, pH 7.0						
ESP at pH 8.2	3	5	6	10	9	

Depth (cm)	0-17	17-45	45-70	70-90	110-140	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	78	72	60	58	56	
Silt % 0.05–0.002mm	8	10	10	8	14	
Clay % 0.002–0 mm	14	18	30	34	30	
Texture class	SL	SL	SCL	SCL	SCL	
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						

Saturation extract:

Moisture %					35.0	
pH-paste					7.3	
ECe (mmho/cm)					10.0	
Ca (me/l)						
Mg ,,						
Na ,,						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO4 ,,						
Sum of anions(me/l)						
SAR						

Clay mineralogy:

SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
T-value(mmol%)						

Moisture % w/v at:

pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 82 / 4400

pH-H_2O (12.5v/v)	8.1		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	0.32	K ,,	1.1	
N%	0.05	Ca ,,	8.0	
P-Olsen (ppm)	19	Mg ,,	5.6	
		Mn ,,	0.7	
		P (ppm)	-	

Various:

Remarks:

Report:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 37

General site information

Mapping unit	: PsU1
Soil classification	: luvic YERMOSOL, sodic phase
Observation no./date	: 54-18; 16/3/82
Location/altitude	: Marsabit District; 37°16'E, 2°26'N; 540 m
Agro-climatic zone	: VII
Parent material	: Sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat to flat
Slope at site	: 0%
Vegetation	: Shrubland with understory of dwarf shrubs and grasses. The main species are: *Acacia reficiens, A. mellifera, Duosperma eremophilum, Indigofera spinosa, Aristida mutabilis, Enneapogon spp.* and *Blepharis linariifolia*
Land use	: Seasonal grazing
Erosion	: Severe splash, moderate rill and slight deflation
Surface stoniness	: Nil
Surface cracking	: Slight, soft sealing, about 2 cm thick
Drainage class	: Well drained

Profile description

A	0-17 cm	Light brown (7.5 YR 6/5 dry), reddish brown (5 YR 4/4 moist); sandy loam, moderate, medium to coarse, subangular blocky; soft when dry, loose when moist, non-sticky and non-plastic when wet; many pores of various sizes; very few, dark minerals; clear and smooth transition to: (sample no. 54-18/2)
BA	17-45 cm	Reddish brown (5 YR 5/4 dry and 5 YR 4/4 moist); sandy loam; weak, fine to coarse, subangular blocky; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many fine and medium, few coarse pores; very few, small dark minerals, clear and smooth transition to: (sample no. 54-18/3)
Bt1	45-70 cm	Dark reddish brown (2.5 YR 3/5 dry), reddish brown (2.5 YR 4/4 moist); sandy clay loam; porous massive, breaking into weak, medium to coarse, subangular to angular blocky; hard when dry, friable when moist, sticky and plastic when wet; thick, continuous, clay cutans; few fine and medium pores; very few, small iron-manganese concretions; very few, small, dark minerals; gradual and smooth transition to: (sample no. 54-18/4)
Bt2	70-110 cm	Dark reddish brown (2.5 YR 3/4 dry and moist); sandy clay loam; porous massive, breaking into weak, fine to coarse, angular blocky; very hard when dry; thick, continuous, clay cutans; few, fine to medium pores; few to moderate pores; few to frequent, small iron-manganese concretions; very few small, dark minerals; clear and smooth transition to: (sample no. 54-18/5)
BC	110-150^{+}cm	Strong brown (7.5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); sandy clay loam; porous massive, breaking into weak, fine to coarse, angular blocky; hard when dry, friable when moist, sticky and plastic when wet; thin, patchy, clay cutans; many fine and medium, few coarse pores; slightly calcareous; very few, small iron-manganese concretions (sample no. 54-18/6)
	REMARKS:	Roots are present mainly to a depth of 70 cm but some also go deeper than 130 cm. The profile is slightly sodic from a depth of 45 cm, from 110 cm the soil is moderately saline.

LABORATORY DATA OF PROFILE DESCRIPTION No: 38

FIELD OBSERVATION No: 55-8 MAPPING UNIT: PsU2

SOIL CLASSIFICATION: luvic YERMOSOL, sodic phase

Laboratory no. ...../81	9467	9468	9469	9470		
Horizon	A	Bw	Bt	BC		
Depth (cm)	0-10	15-30	40-80	85-105		
pH-H_2O (1:2.5 v/v)	7.4	7.7	7.7	8.0		
pH-KCl "	6.4	6.4	6.2	6.8		
EC (mmho/cm) "	0.10	0.06	0.08	0.11		
$CaCO_3$ (%)	-	-	-	-		
$CaSO_4$ (%)						
C (%)	0.10	0.06	0.03	0.06		
N (%)						
C/N						
CEC (me/100g), pH 8.2	10.6	14.4	14.4	17.3		
CEC " " pH 7.0	7.4	10.4	13.6	19.8		
Exch.Ca (me/100g) 1)	4.2/5.0	5.3/5.0	6.0/6.0	6.7/9.0		
" Mg " 1)	1.5/2.2	2.6/3.9	3.8/6.2	5.4/6.7		
" K " 1)	1.3/6.8	1.5/1.0	1.4/1.0	1.2/1.0		
" Na " 1)	tr/0.5	0.1/0.4	0.6/0.4	2.1/2.9		
Sum of cations 1)	7.1/6.5	9.5/10.3	11.7/13.6	15.4/19.6		
Base sat. %, pH 8.2	67	66	81	89		
" " %, pH 7.0	88	99	100	99		
ESP at pH 8.2			4	12		
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3 (mmol%)						

X-ray report: Illite and a mixed layer mineral occur in small amounts. Traces of kaolinite, smectite, feldspars and in the subsoil also traces of palygorskite are found.

Depth (cm)	0-10	15-30	40-80	85-105		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	90	76	76	70		
Silt % 0.05-0.002 mm	2	4	6	16		
Clay % 0.002-0 mm	8	20	18	14		
Texture class	S	SL	SL	SL		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm						
" " 1.0 - 0.50 mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10 mm						
" " 0.10 - 0.05 mm						
Total sand %	66	79	70	66		
Silt %	22	2	5	16		
Clay %	12	19	25	18		
Texture class	SL	SL	SCL	SL		
Bulk density	1.59		1.62			
Moisture % w/v at:						
pF 0	41.2		40.3			
pF 2.0	23.5		26.1			
pF 2.3	17.2		19.6			
pF 2.7						
pF 3.0						
pF 3.7	11.3		13.6			
pF 4.2	9.5		11.6			

Fertility aspects: (0-20cm) Laboratory no. 81 / 9489

			Available	Total
pH-H_2O (1:2.5 v/v)	7.9	Na (me/100g)	0.1	
Exch. acidity (me/100g)		K "	1.0	
C%	0.29	Ca "	3.0	
N%	0.06	Mg "	3.4	
P-Olsen (ppm)	13	Mn "	0.4	
		P (ppm)	-	

Various:

Remarks: 1) Data from survey (top) and special analysis (bottom)

Kenya Soil Survey

PROFILE DESCRIPTION NO. 38

General site imformation

Mapping unit	: PsU2
Soil classification	: luvic YERMOSOL, sodic phase
Observation no./date	: 55-8; 3/9/81
Location/altitude	: Marsabit District, 37°31'E, 2°26'N; 425 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sedimetns derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat
Slope at site	: 1%
Vegetation	: Dwarf shrubland with annual grasses as understory. The main species are *Indigofera spinosa* and *Aristida mutabilis*
Land use	: Heavy grazing
Erosion	: Strong splash and rillwash and moderate deflation
Surface stoniness	: Nil
Surface sealing	: Slight, soft, 2 to 3 cm thick sealing
Drainage class	: Well drained

Profile description

A	0-12 cm	Reddish yellow (7.5 YR 6/6 dry), reddish brown (5 YR 4/4 moist); loamy sand; moderate, fine to medium, subangular blocky; slightly hard when dry, friable when moist, slightly sticky and non-plastic when wet; many fine, few medium and coarse pores; very few, small, dark minerals; clear and smooth transition to: (sample no. 55-8/2)
Bw	12-35 cm	Strong brown (7.5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); sandy loam; porous massive, breaking into weak, fine to medium, subangular blocky; slightly hard when dry, very friable when moist, slightly sticky and non-plastic when wet; many fine, few medium and coarse pores; very few, small, dark minerals; gradual and smooth transition to: (sample no. 55-8/3)
Bt	35-85cm	Yellowish red (5 YR 5/6 dry and 4 YR 4/6 moist); sandy clay loam; porous massive, breaking inot weak, fine to medium, subangular blocky; slightly hard when dry, very friable whenmoist, sticky and plastic when wet; thin, broken, clay cutans; many fine, few medium and coarse pores; very few, small dark minerals; gradual and smooth transition to: (sample no. 55-8/4)
BC	85-107 cm	Strong brown (7.5 YR 5/6 dry), yellowish red (5 YR 4/6 moist); sandy loam; porous massive, breaking into weak, fine to medium, subangular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; many fine, few medium and coarse pores; very few, medium, slightly hard, iron-manganese concretions; very few, small, dark minerals; gradual and smooth transition to: (sample no. 55-8/5)
Cmk	107-150^{+}cm	Over 90%, medium and large, spherical, hard $CaCO_3$ concretions, partly covered with manganese oxides.
	REMARKS:	Roots are present throughout the profile. From 85 cm the soil is moderately sodic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 39

FIELD OBSERVATION No: 54-20 **MAPPING UNIT:** PsU3

SOIL CLASSIFICATION: orthic SOLONETZ

Laboratory no. ....√82	4306	4307	4308	4309	4310	4311
Horizon	A	C	2E	2Bt	2Btn	2BCz
Depth (cm)	0-10	10-25	25-38	38-60	60-100	100-150
pH–H_2O(1:2.5v/v)	8.0	7.8	8.0	7.9	7.4	7.6
pH–KCl ,,	7.0	6.9	6.9	6.7	6.5	7.0
EC(mmho/cm) ,,	0.11	0.19	0.14	0.29	0.50	3.50
$CaCO_3$(%)		++				+++
$CaSO_4$(%)						
C (%)	0.11	0.11	0.06	0.07	0.07	0.04
N (%)						
C/N						
CEC (me/100g), pH 8.2	8.3	20.7	9.1	21.3	20.3	17.7
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	9.0	25.2	11.6	13.6	13.4	30.7
,, Mg ,,	3.0	7.0	3.8	6.2	7.3	5.4
,, K ,,	1.5	3.5	1.2	1.5	1.4	1.0
,, Na ,,	0.2	0.5	0.7	1.7	3.5	1.1
Sum of cations	13.7	36.2	17.3	23.0	25.6	38.2
Base sat. %, pH 8.2	100	100	100	100	100	100
,, ,, %, pH 7.0						
ESP at pH 8.2	2	2	8	8	17	7
Saturation extract:						
Moisture %						
pH–paste						36.0
ECe (mmho/cm)						7.4
Na (me/l)						19.0
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-10	10-25	25-38	38-60	60-100	100-150
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	78	32	78	58	58	54
Silt % 0.05–0.002mm	8	16	4	6	6	12
Clay % 0.002–0 mm	14	52	18	36	36	34
Texture class	SL	C	SL	SC	SC	SCL
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 82 / 4402

			Available	Total
pH–H_2O (1:2.5v/v)	8.0	Na (me/100g)	0.3	
Exch. acidity (me/100g)		K ,,	2.0	
C%	0.23	Ca ,,	19.8	
N%	0.04	Mg ,,	9.4	
P–Olsen(ppm)	25	Mn ,,	0.8	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 39

General site information

Mapping unit	: PsU3
Soil classification	: orthic SOLONETZ
Observation no./date	: 54-20; 18/3/82
Location/altitude	: Marsabit District; 37°25'E, 2° 19'N; 460 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat to flat
Slope at site	: Shrubland with dwarf shrubs and perennial grasses as understory. The main species are *Acacia reficiens*, *Indigofera cliffordiana* and *Sporobolus fimbriatus*.
Land use	: Grazing
Erosion	: Severe splash and rillwash, moderate rill erosion and slight deflation. At the same time also deposition
Surface stoniness	: Nil
Surface crusting	: Slight slump crust and some algaea crusts
Drainage class	: Moderately well drained

Profile description

A	0-10 cm	Reddish yellow (7.5 YR 6/5 dry), yellowish red (5 YR 4/5 moist); sandy loam; weak, fine to medium, subangulr blocky; soft when dry, loose when moist, non-sticky and non-plastic when wet; common fine and medium, many coarse pores, mainly vesicular; very few, small, dark minerals; abrupt and smooth transition to: (sample no. 54-20/2)
C	10-25 cm	Light brown (7.5 YR 6/4 dry), yellowish red (5 YR 4/6 moist); clay; moderate, fine to medium, crumb to angular blocky; slightly hard when dry, very friable when moist, sticky ahd plastic when wet; many pores of various sizes; strongly calcareous; very few, small, micas and dark minerals; abrupt and smooth transition to: (sample no. 54-20/3)
2E	25-38 cm	Reddish yellow (7.5 YR 6/5 dry), yellowish red (5 YR 4/6 moist); sandy loam; porous massive, moderately coherent; slightly hard when dry, loose when moist, non-sticky and non-plastic when wet; many fine and medium, common coarse pores; abrupt and smooth transition to: (sample no. 54-20/4)
2Bt	38-60 cm	Dark red (2.5 YR 3/5 dry), dark reddish brown (2.5 YR 3/4 moist); sandy clay; weak, medium, prismatic, breaking into moderate, medium to coarse, subangular to angular blocky; hard to very hard when dry; very friable when moist, sticky and plastic when wet; thick, continuous, clay cutans; very few, fine, pores; few, very small, iron-manganese concretions; few small, dark minerals; clear and smooth transition to: (sample no. 54-20/5)
2Btn	60-100 cm	Essentially similar to preceeding horizon; structure is massive, breaking into weak, medium to coarse, angular blocky; very hard when dry; gradual and smooth transition to: (sample no. 54-20/6)
2BCz	100-150 cm	Yellowish red (5 YR 4/6 dry), dark red (2.5 YR 3/5 moist); sandy clay loam; porous massive, breaking into weak, fine to medium, subangular blocky; slightly hard when dry, very friable when moist, sticky and plastic when wet; many, fine and medium pores; strongly calcareous; few, very small, iron-manganese concretions; few, small, dark minerals; few salt crystals: (sample no. 54-20/7)
	REMARKS:	Roots present mainly to a depth of 60 cm, some go to 80 cm depth. From 40 cm depth the soil is slightly sodic. The sodicity reaches a maximum between 60 and 100 cm. The soil is strongly saline from a depth of 100 cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 40

FIELD OBSERVATION No: 42-3 **MAPPING UNIT:** PsU4

SOIL CLASSIFICATION: orthic SOLONETZ, saline phase

Laboratory no. ...../77	149	150	151	152	153	
Horizon	A	Btn2	Btn2	Btn3	Btn3	
Depth (cm)	0-11	11-35	35-65	65-90	90-130	
pH-H_2O(12.5 v/v)	8.0	8.6	8.0	8.1	8.3	
pH-KCl ,,	6.9	7.1	7.3	7.4	7.6	
EC(mmho/cm) ,,	0.14	0.90	3.00	3.50	5.50	
$CaCO_3$(%)	0.8	0.8		0.4	1.8	
$CaSO_4$(%)						
C (%)	0.17					
N (%)	0.02					
C/N	8.5					
CEC (me/100g), pH 8.2						
CEC ,, ,, pH 7.0	9.8	15.6	23.8	21.6	22.4	
Exch.Ca (me/100g)	3.2	5.8	9.6	9.6	35.6	
,, Mg ,,	2.6	5.0	7.1	7.2	12.0	
,, K ,,	0.6	1.6	2.5	1.8	1.8	
,, Na ,,	0.4	4.5	10.0	7.9	9.3	
Sum of cations	6.8	16.9	29.2	26.5	58.7	
Base sat. %, pH 8.2						
,, ,, %, pH 7.0	70	100	100	100	100	
ESP at pH 8.2	4	22	41	36	42	
Saturation extract:						
Moisture %			35.1	39.3	65.6	
pH-paste			7.6	7.5	8.3	
ECe (mmho/cm)			20.5	21.5	12.5	
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,			22	28	24	
SO_4 ,,			235	245	35	
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray-report:						

Depth (cm)	0-11	11-35	35-65	65-90	90-130	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	86	66	58	58	56	
Silt % 0.05–0.002mm	4	6	6	8	8	
Clay % 0.002–0 mm	8	28	36	34	36	
Texture class	SL	SCL	SC	SCL	SC	
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm) Laboratory no.

pH-H_2O (1:2.5 v/v)	8.1		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.2	
C%		K ,,	0.6	
N%		Ca ,,	2.2	
P-Olsen (ppm)		Mg ,,	2.4	
		Mn ,,	0.6	
		P (ppm)	250	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 40

General site information

Mapping unit	: PsU4
Soil classification	: orthic SOLONETZ, saline phase
Observation no./date	: 42-3; 14/12/76
Location/altitude	: Marsabit District; 37°13'E, 2°37'M; 480 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Flat to almost flat
Slope at site	: 0%
Vegetation	: Shrubland with dwarf understory, few annual grasses occur as well. The main species are *Acacia reficiens* and *Duosperma eremophilium*. *Salsola dendroides* occurs as well
Land use	: Light grazing
Surface stoniness	: Nil
Surface sealing	: Moderately strong, 5 mm thick
Drainage class	: Moderately well drained

Profile description

A	0-11 cm	Reddish yellow (7.5 YR 6/6 dry), yellowish red (5 YR 4/6 moist); loamy sand; single grain and weak, fine, subangular blcoky; soft when dry, loose when moist, non-sticky and non-plastic when wet; abrupt and wavy transition to: (sample no. 42-3a)
Btn1	11-35 cm	Reddish brown (5 YR 4/4 dry) and (5 YR 3/4 moist); sandy clay loam; moderate, coarse columnar, breaking into moderate, coarse, angular blocky; very hard when dry, friable when moist, non-sticky and non-plastic when wet; moderately thick, broken clay cutans; few, fine pores; gradual and wavy transition to: (sample no. 42-3b)
Btn2	35-65 cm	Reddish brown (5 YR 4/4 dry), dark reddish brown (5 YR 3/3 moist); sandy clay; moderate, medium, angular blocky; very hard when dry, friable when moist, slightly sticky and slightly plastic when wet; moderately thick, continuous, clay cutans; few, medium pores; very few, small, biotite; gradual and wavy transition to: (sample no. 42-3c)
Btn3	65-130^{+}cm	Strong brown (7.5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); sandy clay loam to sandy clay; calcareous from 90cm; few, small biotite (sample nos. 42-3c and 3d from 69-90cm and from 90-130cm respectively)
	remarks;	Roots are only present in the topsoil. The soil is strongly saline from 35cm and strongly sodic from 11cm downwards. The description of the soil below 65cm depth is based on an augering.

LABORATORY DATA OF PROFILE DESCRIPTION No: 41

FIELD OBSERVATION No: 54-8 **MAPPING UNIT:** PsU5

SOIL CLASSIFICATION: orthic SOLONETZ

Laboratory no. ...../ 81	9450	9451	9452	9453	9454	9455
Horizon	A	AE	Btn1	Btn2	Btn3	Btn4
Depth (cm)	0-10	10-30	35-50	60-90	95-120	135-170
pH–H_2O (1:2.5 v/v)	8.1	7.9	7.8	8.7	8.2	7.6
pH–KCl ,,	6.0	5.8	5.6	6.6	7.1	6.6
EC (mmho/cm) ,,	0.07	0.07	0.18	0.65	0.22	4.00
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.12	0.03	0.06	0.07	0.03	0.03
N (%)						
C/N						
CEC (me/100g), pH 8.2	6.4	4.6	11.8	23.7	21.8	23.8
CEC ,, ,, pH 7.0	5.8	3.6	11.2	43.6	16.4	20.2
Exch. Ca (me/100g) 1)	1.8/4.0	1.5/2.0	2.8/6.0	4.6/15.0	4.6/13.0	7.4/15.0
,, Mg ,, 1)	1.5/2.7	1.0/1.1	2.3/5.0	5.4/8.3	4.9/7.9	4.4/7.1
,, K ,, 1)	0.8/0.4	0.6/0.2	1.1/5.6	1.7/0.7	1.0/0.5	1.0/0.3
,, Na ,, 1)	0.4/0.6	0.3/0.7	1.1/1.5	3.8/6.0	6.6/10.5	6.8/14.0
Sum of cations	4.5	3.4	7.3	14.5	17.1	19.6
Base sat. %, pH 8.2	70	74	60	65	79	82
,, ,, %, pH 7.0	100	100	100	69	100	100
ESP at pH 8.2	6	6	9	16	30	28
Saturation extract:						
Moisture %						
pH–paste						
ECe (mmho/cm)						9.9
Na (me/l)						20.5
K ,,						161.5
Ca ,,						0.3
Mg ,,						23.2
Sum of cations (me/l)						28.0
CO_3 (me/l)						213.0
HCO_3 ,,						3.6
Cl ,,						6.8
SO_4 ,,						183.0
Sum of anions (me/l)						11.8
Adj. SAR						205.2
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						

X-ray report: Illite and a mixed layer clay mineral occur together in small amounts. With depth the occurrence of smectite increases (from nothing to a moderate amount). Traces of kaolinite are present throughout the profile. Palygorskite is present throughout, increasing with depth (from traces to a small amount).

Depth (cm)	0-10	10-30	35-50	60-90	95-120	135-170
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	88	94	78	58	66	64
Silt % 0.05–0.002 mm	8	2	4	6	4	14
Clay % 0.002–0 mm	4	4	18	36	30	22
Texture class	S	S	SL	SC	SCL	SCL
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0 mm						
,, ,, 1.0 – 0.50 mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10 mm						
,, ,, 0.10 – 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0	31.4		42.1			
pF 2.0	15.5		34.8			
pF 2.3	11.3		30.4			
pF 2.7						
pF 3.0						
pF 3.7	7.0		19.2			
pF 4.2	5.7		17.8			

Fertility aspects: (0–20 cm)	top	bottom	Laboratory no. 81	9485 top / 9486 bottom	
pH–H_2O (1:2.5 v/v)	7.4	6.7		Available top	bottom Total
Exch. acidity (me/100g)			Na (me/100g)	0.1	4.8
C%	0.14	0.17	K ,,	0.4	0.8
N%	0.03	0.04	Ca ,,	1.4	3.6
P–Olsen (ppm)	8	6	Mg ,,	1.8	3.8
			Mn ,,	0.3	0.4
			P (ppm)		

Various:

Remarks: 1) Data from survey (top) and special analysis (bottom).

Kenya Soil Survey

PROFILE DESCRIPTION NO. 41

General site information

Mapping unit	: PsU5
Soil classification	: orthic SOLONETZ
Observation no./date	: 54-8; 3/9/81
Location/altitude	: Marsabit District; 37°28'E, 2°18'N; 475 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat
Slope at site	: 0.5-1%
Vegetation	: Annual grassland to shrubland. *Acacia mellifera*, *A. reficiens* and *Indigofera spinosa* annual and some perennial grasses are the most common species.
Land use	: Grazing
Erosion	: Severe splash and rillwash, slight rill and moderate deflation
Surface stoniness	: Nil
Surface sealing	: Moderate
Drainage class	: Moderately well drained. After heavy rains water can be stagnant in the depressions for a few days.

Profile description

A	0-8 cm	Strong brown (7.5 YR 5/6 dry), reddish brown (5 YR 4/4 moist), sand; porous massive, breaking into weak, fine to medium subangular blocky; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; many pores of various sizes; very few, small, dark minerals; clear and smooth transition to: (sample no. 54-8/2)
AE	8-32 cm	Yellowish red (5 YR 5/8 dry), red (2.5 YR 4/6 moist); sand; porous massive, weakly coherent; soft when dry, loose when moist, non-sticky and non-plastic when wet; many pores of various sizes; abrupt and tonguing transition to (tongues of 20cm length any about 1cm wide, more than 20cm apart): (sample no. 54-8/3)
Btn1	32-55cm	Dark red (2.5 YR 3/6 dry and 2.5 YR 3/5 moist); sandy loam; strong, coarse, columnar (columns have bleached caps), breaking into weak, coarse, angular blocky; very hard when dry, very friable when moist, sticky and plastic when wet; moderately thick, continuous clay cutans; many fine, common medium and coarse pores; gradual and smooth transition to: (sample no. 54-8/4)
Btn2	55-90 cm	Reddish brown (2.5 YR 4/4 dry), dark red (2.5 YR 3/5 moist); sandy clay; moderate, medium to coarse prismatic, breaking into moderate, medium to coarse, subangular blocky; hard to very hard when dry, very friable when moist, sticky and plastic when wet; thick, continuous, clay cutans; common fine and few, medium to coarse pores; slightly calcareous; very few, small, dark minerals; clear and smooth transition to: (sample no. 54-8/5)
Btn3	90-130 cm	Red (2.5 YR 4/6 dry), dark reddish brown (2.5 YR 3/4 moist); sandy clay loam; porous massive, breaking into weak, medium to coarse prismatic, breaking into weak, medium to coarse, subangular blocky; hard when dry, very friable when moist, sticky and plastic when wet; moderately thick, continuous, clay cutans; common fine, few medium to coarse pores; moderately calcareous; few, small to medium, soft $CaCO_3$ concretions; few, small, soft, manganese concretions; very few, small, dark minerals; gradual and smooth transition to (sample no. 54-8/6)
Btn4	130-170^{+}cm	Essentially similar as above, but strongly calcareous with few, small, salt crystals.
	REMARKS:	The soil is slightly sodic from the top and strongly sodic from a depth of 60 cm. Roots are present to a depth of 1 m.

LABORATORY DATA OF PROFILE DESCRIPTION No: 42

FIELD OBSERVATION No: 54-4 **MAPPING UNIT:** PsUA1

SOIL CLASSIFICATION: cambic ARENOSOL

Laboratory no. ...../81	4350	4351	4352	4353		
Horizon	A	AB	Bw2	Bk		
Depth (cm)	0-25	40-70	80-100	120-150		
pH-H_2O(1$_{2.5}$ v/v)	7.4	7.3	7.6	7.7		
pH-KCl "	6.3	6.5	6.7	6.8		
EC(mmho/cm) "	0.10	0.16	0.20	0.75		
$CaCO_3$(%).	+	+	+	++		
$CaSO_4$(%)						
C (%)	0.29	0.09	0.32	0.09		
N (%)	0.03					
C/N	9.7					
CEC (me/100g), pH 8.2	9.0	9.0	10.0	9.0		
CEC " " pH 7.0	5.0	5.6	10.6	7.0		
Exch.Ca (me/100g) 1)	8.6/2.4	6.2/1.6	16.8/5.2	19.7/4.0		
" Mg " 1)	1.5/1.4	1.6/1.2	2.2/2.0	1.8/1.4		
" K " 1)	0.9/0.1	0.8/0.1	1.5/0.2	0.9/0.1		
" Na " 1)	0.1/0.4	0.1/0.4	0.2/0.4	1.5/0.2		
Sum of cations	11.1/4.3	8.7/3.3	20.7/7.9	23.8/5.6		
Base sat. %, pH 8.2	100	97	100	100		
" " %, pH 7.0	86	59	75	80		
ESP at pH 8.2	1	1	2	8		

Depth (cm)	0-25	40-70	80-100	120-150		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	80	78	52	76		
Silt % 0.05-0.002mm	14	12	40	16		
Clay % 0.002-0 mm	6	10	8	8		
Texture class	LS	SL	L	SL		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
" " 1.0 - 0.50mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10mm						
" " 0.10 - 0.05mm						
Total sand %		82	57	81		
Silt %		7	19	11		
Clay %		11	14	8		
Texture class		LS/SL	SL	LS		
Bulk density						

Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions(me/l)						
Adj. SAR						

Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3(mmol%)						

X-ray report: Illite is the dominating clay mineral.
Traces of kaolinite are present as well.

Fertility aspects: (0-20 cm) **Laboratory no.** 81 / 4370

			Available	Total
pH-H_2O (12.5 v/v)	8.2			
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	0.29	K "	0.7	
N%	0.03	Ca "	7.3	
P-Olsen(ppm)	10	Mg "	2.4	
		Mn "	0.4	
		P (ppm)	540	

Various:

Remarks: 1) Data from survey (top) and special analysis (bottom)

Kenya Soil Survey

PROFILE DESCRIPTION NO. 42

General site information

Mapping unit	: PsUA1
Soil classification	: cambic ARENOSOL
Observation no./date	: 54-4; 14/3/81
Location/altitude	: Marsabit District; 37°2'E, 2°24'N; 660 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat to very gently undulating. Profile located on slight elevation.
Slope at site	: 0-1%
Vegetation	: Dwarf shrubland with bushes andgrasses. Mainly *Acacia reficiens, Indigofera spinosa, Duosperma eremophiulum,* annual and perennial grasses.
Land use	: Occasionally grazing
Erosion	: Severe splash and rillwash
Surface stoniness	: Nil
Surface sealing	: Slight to moderate, with algae crusts as well
Drainage class	: Somewhat excessively drained

Profile description

A	0-30 cm	Light yellowish brown (10 YR 6/4 dry), dark brown (7.5 YR 4/4 moist); loamy sand; porous massive, weakly coherent; soft when dry, very friable when moist, non-sticky and non-plastic when wet; few pores of various sizes; moderately calcareous; very few, small, dark minerals; gradual and smooth transition to: (sample no. 54-4/I)
AB	30-56 cm	Brownish yellow (10 YR 7/6 dry), dark brown (7.5 YR 3/4 moist); sandy loam; porous massive, moderately coherent; soft to slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; few fine, many medium pores; very few, small, dark minerals;clear and smooth transition to: (sample no. 54-4/II)
Bw1	56-80 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/4 moist); sandy loam; porous massive, moderately coherent; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; common fine, few medium pores; very few, small micas and dark minerals; gradual and smooth transition to:
Bw2	80-100 cm	Essentially the same as above, but hard when dry and slightly calcareous; gradual and smooth transition to: (sample no. 54-4/III)
Bw3	100-120 cm	Dark yellowish brown (10 YR 4/4 dry), dark brown (7.5 YR 3/3 moist); fine gravelly sandy loam; porous massive, moderately coherent; hard when dry, very friable when moist, non-sticky and non-plastic when wet; many, fine pores; moderately calcareous, very few, medium, soft, carbonate concretions; frequent, small, micas; clear and smooth transition to: (sample no. 54-4/IV)
Bk	120-150^{+}cm	Essentially the same as above, but strongly calcareous and an increasing amount of carbonate concretions (to about 10%)
	REMARKS:	Roots are present throughout the profile showing a decreasing intensity with depth. The surface crust is about 3 cm thick, soft to slightly hard when dry and has many vesicular, discontinuous pores.

LABORATORY DATA OF PROFILE DESCRIPTION No: 43

FIELD OBSERVATION No: 54-7 **MAPPING UNIT:** PsUA1

SOIL CLASSIFICATION: luvic YERMOSOL, sodic phase

Laboratory no. ...../81	7911	7912	7913	7914	7915	7916
Horizon	AC	2A	2Bu	2Bt1	2Bt2	2Ck
Depth (cm)	8-20	20-30	40-55	75-95	110-130	140-170
pH-H_2O(1:2.5 v/v)	8.8	8.6	8.6	8.1	8.2	7.9
pH-KCl ,,	7.3	7.0	7.3	7.1	7.1	7.0
EC(mmho/cm) ,,	0.30	0.12	0.10	0.35	0.30	0.70
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.17	0.29	0.18			
N (%)	0.05					
C/N	3.4					
CEC (me/100g), pH 8.2	10.0	5.0	8.0	6.2	9.6	8.8
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	17.4	8.8	7.2	7.2	11.3	39.3
,, Mg ,,	3.1	1.9	1.9	1.6	1.8	2.3
,, K ,,	1.8	1.2	1.0	0.8	0.8	0.8
,, Na ,,	0.2	0.1	0.3	0.4	0.6	1.1
Sum of cations	22.5	12.0	10.4	10.0	14.5	43.5
Base sat. %, pH 8.2	100	100	100	100	100	100
,, ,, %, pH 7.0						
ESP at pH 8.2	2	2	4	7	6	12

Saturation extract:

Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						

Clay mineralogy:

SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						

X-ray report: Illite is the dominating clay mineral and occurs in moderate amounts. Kaolinite occurs in small amounts. Traces of smectite are found in the topsoil and it increases with depth to small amounts. A small amount of a mixed layer clay mineral is present as well, besides traces of feldspars.

Depth (cm)	8-20	20-30	40-55	75-95	110-130	140-170
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	52	70	69	66	68	60
Silt % 0.05-0.002mm	28	11	12	10	12	17
Clay % 0.002-0 mm	20	19	19	24	20	23
Texture class	SL	SL	SL	SCL	SL/SCL	SCL
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density	1.58	1.58		1.63		

Moisture % w/v at: depth	(2-7)	(25-30)		(80-85) cm		
pF 0	37.3	38.2		37.4		
pF 2.0	18.8	20.3		20.0		
pF 2.3	13.7	15.9		13.9		
pF 2.7						
pF 3.0						
pF 3.7	10.4	7.9		8.9		
pF 4.2	9.3	7.0		8.5		

Fertility aspects: (0-20cm) Laboratory no. 81/7892

pH-H_2O (1:2.5 v/v)	8.6		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.1	
C%	0.04	K ,,	0.8	
N%	0.30	Ca ,,	11.2	
P-Olsen (ppm)	20	Mg ,,	1.9	
		Mn ,,	0.5	
		P (ppm)		

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 43

General site information

Mapping unit	: PsUA1
Soil classification	: luvic YERMOSOL, sodic phase
Observation no./date	: 54-7; 17/7/81
Location/altitude	: Marsabit District; 37°2'E, 2°23'N; 660 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat to very gently undulating. Profile located in slight depression
Slope at site	: 0%
Vegetation	: Dwarf shrubland, dominated by *Duosperma eremophilum*.
Land use	: Occasionally grazing
Erosion	: Moderate splash and rillwash and rill erosion
Surface stoniness	: Nil
Surface sealing	: Slight sealing, soft crusting
Drainage class	: Well drained

Profile description

A	0-8 cm	Reddish yellow (7.5 YR 6/5 dry), brown (7.5 YR 4/4 moist); sandy loam; weak, thin, platy; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; many fine and medium, few, coarse pores; moderately calcareous; very few, small micas and dark minerals; abrupt and smooth transition to:
AC	8-20 cm	Essentially the same as above, but structure is porous massive, breaking into very weak, medium and coarse, subangular blocky; soft when dry; abrupt and smooth transition to: (sample no. 54-7/1)
2A	20-45 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/4 moist); sandy loam; porous massive, moderately coherent, breaking into very weak, medium to coarse, subangular blocky; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many fine, common medium and few coarse pores; moderately calcareous; very few, small micas and dark minerals, clear and smooth transition to: (sample no. 54-7/2)
2Bu	45-65 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/4 moist); sandy loam; porous massive, slightly coherent; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many fine and medium, few coarse pores; slightly calcareous; few, small,micas and dark minerals; gradual and smooth transition to: (sample no. 54-7/3)
2Bt	65-140 cm	Brown to dark brown (7.5 YR 4/4 dry and 7.5 YR 3/4 moist); sandy clay loam; porous massive, strongly coherent; hard when dry, very friable when moist, sticky and plastic when wet; thin, patchy, clay cutans; many fine, few medium and coarse pores; moderately calcareous; few, medium, soft $CaCO_3$ concretions (increasing with depth); very few, small micas and dark minerals; clear and smooth transition to: (sample nos.54-7/4 and 54-7/5 from 75-95 cm and from 110-130 cm respectively)
2Ck	140-170$^+$cm	Yellow (10 YR 7/5 dry), dark brown (7.5 YR 4/4 moist); sandy clay loam; porous massive, moderately coherent; slightly hard when dry, very friable when moist, sticky and plastic when wet; strongly calcareous; few to frequent, soft $CaCO_3$ concretions; few, small, micas and dark minerals (sample no. 54-7/6)
	REMARKS:	Roots are present to a depth of more than 150 cm. Below 170 cm the texture changes to sand, with gravelly, loamy and clayey layers.

LABORATORY DATA OF PROFILE DESCRIPTION No: 44

FIELD OBSERVATION No: 66-4 **MAPPING UNIT:** PsUA2

SOIL CLASSIFICATION: cambic ARENOSOL

Laboratory no. ...../80	12396	12397	12398	12399		
Horizon	A	AB	Bw	C		
Depth (cm)	0-25	25-45	46-85	85-170		
pH-H_2O (12.5 v/v)	7.4	7.0	6.3	6.5		
pH-KCl "	6.3	5.2	4.5	4.2		
EC (mmho/cm) "	0.04	0.03	0.03	0.04		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.14	0.11	0.17	0.08		
N (%)						
C/N						
CEC (me/100g), pH 8.2	5.5	4.4	3.8	3.8		
CEC " " pH 7.0	4.8	4.6	5.0	3.2		
Exch. Ca (me/100g) 1)	4.1/2.0	3.0/1.0	1.8/0.6	1.1/0.0		
" Mg " 1)	0.9/1.3	0.9/1.2	0.8/1.8	0.8/1.6		
" K " 1)	0.5/0.4	0.4/0.4	0.3/0.3	0.2/0.2		
" Na " 1)	tr/0.5	tr/0.6	nil/1.1	tr/0.7		
Sum of cations 1)	5.5/4.2	4.3/3.1	2.6/3.8	1.9/2.5		
Base sat. %, pH 8.2	100	100	79	56		
" " %, pH 7.0	87	68	76	78		
ESP at pH 8.2	<1	<1	<1	<1		

Depth (cm)	0-25	25-45	46-85	85-170		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	88	90	90	92		
Silt % 0.05-0.002 mm	4	4	4	4		
Clay % 0.002-0 mm	8	6	6	4		
Texture class	S	S	S	S		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm						
" " 1.0 - 0.50 mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10 mm						
" " 0.10 - 0.05 mm						
Total sand %	87		88	88		
Silt %	5		5	6		
Clay %	8		7	6		
Texture class	LS		S	S		
Bulk density		1.56	1.52			
Moisture % w/v at:						
pF 0		32.3	31.4			
pF 2.0		13.4	13.0			
pF 2.3		6.4	6.3			
pF 2.7		4.5	3.6			
pF 3.0						
pF 3.7						
pF 4.2						

Saturation extract:

Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K "						
Ca "						
Mg "						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions (me/l)						
Adj. SAR						

Fertility aspects: (0-20 cm) Laboratory no. 80 / 12420

pH-H_2O (1: 2.5 v/v)	7.4		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.2	
C%	0.58	K "	0.6	
N%	0.03	Ca "	4.0	
P-Olsen (ppm)		Mg "	2.0	
		Mn "	0.3	
		P (ppm)	19	

Clay mineralogy:

SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3 (mmol%)						

Various:

X-ray report:

Illite, kaolinite and a mixed layer mineral occur in small amounts. Traces of smectite are present as well (Bw-horizon)

Remarks:

1) Data from survey (top) and special analysis (bottom)

Kenya Soil Survey

PROFILE DESCRIPTION NO. 44

General site information

Mapping unit	: PsUA2
Soil classification	: cambic ARENOSOL
Observation no./date	: 66-4; 17/10/80
Location/altitude	: Marsabit District; 37°28'E, 1°53'N; 540 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat to very gently undulating
Slope at site	: 1% (on slight elevation)
Vegetation	: Dwarf shrubland with annual grasses. The main species are: *Indigofera spinosa* and *Aristida mutabilis*.
Land use	: Heavy grazing
Erosion	: Moderate to severe splash and rillwash, slight deflation
Surface stoniness	: Nil, but a 1 cm thick layer of coarse sand is present
Surface sealing	: Moderate, 2 to 3 mm thick
Drainage class	: Somewhat excessively drained

Profile description

A	0-25 cm	Strong brown (7.5 YR 5/6 dry), dark reddish brown (5 YR 3/4 moist); sand; massive, weakly coherent, breaking into weak, fine to medium, subangular blocky; soft when dry, loose when moist, non-sticky and non-plastic when wet; few fine pores; very few, small, weatherable minerals; gradual and smooth transition to: (sample no. 66-4/1)
AB	25-46 cm	Strong brown (7.5 YR 4/6 dry), reddish brown (5 YR 4/4 moist); sand; massive, weakly coherent, breaking into very weak, fine to medium, subangular blocky; soft when dry, loose when moist, non-sticky and non-plastic when wet; few, fine and coarse pores; very few, small to medium, soft $CaCO_3$ nodules; very few, weatherable minerals; gradual and smooth transition to: (sample no. 66-4/2)
Bw	46-85 cm	Yellowish red (5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); slightly, fine gravelly sand; further similar as above; gravel (smaller than 1 cm) consists of quartz and feldspars; gradual and smooth transition to: (sample no. 66-4/3)
C	85-170 cm	Reddish yellow (7.5 YR 7/6 dry), strong brown (7.5 YR 4/6 moist); slightly gravelly sand; massive, weakly coherent; slightly hard when dry; loose when moist, non-sticky and non-plastic when wet; subangular gravel (2 to 10 mm) consists of quartz and feldspars; very few, small, micas (sample no. 66-4/4)
	REMARKS:	Roots are well distributed throughout the profile.

LABORATORY DATA OF PROFILE DESCRIPTION No: 45

FIELD OBSERVATION No: 66-5 **MAPPING UNIT:** PsUA2

SOIL CLASSIFICATION: vertic* YERMOSOL

Laboratory no. ...../80	12400	12401	12402	12403		
Horizon	Au1	Au2	Bw1	Bw2		
Depth (cm)	0-18	18-40	40-65	65-110		
pH–H_2O (1:2.5v/v)	7.8	7.1	7.0	7.2		
pH–KCl ,,	6.9	6.1	5.7	6.0		
EC (mmho/cm) ,,	0.30	0.30	0.18	0.19		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.50	0.22	0.14	0.06		
N (%)	0.09					
C/N	5.5					
CEC (me/100g), pH 8.2	26.5	27.6	26.8	25.7		
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	23.6	14.1	12.2	13.6		
,, Mg ,,	6.0	5.3	4.5	4.0		
,, K ,,	3.0	2.0	1.3	0.9		
,, Na ,,	0.2	0.2	0.2	0.2		
Sum of cations	32.8	21.6	18.2	18.7		
Base sat. %, pH 8.2	100	78	67	73		
,, ,, %, pH 7.0						
ESP at pH 8.2	<1	<1	<1	<1		

Depth (cm)	0-18	18-40	10-65	65-110		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	46	46	50	52		
Silt % 0.05–0.002mm	16	14	10	12		
Clay % 0.002–0 mm	38	40	40	36		
Texture class	SC	SC	SC	SC		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25 mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %	41	44	44	46		
Silt %	31	28	37	30		
Clay %	28	28	19	24		
Texture class	CL	CL	L	L		
Bulk density	1.22	1.34	1.44			

Saturation extract:

Moisture %						
pH–paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						

Clay mineralogy:

SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						

X-ray report: Kaolinite, illite, smectite and a mixed layer mineral are present in small amounts.

Moisture % w/v at:

pF 0	50.2	45.0	42.9			
pF 2.0	36.0	31.0	33.7			
pF 2.3	27.0	24.1	26.3			
pF 2.7	23.3	21.0	21.6			
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 80 / 12421

pH–H_2O (1:2.5v/v)	7.8		Available	Total
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	0.08	K ,,	1.4	
N%	0.07	Ca ,,	17.1	
P–Olsen (ppm)	–	Mg ,,	4.2	
		Mn ,,	0.5	
		P (ppm)	26	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 45

General site information

Mapping unit	: PsUA2
Soil classification	: vertic* YERMOSOL
Observation no./date	: 66-5; 18/10/80
Location/altitude	: Marsabit District; 37°28'E, 1°54'N; 540 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated sediments derived from undifferentiated Basement System rocks
Physiography	: Sedimentary plain
Relief	: Almost flat to very gently undulating
Slope at site	: 0% (in sight depression)
Vegetation	: Dwarf shrubland, dominated by *Duosperma eremoplium* with perennial grasses as understory
Land use	: Grazing
Erosion	: Moderate rill erosion, but deposition as well
Surface stoniness	: Nil
Surface sealing	: In places a soft crust. Generally cracking and in places piping.
Drainage class	: Well drained, after heavy rains the depressions may be flooded for a short time

Profile description

Au1	0-18 cm	Brown to dark brown (7.5 YR 5/4 dry and 7.5 YR 4/4 moist); sandy clay; strong, fine to medium, crumb and subangular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; common fine, few medium pores; moderately calcareous; few, small micas; clear and smooth transition to: (sample no. 66- 5/1)
Au2	18-40 cm	Colours as above; sandy clay, weak, medium to coarse, prismatic; slightly hard to hard when dry, friable when moist, sticky and plastic when wet, many fine, few medium and coarse pores; slightly calcareous; few, small, micas; gradual and smooth transition to: (sample no. 66-5/2)
Bw1	40-65 cm	Reddish brown (5 YR 4/4 dry), dark reddish brown (5 YR 3/4 moist); sandy clay weak, coarse prismatic; slightly hard to hard when dry, friable when moist, sticky and plastic when wet; many fine, few medium and coarse pores; slightly clacareous; very few, small, soft $CaCO_3$ concretions; few, small, micas; gradual and smooth transition to: (sample no. 66-5/3)
Bw2	65-110cm	Dark reddish brown (5 YR 3/4 dry and moist); sandy clay; massive, strongly coherent; very hard when dry, friable when moist, sticky and plastic when wet; patchy slickensides; few, fine pores; slightly calcareous; few, small micas. (sample no. 66-5/4)
	REMARKS:	Roots are present to a depth of about 110cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 46

FIELD OBSERVATION No: 42-16 **MAPPING UNIT:** PlnX1

Laboratory no...../ 81	9421	9422	9423	9424	9425	9426	9427
Horizon	Az1	Az2	Az3	Bz1	Bz2	Bz2	Cr
Depth (cm)	0-1	1-13	13-25	30-40	50-70	90-120	130-140
pH-H_2O(1:2.5v/v)	9.8	9.2	9.5	9.6	9.6	9.5	9.1
pH-KCl ,,	8.5	8.7	8.9	8.9	8.9	8.8	7.5
EC(mmho/cm) ,,	15.0	40.0	35.0	35.0	35.0	30.0	0.02
$CaCO_3$(%)	6.9	7.7	8.4	7.4	6.6	6.2	10.4
$CaSO_4$(%)							
C (%)	0.6	0.3	0.3	0.4	0.3	0.2	0.5
N (%)							
C/N							
CEC (me/100g), pH 8.2	23.0	35.0	45.8	49.0	54.0	59.4	55.8
CEC ,, ,, pH 7.0		38.8	43.6	40.8		44.6	8.2
Exch.Ca (me/100g)	11.1	37.0	16.8	46.5	17.3	26.5	39.0
,, Mg ,,	0.4	1.7	0.7	1.8	0.8	1.4	5.7
,, K ,,	1.6	3.2	2.8	3.8	3.2	3.8	4.4
,, Na ,,	19.4	15.5	14.4	17.5	14.4	29.6	29.2
Sum of cations	32.4	57.4	34.7	69.6	35.7	61.3	78.3
Base sat. %, pH 8.2	100	100	76	100	66	100	100
,, ,, %, pH 7.0		100	80	100		100	100
ESP at pH 8.2	84	44	31	36	27	50	52
Saturation extract:							
Moisture %	29.6	37.6	60.7	68.3	71.4		
pH-paste	7.5	7.3	8.2	8.0	8.0		
ECe (mmho/cm)	21.0	105.0	100.0	100.0	40.0		
Na (me/l)							
K ,,							
Ca ,,							
Mg ,,							
Sum of cations(me/l)							
CO_3(me/l)							
HCO_3 ,,							
Cl ,,							
SO_4 ,,							
Sum of anions(me/l)							
Adj. SAR							
Clay mineralogy:							
SiO_2/Al_2O_3(mol/mol)							
SiO_2/R_2O_3 ,,							
Fe_2O_3(mmol%)							
X-ray report:							

SOIL CLASSIFICATION: orthic SOLONCHAK, sodic phase

Depth (cm)	0-1	1-13	13-25	30-40	50-70	90-120	130-140
Gravel %							
Texture, limited pretreatment:							
Sand % 2.0 - 0.05 mm	48	54	18	24	24	22	12
Silt % 0.05-0.002mm	12	6	42	34	24	18	12
Clay % 0.002-0 mm	40	40	40	42	52	60	76
Texture class	SC	SC	SLSL	C	C	C	C
Dispersed clay %							
Flocculation index							
Texture USDA:							
Sand % 2.0 - 1.0mm							
,, ,, 1.0 - 0.50mm							
,, ,, 0.50 - 0.25mm							
,, ,, 0.25 - 0.10mm							
,, ,, 0.10 - 0.05mm							
Total sand %							
Silt %							
Clay %							
Texture class							
Bulk density							
Moisture % w/v at:							
pF 0							
pF 2.0							
pF 2.3							
pF 2.7							
pF 3.0							
pF 3.7							
pF 4.2							

Fertility aspects: (0- cm)		Laboratory no. /		
			Available	Total
pH-H_2O (1: v/v)		Na (me/100g)		
Exch. acidity (me/100g)		K ,,		
C%		Ca ,,		
N%		Mg ,,		
P-Olsen (ppm)		Mn ,,		
		P (ppm)		

Various:

Remarks:

PROFILE DESCRIPTION NO. 46

General site information

Mapping unit	: PlnX1
Soil classification	: orthic SOLONCHAK, sodic phase
Observation no./date	: 42-16; 15/9/81
Location/altitude	: Marsabit District; 37°25'E, 3°55'N; 400 m
Agro-climatic zone	: VII
Parent material	: Unconsolidated lacustrine sediments, derived from various sources
Physiography	: Non-dissected lacustrine plain
Relief	: Flat
Slope at site	: 0%
Vegetation	: Bare
Land use	: Only used as salt lick for wild and domestic animals
Erosion	: Nil
Surface stoniness/rockiness	: Nil
Surface crusting	: A hard, 3 mm thick salt crust forms the surface
Drainage class	: Poorly drained, the soil is flooded once or twice yearly

Profile description

Az1	0-1/2 cm	White yellowish, hard salt crust, abrupt and wavy transition to: (sample no. 42-16/1)
Az2	1/2-13cm	Reddish brown (5 YR 4/4 slightly moist); dusky red (2.5 YR 3/2 moist); sandy clay; strong, fine to medium, granular; soft when dry, very friable when moist, sticky and plastic when wet; very many pores of various sizes; strongly calcareous; many needle shaped crystals (puffed layer); abrupt and smooth transition to: (sample no. 42-16/2)
Az3	13-27 cm	Dark reddish brown (5 YR 3/2 moist); silty clay loam; porous massive, moderately coherent; friable when moist, sticky and plastic when wet; many, interstitial, not continuous, pores of various sizes; strongly calcareous; frequent salt crystals; clear and smooth transition to: (sample no. 42-16/3)
Bz1	27-45 cm	Dark reddish brown (5 YR 3/3 moist); clay; further similar as above, but also thin, patchy, clay cutans; gradual and smooth transition to: (sample no. 42-16/4)
Bz2	45-125 cm	Reddish brown (5 YR 4/3 moist); clay; further similar as above; abrupt and smooth transition to: (samples nos. 42-16/5 and 42-16/6 from 50-70 cm and from 90-120 cm respectively)
Cr	125-140^{+}cm	Light greyish brown (10 YR 6/2 wet); clay, with a n-value between 0.7 and 1; very sticky and plastic when wet; strongly calcareous (sample no. 42-16/7)
	REMARKS:	Roots are absent. The whole soil is strongly saline and strongly sodic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 47

FIELD OBSERVATION No: 43-5 **MAPPING UNIT:** PlnXA

Laboratory no. ...../81	9436	9437	9438	9439		
Horizon	AB	2Cz1	2Cz2	2Cz3		
Depth (cm)	0-20	20-35	35-50	55-100		
pH-H_2O (1: 2.5 v/v)	10.8	10.9	10.8	10.9		
pH-KCl ,,	9.8	10.4	10.4	10.4		
EC (mmho/cm) ,,	22.0	26.0	27.0	25.0		
$CaCO_3$ (%)	4.6	1.7	2.3	2.3		
$CaSO_4$ (%)						
C (%)	0.1	0.1	0.3	0.1		
N (%)						
C/N						
CEC (me/100g), pH 8.2	36.0	28.4	39.2	26.2		
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	8.6	1.4	0.8	1.4		
,, Mg ,,	0.6	tr	0.2	0.4		
,, K ,,	0.9	0.9	1.0	0.7		
,, Na ,,	98.1	34.3	53.7	34.3		
Sum of cations	108.2	36.6	55.7	36.8		
Base sat. %, pH 8.2	100	100	100	100		
,, ,, %, pH 7.0						
ESP at pH 8.2 1)	100	100	100	100		
Saturation extract:						
Moisture %	42.0	n.d	28.3	43.0		
pH-paste	7.3	n.d	9.1	9.1		
ECe (mmho/cm)	15.0	n.d	18.0	65.0		
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						

X-ray report:

SOIL CLASSIFICATION: takyric SOLONCHAK, sodic phase

Depth (cm)	0-20	20-35	35-50	55-100		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	24	32	30	48		
Silt % 0.05-0.002mm	16	38	28	36		
Clay % 0.002-0 mm	60	30	42	16		
Texture class	C	CL	C	L		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0- cm) Laboratory no. /

pH-H_2O (1: v/v)			Available	Total
Exch. acidity (me/100g)		Na (me/100g)		
C%		K ,,		
N%		Ca ,,		
P-Olsen (ppm)		Mg ,,		
		Mn ,,		
		P (ppm)		

Various:

Remarks: 1) No corrections for free salts

Kenya Soil Survey

PROFILE DESCRIPTION NO. 47

General site information

Mapping unit	: PlnXA
Soil classification	: takyric SOLONCHAK, sodic phase
Observation no./date	: 43-5; 11/9/81
Location/altitude	: Marsabit District; 37°36'E, 2°59'N; 400 m
Agro-climatic zone	: VII
Parent material	: Lacustrine sediments, derived from various sources
Physiography	: Non-dissected, lacustrine plain
Relief	: Flat
Slope at site	: 0%
Vegetation	: Bare
Land use	: Only used as a salt lick for wild and domestic animals
Erosion	: Slight deflation. Deposition after heavy rains
Surface stoniness/rockiness	: Non to fairly rocky in places
Surface sealing, cracking	: Very hard, cracked crust. Crust 1.5cm thick, cracks 1.5cm wide.
Drainage class	: Very poorly drained. Once or twice a year the area is flooded during a few days till a few weeks.

Profile description

AB	0-20 cm	Reddish brown (5 YR 4/3 dry and 5 YR 4/4 moist); clay; strong, coarse prismatic, breaking into strong, fine to coarse, subangular blocky; hard when dry, very friable when moist, sticky and plastic when wet; many medium and coarse, discontinuous,vesicular and interstitial pores, many vertical cracks; strongly calcareous; few, small salt crystals; abrupt and smooth transition to: (sample no. 43-5/1)
2Cz1	20-35 cm	Greyish brown (2.5 Y 5/2 moist); clay loam; massive, moderately coherent, breaking into weak, medium to coarse, angular blocky; friable when moist, sticky and plastic when wet; no visible pores; small cracks filled with overlying material; strongly calcareous; very few, small, soft $CaCO_3$ fibres; very few, small, micas and dark minerals; abrupt and smooth transition to: (sample no. 43-5/2)
2Cz2	35-50 cm	Greyish brown (2.5 Y 5/2 moist); clay; massive, moderately coherent, breaking into weak, medium to coarse, angular blocky; friable when moist, sticky and plastic when wet; few, brown, cutans (matrans); strongly calcaerous; very few, small, soft $CaCO_3$ fibres; very few, large, hard, gypsum concretions (10 to 40 cm); very few, small, micas and dark minerals; abrupt and smooth transition to: (sample no. 43-5/3)
2Cz3	50-100 cm	Greyish brown (2.5 Y 5/2 moist); loam; massive, moderately coherent, breaking into weak, medium to coarse, angular blocky; friable when moist, slightly sticky and non-plastic when wet; very few, small micas and dark minerals (sample no. 43-5/4)
	REMARKS:	On top occasionally a few rounded quartz gravels are found.

LABORATORY DATA OF PROFILE DESCRIPTION No: 48

FIELD OBSERVATION No: 42-23 **MAPPING UNIT:** AA2

SOIL CLASSIFICATION: calcaric FLUVISOL, sodic phase

Laboratory no. ...../82	7159	7160	7161			
Horizon	A	C1	C2			
Depth (cm)	0-25	25-75	75-100			
pH-H_2O(1:2.5 v/v)	8.6	8.8	9.0			
pH-KCl "	7.4	7.6	7.8			
EC(mmho/cm) "	0.14	0.14	0.14			
$CaCO_3$(%).						
$CaSO_4$(%)						
C (%)	0.20	0.17	0.06			
N (%)						
C/N						
CEC (me/100g), pH 8.2	6.0	3.0	1.4			
CEC " " pH 7.0						
Exch.Ca (me/100g)	18.5	18.5	14.0			
" Mg "	0.8	0.5	tr			
" K "	1.0	0.4	0.5			
" Na "	0.4	0.1	0.3			
Sum of cations	20.7	19.5	14.8			
Base sat. %, pH 8.2	100	100	100			
" " %, pH 7.0						
ESP at pH 8.2	7	3	22			

Depth (cm)	0-25	25-75	75-100			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	60	82	96			
Silt % 0.05-0.002mm	30	10	2			
Clay % 0.002-0 mm	10	8	2			
Texture class	SL	LS	S			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
" " 1.0 - 0.50mm						
" " 0.50 - 0.25 mm						
" " 0.25 - 0.10mm						
" " 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						

Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K "						
Ca "						
Mg "						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 "						
Cl "						
SO_4 "						
Sum of anions(me/l)						
Adj. SAR						

Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 "						
Fe_2O_3(mmol%)						

X-ray report:

Fertility aspects: (0-20 cm) Laboratory no. 82 / 7121

			Available	Total
pH-H_2O (12.5 v/v)	9.0			
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	0.1	K "	0.5	
N%	0.03	Ca "	20.0	
P-Olsen(ppm)	6	Mg "	4.2	
		Mn "	0.3	
		P (ppm)	450	

Various:

Remarks:

Kenya Soil Survey

FILE DESCRIPTION NO. 48

eral site information

pping unit	: AA2
il classification	: calcaric FLUVISOL, sodic phase
servation no./date	: 42-23; 9/6/82
cation/altitude	: Marsabit District; 37°10'E, 2°39'N; 480 m
ro-climatic zone	: VII
rent material	: Alluvial deposits, derived from volcanic and undifferentiated Basement System rocks
ysiography	: Floodplain
lief	: Flat to almost flat
ope at site	: 0%
getation	: *Acacia tortillis* woodland with dwarf shrub and grass understory
nd use	: Slight grazing
sion	: Moderate rill erosion and slight deflation with occasionally deposition
rface stoniness	: Nil
rface sealing, crusting	: Moderately strong crust
ainage class	: Somewhat excessively drained

ofile description

0-25 cm	Yellowish brown (10 YR 5/4 dry), reddish brown (5 YR 4/3 moist); sandy loam; slightly layered with thin layers of silt to sandy loam; porous massive; soft when dry, very friable when moist, sticky and non-plastic when wet; many fine pores; strongly calcareous; frequent, small, micas and feldspars; clear and smooth transition to: (sample no. 42-23/2)
25-75 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/4 moist); slightly gravelly loamy sand; single grain; loose when dry and moist, non-sticky and non-plastic when wet; strongly calcareous; frequent, small micas and feldspars; clear and smooth transition to: (sample no. 42-23/3)
75-110^{+}cm	Pink (7.5 YR 7/4 dry), brown (7.5 YR 5/4 moist); slightly gravelly to gravelly sand; stratified, alternating sand, gravelly sand, gravel or silt layers of varying thickness; single grain; loose when dry and moist, non-sticky and non-plastic when wet; strongly calcareous; frequent, small, micas and feldspars (sample no. 42-23/4)

MARKS: Roots are present to about 70 cm depth. The gravel in the profile consists of rounded basalt and subangular quartz and feldspars.

LABORATORY DATA OF PROFILE DESCRIPTION No: 49

FIELD OBSERVATION No: 54-9 **MAPPING UNIT:** AA3

Laboratory no. ...../ 81	9456	9457	9458	9459	9460	
Horizon	AC	2A	2Ck	3C1	3C2	
Depth (cm)	0-15	15-35	45-70	75-100	110-150	
pH-H_2O(1:2.5 v/v)	8.3	8.4	8.3	7.9	8.2	
pH-KCl ,,	7.1	7.3	7.3	6.9	7.0	
EC(mmho/cm) ,,	0.25	0.22	0.20	0.60	0.35	
$CaCO_3$ (%)	0.8	0.9	1.1	0.5	1.0	
$CaSO_4$ (%)						
C (%)	0.4	0.1	-	0.1	0.1	
N (%)						
C/N						
CEC (me/100g), pH 8.2	19.0	14.4	15.2	24.7	27.4	
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	28.0	11.8	17.4	30.0	27.3	
,, Mg ,,	2.2	1.5	1.2	2.1	1.1	
,, K ,,	1.6	1.1	0.9	1.2	0.8	
,, Na ,,	0.2	0.1	0.1	0.6	0.6	
Sum of cations	32.0	14.5	19.6	33.9	29.8	
Base sat. %, pH 8.2	100	100	100	100	100	
,, ,, %, pH 7.0						
ESP at pH 8.2	1	<1	<1	2	2	
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						

X-ray report: Illite is the dominating clay mineral. Montmorillonite and kaolinite are both present in smaller amounts.

SOIL CLASSIFICATION: calcaric FLUVISOL

Depth (cm)	0-15	15-35	45-70	75-100	110-150	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	36	72	86	32	60	
Silt % 0.05-0.002 mm	52	16	4	46	14	
Clay % 0.002-0 mm	12	12	10	22	26	
Texture class	SCL	SL	LS	L	SCL	
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm						
,, ,, 1.0 - 0.50 mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10 mm						
,, ,, 0.10 - 0.05 mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 81 / 9487

			Available	Total
pH-H_2O (1:2.5 v/v)	8.0			
Exch. acidity (me/100g)		Na (me/100g)	0.4	
C%	0.4	K ,,	0.9	
N%	0.1	Ca ,,	22.0	
P-Olsen (ppm)	16	Mg ,,	4.0	
		Mn ,,	0.7	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 49

General site information

Mapping unit	: AA3
Soil classification	: calcaric FLUVISOL
Observation no./date	: 54-9; 8/9/81
Location/altitude	: Marsabit District; 37°28'E, 2°3'N; 550 m
Agro-climatic zone	: VII
Parent material	: Alluvial deposits derived from Basement System rocks and mixed with volcanic ashes
Physiography	: Flood plain
Relief	: Flat, slope less than 1%
Slope at site	: 0.5%
Vegetation	: Grassland with annual and perennial grasses
Land use	: Heavy grazing
Erosion	: In dry season after clearing of the vegetation severe deflation
Surface stoniness	: Nil
Surface sealing	: Moderate slump crust
Drainage class	: Well drained

Profile description

AC	0-15 cm	Yellowish brown (10 YR 7/6 dry), dark brown (7.5 YR moist); silt loam; strong, thin, platy; soft to slightly hard when dry, very friable when moist, sticky and slightly plastic when wet; few, fine, pores; strongly calcareous; frequent, small, micas; abrupt and smooth transition to: (sample no. 54-9/2)
2A	15-40 cm	Very pale brown (10 YR 7/4 dry), dark brown (7.5 YR 4/4 moist); fine sandy loam; porous massive, breaking into weak, medium to coarse, subangular blocky; slightly hard when dry, very friable when moist, slightly sticky and non-plastic when wet; many pores of various sizes; slightly calcareous; few, small, micas; gradual and smooth transition to: (sample no. 54-9/3)
2Ck	40-75 cm	Reddish yellow (8.75 YR 7/6 dry), dark brown (7.5 YR 4/4 moist); slightly gravelly loamy sand, porous massive, breaking into weak, fine to medium, subangular blocky; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; many fine and medium, common coarse pores; strongly calcareous; gravel (3-4 mm) consists of quartz and feldspars; few, small, micas; at 75 cm few, 3-4 cm large, pieces of gravel; abrupt and smooth transition to: (sample no. 54-9/4)
3C1	75-106 cm	Very pale brown (10 YR 7/4 dry), strong brown (7.5 YR 4/6 moist); loam; weak, medium to coarse prismatic; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many fine and medium, common coarse pores; strongly calcareous; frequent, small, micas; abrupt and clear transition to: (sample no. 54-9/5)
3C2	106-150^{+}cm	Reddish yellow (7.5 YR 6/6 dry), dark brown (7.5 YR 4/4 moist); sandy clay loam; porous massive, moderately coherent; from 106 to 110: strong, thin, platy; slightly hard when dry, very friable when moist, sticky and plastic when wet; many, fine and medium pores, strongly calcareous; few, small micas (sample no. 54-9/6)
	REMARKS:	Roots are present mainly to 40cm depth, some go up to 100cm depth.

LABORATORY DATA OF PROFILE DESCRIPTION No: 50

FIELD OBSERVATION No: 43-10 **MAPPING UNIT:** AA4

SOIL CLASSIFICATION: orthic SOLONCHAK, stony and sodic phase

Laboratory no. ...../82	4345	4346	4347	4348	4349	
Horizon	A	Bu	3Ckz	3Cz1	3Cz2	
Depth (cm)	0-15	15-40	50-90	95-130	130-150	
pH–H_2O(1:2.5v/v)	8.3	8.8	8.0	7.8	7.7	
pH–KCl ,,	7.2	7.4	7.5	7.4	7.4	
EC(mmho/cm) ,,	0.2	0.8	5.0	8.5	9.5	
$CaCO_3$(%)*						
$CaSO_4$(%)						
C (%)	0.12	0.07	0.04	0.10	0.09	
N (%)						
C/N						
CEC (me/100g), pH 8.2	9.1	6.1	13.0	22.0	20.3	
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	12.6	9.4	32.2	24.5	32.5	
,, Mg ,,	4.5	1.7	5.2	6.7	5.9	
,, K ,,	1.3	1.2	1.3	1.9	2.1	
,, Na ,,	0.3	0.8	1.7	3.1	3.4	
Sum of cations	18.7	13.1	40.4	36.2	43.9	
Base sat. %, pH 8.2	100	100	100	100	100	
,, ,, %, pH 7.0						
ESP at pH 8.2	3	12	10	18	17	
Saturation extract:						
Moisture %		20.0	33.0	32.0	32.0	
pH–paste		8.3	7.7	7.1		
ECe (mmho/cm)		4.5	26.0	45.0	40.0	
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X–ray report:						

Depth (cm)	0-15	15-40	50-90	95-130	130-150	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	78	78	60	60	68	
Silt % 0.05–0.002mm	10	8	12	24	16	
Clay % 0.002–0 mm	12	14	28	16	16	
Texture class	SL	SL	SCL	SL	SL	
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
,, ,, 1.0 – 0.50mm						
,, ,, 0.50 – 0.25mm						
,, ,, 0.25 – 0.10mm						
,, ,, 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20 cm) Laboratory no. 82/4393

			Available	Total
pH–H_2O (1: 2.5v/v)	8.4			
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	0.14	K ,,	0.7	
N%	0.03	Ca ,,	23.0	
P–Olsen (ppm)	9	Mg ,,	9.4	
		Mn ,,	0.4	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 50

General site information

Mapping unit	: AA4
Soil classification	: orthic SOLONCHAK, stony and sodic phase
Observation no./date	: 43-10; 26-3-82
Location/altitude	: Marsabit District; 37°57'E, 2°34'N; 840m
Agro-climatic zone	: VII
Parent material	: Alluvial deposits derived from volcanic rocks, inclusive ashes
Physiography	: Flood plain
Relief	: Flat to almost flat
Slope at site	: 0.5%
Vegetation	: Very low cover with Indigofera dwarf shrubs and some annual grasses
Land use	: Seasonal grazing
Erosion	: Strong splash and rillwash, moderate deflation
Surface stoniness/rockiness	: Nil to fairly stony and gravelly
Drainage class	: Well drained

Profile description

A	0-15 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 4/4 moist); gravelly sandy loam; very weak, fine to medium, granular and subangular blocky; soft when dry, very friable when moist; non-sticky and non-plastic when wet; many pores of different sizes; strongly calcareous; gravel (<1cm) consists of basalt, olivine, augite and quartz; gradual and smooth transition to: (sample no. 43-10/2)
Bu	15-42 cm	Essentially the same as above, but structure is very weak, fine to medium, subangular blocky; abrupt and smooth transition to: (sample no. 43-10/3)
2C	42-48 cm	As above but with texture of very stony sandy loam, stones consist of subangular basalt (<10cm)
3Ckz	48-93 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/4 moist); slightly gravelly sandy clay loam; porous massive, moderately coherent; slightly hard when dry, very friable when moist; sticky and plastic when wet; patchy moderately thick (clay) cutans; many fine and medium, few coarse pores; strongly calcareous; frequent (40%), medium, soft $CaCO_3$ concretions; fine gravel consists of quartz, lava and weathered olivine; clear and smooth transition to: (sample no. 43-10/4)
3Cz1	93-130 cm	Brown (7.5 YR 5/4 dry), dark brown (7.5 YR 3/3 moist); sandy loam; massive, weakly coherent; soft when dry, very friable when moist, slightly sticky and plastic when wet; very few, fine and medium pores; strongly calcareous; abrupt and smooth transition to: (sample no. 43-10/5)
3Cz2	130-150^{+}cm	Reddish brown (5 YR 5/3 dry), dark reddish brown (5 YR 3/2 moist); sandy loam; weak, medium to coarse, angular blocky; slightly hard when dry, friable when moist, non-sticky and non-plastic when wet; patchy, thin, (clay) cutans; few pores of various sizes; slightly calcareous; few, small, salt crystals. (sample no. 43-10/6)

LABORATORY DATA OF PROFILE DESCRIPTION No: 51

FIELD OBSERVATION No: 55-10 **MAPPING UNIT:** AA5

SOIL CLASSIFICATION: haplic YERMOSOL

Laboratory no. ...../82	4320	4321	4322			
Horizon	A	C1	C2			
Depth (cm)	0-15	15-60	60-110			
pH-H_2O(1:2.5v/v)	7.8	8.8	8.2			
pH-KCl ,,	6.9	7.0	7.1			
EC(mmho/cm) ,,	0.29	0.09	0.09			
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.17	0.11	0.19			
N (%)						
C/N						
CEC (me/100g), pH 8.2	27.0	31.7	16.4			
CEC ,, ,, pH 7.0						
Exch.Ca (me/100g)	30.2	34.5	22.5			
,, Mg ,,	14.5	16.7	15.5			
,, K ,,	4.1	4.1	3.0			
,, Na ,,	0.7	0.9	1.0			
Sum of cations	49.5	56.2	42.0			
Base sat. %, pH 8.2	100	100	100			
,, ,, %, pH 7.0						
ESP at pH 8.2	3	3	6			
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-15	15-60	60-110			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	26	26	38			
Silt % 0.05-0.002mm	22	20	14			
Clay % 0.002-0 mm	52	54	48			
Texture class	C	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-20 cm) Laboratory no. 82 / 4412

			Available	Total
pH-H_2O (1:2.5v/v)	7.9			
Exch. acidity (me/100g)		Na (me/100g)	0.5	
C%	0.75	K ,,	0.9	
N%	0.10	Ca ,,	26.0	
P-Olsen (ppm)	12	Mg ,,	19.2	
		Mn ,,	0.2	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey

PROFILE DESCRIPTION NO. 51

General site information

Mapping unit	: AA5
Soil classification	: haplic YERMOSOL
Observation no./date	: 55-10; 17/3/82
Location/altitude	: Marsabit District; 37°35'E, 2°30'N; 450 m
Agro-climatic zone	: VII
Parent material	: Alluvial sediments derived from various sources
Physiography	: Floodplain
Relief	: Flat
Slope at site	: 0%
Vegetation	: Bushed grassland with *Acacia tortillis*, *Salvadora persica*, and perennial grasses as the most common species.
Land use	: Grazing and wood cutting for building materials
Erosion	: Strong rill erosion and moderate deflation Seasonally deposition may take place as well.
Surface stoniness/rockiness	: Nil
Surface sealing/crusting	: A strong surface crust is present
Drainage class	: Moderately well drained. Flooding may occur twice yearly for a few days.

Profile description

A	0-15 cm	Light brown (7.5 YR 6/5 dry), dark brown (7.5 YR 4/4 moist); clay; moderate, medium to coarse prismatic, breaking into strong, fine to medium, angular blocky; hard when dry, very friable when moist, sticky and plastic when wet; many fine and medium, common coarse pores; moderately calcareous; clear and smooth transition to: (sample no. 55-10/2)
C1	15-60 cm	Brown (7.5 YR 5/5 dry), yellowish red (5 YR 4/6 moist); clay; weak, medium to coarse prismatic, breaking into moderate, fine to medium, angular blocky; hard when dry, very friable when moist; sticky and plastic when wet; many, fine and medium, few coarse pores; moderately calcareous; gradual and smooth transition to: (sample no. 55-10/3)
C2	60-110cm	Yellowish red (5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); clay, massive, moderately coherent; slightly hard when dry, very friable when moist, sticky and plastic when wet; many pores of various sizes; strongly calcareous; very few, medium $CaCO_3$ concretions (sample no. 55-10/4)
	REMARKS:	Roots are present to a depth of more than 100 cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 52

FIELD OBSERVATION No: 43-4 **MAPPING UNIT:** DXA

SOIL CLASSIFICATION: cambic ARENOSOL sodic phase overlying orthic SOLONCHAK, sodic phase

Laboratory no. ...../ 81	9430	9431	9432	9433	9434	9435
Horizon	AC	ABb	Cb1	Cb2	2Cz1	2Cz2
Depth (cm)	0-50	60-100	100-130	135-145	150-180	190-220
pH-H_2O (1:2.5 v/v)	9.1	9.4	9.4	10.0	10.5	10.5
pH-KCl ,,	8.1	8.5	8.2	8.5	9.2	9.4
EC (mmho/cm) ,,	0.25	0.15	0.25	0.45	0.55	6.0
$CaCO_3$ (%)	1.9	1.4	3.5	2.4	4.4	2.0
$CaSO_4$ (%)						
C (%)	0.06	0.03	0.06	0.03	0.07	0.06
N (%)						
C/N						
CEC (me/100g), pH 8.2	4.8	6.6	13.0	5.4	34.6	7.8
CEC ,, ,, pH 7.0						
Exch. Ca (me/100g)	5.6	9.3	9.3	10.2	2.6	5.6
,, Mg ,,	0.5	0.6	1.1	0.8	1.0	1.0
,, K ,,	0.2	0.2	0.4	0.3	0.1	1.7
,, Na ,,	0.6	1.3	2.6	3.6	34.3	86.7
Sum of cations	6.9	11.4	13.4	14.9	38.0	95.0
Base sat. %, pH 8.2	100	100	100	100	100	100
,, ,, %, pH 7.0						
ESP at pH 8.2	11	20	20	66	23	>100

Depth (cm)	0-50	60-100	100-130	135-145	150-180	190-220
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	98	96	88	94	46	30
Silt % 0.05-0.002mm	2	4	6	6	10	18
Clay % 0.002-0 mm	0	0	6	0	44	52
Texture class	S	S	S	S	SC	C
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm						
,, ,, 1.0 - 0.50mm						
,, ,, 0.50 - 0.25 mm						
,, ,, 0.25 - 0.10mm						
,, ,, 0.10 - 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Saturation extract:

Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ,,						
Ca ,,						
Mg ,,						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ,,						
Cl ,,						
SO_4 ,,						
Sum of anions (me/l)						
Adj. SAR						

Clay mineralogy:

SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ,,						
Fe_2O_3 (mmol%)						

X-ray report: Small amounts of montmorillionite and illite are present in the first 145 cm; below 145cm moderate amounts of montmorillionite and illite are present.

Fertility aspects: (0- 20cm) **Laboratory no.** 81 /9483

			Available	Total
pH-H_2O (1:2.5 v/v)	8.5			
Exch. acidity (me/100g)		Na (me/100g)	0.3	
C%	0.17	K ,,	0.3	
N%	0.04	Ca ,,	10.3	
P-Olsen (ppm)	9	Mg ,,	2.4	
		Mn ,,	0.2	
		P (ppm)	-	

Various:

Remarks:

Kenya Soil Survey
Drawing No. 79060

PROFILE DESCRIPTION NO. 52

General site information

Mapping unit	: DXA
Soil classification	: cambic ARENOSOL, sodic phase overlying orthic SOLONCHAK, sodic phase
Observation no./date	: 43-4; 5/9/81
Location/altitude	: Marsabit District; 37°27'E, 2°35'N; 420 m
Agro-climatic zone	: VII
Parent material	: Aeolian deposits, from various sources, overlying various material (Pleistocene)
Physiography	: Dunes
Relief	: Irregular, undulating to rolling, with flat inter-dunal areas
Slope at site	: 12%
Vegetation	: *Indigofera spinosa* dwarf shrubland with annual and perennial grasses as understory and mainly *Euphorbia cuneata* shrubs
Land use	: Heavy grazing
Erosion	: Moderate splash and rillwash and slight deflation
Surface stoniness	: Nil
Surface sealing	: Nil
Drainage class	: Excessively drained

Profile description

AC	0-60 cm	Light brown (7.5 YR 6/4 dry), brown (7.5 YR 5/4 moist); medium sand; single grain; loose when dry and moist, non-sticky and non-plastic when wet; moderately calcareous; very few, small, dark minerals; gradual and smooth transition to: (sample no. 43-4/1)
ABb	60-130 cm	Strong brown (7.5 YR 5/6 dry), reddish brown (5 YR 4/4 moist); medium sand; massive, weakly coherent to moderately coherent with depth; soft to hard (deeper) when dry, loose when moist, non-sticky and non-plastic when wet; common, fine pores; strongly calcareous; very few, small, dark minerals; gradual and smooth transition to: (sample nos. 43-4/2 and 43-4/3 from 60-100 and from 100-130 cm respectively)
ACb	130-145cm	Brown (7.5 YR 5/4 dry), reddish brown (5 YR 4/4 moist); coarse sand; slightly layered; massive, moderately coherent; hard when dry, loose when moist, non-sticky and non-plastic when wet; common, fine pores; strongly calcareous; very few, medium, soft $CaCO_3$ concretions; very few, small, dark minerals
2Czb	145-180 cm	Dark brown (7.5 YR 4/2 moist); sandy clay; strong, medium to coarse prismatic; very hard when dry friable when moist; sticky and plastic when wet, moderately thick, continuous, cutans (matrans); common fine pores; 1-4 mm wide, vertical cracks, partly filled with sand from overlying horizon; strongly calcareous; very few, medium, soft and hard $CaCO_3$; abrupt and smooth transition to: (sample no. 43-4/5)
3Czb	180-230$^+$cm	Dark brown (7.5 YR 4/2 moist); clay; with black and white mottles; moderate, fine, angular blocky; hard when dry, friable to firm when moist, sticky and plastic when wet; thick, continuous, cutans (matrans) no pores; moderately calcareous; very few, medium, soft $CaCO_3$ concretions; few, salt crystals (sample no. 43-4/6)

REMARKS: Roots present to more than 1.00 m depth. The whole profile is strongly sodic, the underlying fine sediments are strongly saline as well. In this profile a buried AB horizon was present in the dunes. In general cambic characteristics occur in the dunes. In the interdunal flats, strongly saline, clay soils are dominating.

Appendix 5. SUMMARY OF FERTILITY STATUS OF THE TOPSOIL OF THE DIFFERENT MAPPING UNITS

mapping unit	available nutrients 1) K	Ca	Mg	P	C	CEC	pH	remarks
	(me/100g)			(ppm)	(%)	(me/100g)	(H2O)	
MUC	0.25	1.0	2.1	4	0.6	5	6.5	
MV1	0.14	12.2	7.3	5	4	30	5.3	
MV2P	0.48	15.9	8.6	8		38	6.3	
MVC	no data							
MPP	0.32	10.7	10.0	2	2	30	8.6	
HUP	0.42	6-40	1.7	18	0.3	10	7.8	
HVP	see FV2P							
HP1P	see MPP							
HP2P	0.50	37.0	4.0	6	0.3	25	7.6	
U1V1	0.25	7.5	7.5	11*	2.5	30	6.2	
U1V2	0.9	12	6.4	10	1.2	20	6.8	
U1V3P	1.1	14.0	6.0	10	1.1	21	6.6	
U2F1	0.8	7.2	3.5	16	0.3	15	7.8	
U2FA	0.9	8.4	3.3	20	0.2	14	7.8	
LsV1P	1.34	19.0	6.0	12	0.08	9.1	8.8	
LsV2	0.9	5.6	4.6	4	1	25	6.8	
LsV3p	0.16	10.7	10.0	2	0.8	37	8.8	
LsVC1	0.64	32.2	5.6	7	0.3	20	8.1	P : 3 to 13
LsVC2	as LsVC1							
LsXp	0.40	10.9	3.4	15	0.1	3.6	9.4	
LnV1	0.42	34.0	3.4	3	0.1	11	8.8	
LnV2	1.14	32.0	7.2	7	0.08	30	8.2	
LnV3p	0.52	37.0	3.8	7	0.3	35	8.5	
LnV4p	0.22	7.3	8.9	3	0.2	10	8.1	
LdVP	0.52	14.0	7.4	17	0.4	35	7.3	
RVp	1.24	9.4	8.4	7	1	15	7.9	
RVA	see FV1P							
	1.1	15.7	8.3	5	1	35		(lower slopes
	0.20	14.3	10.0	216*	1.5	30	6.8	(middle slopes
RVC	no data						7	(upper slopes
FU1	0.47	2.6	2.7	10	0.2	5	8.0	

ppendix 5.(contd).

apping nit	available nutrients 1) K	Ca (me/100g)	Mg	P (ppm)	C (%)	CEC (me/100g)	pH (H2O)	remarks
UA	0.62	4.5	2.2	26*	0.3	6	8.0	upper slopes
	0.75	6.9	2.9	15	0.2	12	7.0	lower slopes
V1P	0.71	27	3.6	11	0.3	26	8.3	
V2p	0.40	29	8.4	3	0.2	33	8.6	
V3P	1.0	34	6.8	10	0.6	11	8.9	
VC	0.30	33	5.4	3	0.2	33	9.2	
V1p	0.47	41	5.0	6	0.3	20	8.3	
V2	0.57	37	7.6	23*	0.5	30	8.4	
V3	no data							
VC	0.63	30	5.6	9	0.3	30	0.6	C : 0.1-0.5 (high ESP)
PvVp	0.46	35	6.0	5	0.5	30	8.5	
PnSP	no data							
PnSA	0.22	0.6	2.4	3	0.2	4	8.2	high ESP
PdSP	no data							
PsUK	0.8	21.5	4.8	12	0.1	4	8.3	
PsU1	0.98	10.8	4.4	17	0.3	8	8.0	C: 0.2-0.5; Ca:4.6-25.0
PsU2	1.0	3.0	3.4	13	0.2	10	7.8	
PsU3	0.32	10.7	10.0	2	0.15	14	8.0	CEC: 8-20
PsU4	0.54	12.5	3.9	11	0.2	15	8.5	moderately high ESP
PsU5	0.51	3.7	2.5	9	0.15	8	8.3	high ESP where B at surface
PsUA1	0.78	11.7	3.1	15	0.2	9	7.8	
PsUA2	0.58	4.0	2.0	19*	0.2	5	7.4	fertility of depressions higher
PlnX1	no data				0.6	40	9.0	extremely saline and sodic
PlnXA	" "				0.3	25	9.8	"
PldXC	0.58	29.0	5.6	5	0.2	28	9.2	moderately high ESP
AUC	1.1	14.5	4.1	100*	0.3	var.	7.7	all data variable

Appendix 5 (contd.)

mapping unit	available nutrients 1) K	Ca	Mg	P	C	CEC	pH	remarks
	(me/100g)			(ppm)	(%)	(me/100g)	(H2O)	
AA1	no data							
AA2	0.57	10	4.5	11	0.2	6	8.0	
AA3	0.59	11	2.6	14	0.2	14	8.2	
AA4	0.72	23	9.4	9	0.1	9	8.3	
AA5	0.88	26	19.2	12	0.2	27	7.9	
AAC	0.47	30	4.5	6	0.2	20	9.0	variable data
DXA	0.25	9.8	1.9	8	0.15	4	9.4	high ESP; depressions strongly saline

1) K, Ca, Mg : Mehlich analyses

P : P - Olsen unless with an asterix (P = P - Mehlich)*