Working group E: Land qualities for extensive grazing

Land qualities and land characteristics relevant for major land utilization types – an assessment with Kenyan examples

by M.M. Gatahi
Kenya Soil Survey
National Agricultural Laboratories
Nairobi, Kenya.

Abstract

The volume of ecological data on characteristics for evaluating rangelands for extensive grazing is accumulating rapidly. However, the task of integrating the results of these evaluations into the principles and concepts of the framework for land evaluation still remains.

A brief assessment of the land qualities/characteristics for the major land utilization types is presented. The ratings which have been used by the Kenya Soil Survey for these land qualities are presented. Finally, an example of a conversion table used to determine the suitability rating of land for the specific use being considered is given.

Introduction

Rangelands are fragile ecosystems whose ecological balance must be carefully managed to avoid the decline of their resources. However, most of the rangelands are in a steady state of decline. Land evaluation of rangelands is therefore of immediate concern, if the decline rates are to be slowed or reversed.

The results of many rangeland surveys have not been fully utilized in the past. Risopoulos (1975) attributed this incomplete utilization of results to two factors. Firstly the very fragmentary manner in which they were conducted, thus in an area some detailed information on vegetation may be available, but only scanty or no information on soils and water resources (both surface and ground water).

Secondly, the maps may be too complicated for the users, for example some surveys were based on vegetation and soils. For each soil unit (type) certain number of plant associations were indentified, but very often the number of these associations were too many for any meaningful interpretation by technicians in charge of planning or development.

Various methods have been used to assess rangelands. This has made the transfer of technology and extrapolation of results from one site to another difficult. To make an exchange of experiences possible there was clearly a need of standardization, thus a 'framework for land evaluation' (FAO, 1976) was formulated.

The 'framework' employs the concepts of land characteristics and land qualities in its land evaluation procedure. Land characteristics are attributes of land which can be measured or estimated e.g. rainfall, slope, biomass of vegetation and soil texture. Land characteristics are generally used to describe land mapping units. Difficulties arise when land characteristics are employed directly in evaluation due to interactions between them. Land qualities are therefore used in evaluation. Land qualities are complex attributes of land, which act in a distinct manner in their influence on the suitability of land for specified purposes.

To evaluate rangelands for extensive grazing, various attibutes have been employed. The specific attribute selected as a 'diagnostic criterion' varies from site to site.

Kenya Soil Survey (KSS) had carried land evaluation for extensive grazing in a number of areas including Kindaruma, Kapenguria, Amboseli-Kibwezi and Kiboko. In its evaluation KSS has closely followed the principles and concepts outlined in the 'framework'.

The major land utilization types which have been considered in Kenya include those in which cattle, goats, sheep and wildlife or their com- binations are kept. This paper aims to assess the land qualities/ characteristics, which are relevant to these LUTs and to show how some of these qualities have been rated by KSS in its land evaluation.

Relevant land qualities and characteristics

In most of their evaluations, range ecologists have used land attributes such as rainfall, slope angle, soil (depth and stoniness), ground vegetation and land qualities such as erosion, flooding and ability to burn as the evaluation criteria. The criteria and methods used were discussed during a seminar on 'Evaluation and mapping of tropical African rangelands' held in Bamako – Mali (1975). More recently Pratt and Gwynne (1977) have treated East African rangelands – classification and management.

In most of their evaluations, range ecologists have employed land characteristics as diagnostic criteria. This approach, however, overlooks the interactions between land characteristics referred to earlier. Before examining which land qualities are relevant for the LUTs it is worthwhile to think of the desired results of an evaluation based on their subsequent utilization. The desirable conclusion of land evaluation for extensive grazing is a statement on the land's carrying capacity and the management practices required for sustained production (Zonneveld, 1979; Pratt, 1975; Boudet, 1975). However, there are problems associated with the estimation of carrying capacity. Firstly on many occasions there is lack of data on the herbage production together with its nutritive value. Secondly, even where such data exist the percentage of herbage lost through a) termites, desiccation and wind, fire and trampling, b) selective grazing and abnormal climatic conditions are difficult to quantify (Pratt, 1975). Due to these difficulties in carrying capacity estimation the results of land evaluation are nog always quantifying carrying capacity as is desired.

Thalen (1979) (cited by Zonneveld,1979) listed the relevant land qualities as – (i) accessibility, (ii) climatic hardships, (iii) edemic pests and diseases, (iv) forage production, (v) nutritive value (vi) proper use factors (vii) availability of drinking water, and (viii) resistance to soil erosion.

The KSS has used these land qualities in its evalution for extensive grazing. In Amboseli-Kibwezi all these were used except land qualities ii, iii, vi. In addition for the land evaluation in Kindaruma, Kapenguria, Kwale and Kiboko the land quality (iv) was not used as a criterion, but instead qualities which affect production were used. The land qualities relevant for the major LUTs – involving cattle, goats and sheep – may be categorized into three groups, viz. those qualities which:

A affect the primary productivity of land;

B directly affect the performance of animals;

C affect the management practices to be employed.

The data obtained from KSS resource surveys is not adequate to determine the quantity of dry matter or its nutritive value. Therefore all the land qualities which affect primary production are assessed.

A. Land qualities affecting primary productivity

The land qualities in this category include availability of moisture, nutrients and oxygen, and susceptibility to soil erosion. Other land qualities which may be considered are presence of hazard of salinity and sodicity.

(i) Availability of moisture

This land quality is often the most limiting one in rangelands. It may be calculated from rainfall, evapotranspiration, infiltration rates and soil moisture storage capacity over the effective rooting depth of the forage plants in an area.

The effect of rainfall on range productivity is well documented in literature. Diarra and Breman (1975) reported the use of rainfall to estimate primary productivity in the Sahel; Pratt and Gwynne (1977) used moisture availability index to delineate ecological zones and to estimate the carrying capacity. The use of rainfall alone presumes that other characteristics are not significant. However, this assumption may not always be true, for example, production may differ in areas of same rainfall, but with soils of different moisture storage capactities.

The ideal situation is where the availability of moisture is estimated by means of a water balance study which takes into account rainfall, soil moisture storage capacity, evapotranspiration and possibly, infiltration rates. This approach has been attempted in Kenya for cashewnuts and coconuts (Gatahi, 1983), but has not been applied for evaluating rangelands.

Presently KSS uses climate (agroclimatic zones) and the soil moisture storage capacity for assessing this quality.

The climate, however, varies little within one agroclimatic zone therefore the bigger emphasis is on the soil moisture storage capacity Touber (1983). The rating classes used for moisture storage capacity are those of Braun and van de Weg (1977) given below:

Generally the number of characteristics and qualities that will be taken into account will depend on the type of data available, the analytical facilities and the time available.

(ii) Availability of nutrients

Plant growth depends on soil for nutrients. The quality availability of nutrients will therefore determine the vigour of forage and its nutritive value.

Rating	Available moisture storage capacity in mm/10cm	Description
1	> 160	very high
2	121 – 160	high
3	80 – 120	moderate
4	40 – 79	low
5	< 40	very low

Imbalances in content of nutrients in the soil may cause toxic levels in forage or the lack of some elements needed by animals.
The characteristics and qualities which may be used for assessment of this land quality are cation exchange capacity (CEC), available nutrients including potassium, calcium, magnesium, phosphorus, nitrogen and trace elements.
The KSS uses CEC, available (exchangeable) cations, available phosphorus, % carbon of topsoil determined by Mehlich method. The cations, calcium, magnesium, potassium and phosphorus determined by total analysis (25% HCl extractable). The ratings of the availability is given in appendix 1.

(iii) Availability of oxygen

Plants respond in different ways to impeded drainage. Flooding for long periods may even kill some plants. The oxidation potential (Eh/cm) is the ideal parameter for determining the availability of oxygen. Due to lack of data on oxidation potentials the KSS uses internal drainage classes (adopted from the Soil Survey Manual). The rating classes are given below:

Rating	Description	Drainage class
1	very high	well to excessively drained
2	high	moderately well drained
3	moderate	imperfectly drained
4	low	poorly drained
5	very low	very poorly drained

(iv) Susceptibility to soil erosion

The removal of fertile topsoil has detrimental effects on plant production. Susceptibility to erosion is based on the assessment of erosivity involving rainfall (climate), slope (class and length) and soil erodibility based on (i) organic matter content, (ii) the flocculation index, (iii) silt clay ratio (topsoil) and (iv) bulk density (topsoil).
The subrating on slope class is considered more important and is thus accorded a heavier subrating as shown below:

Rating	Slope class
1	A+B
3	B+BC+C
5	CD+D
7	E+F

The subrating on erosivity is based on climate. The important parameter rainfall intensity and duration of storm would be a better indication, however, the information of these parameters as they relate to soil loss is still scanty. Agroclimatic-zones are therefore used and are rated as shown below:

Rating	Agroclimatic zone
0	I and II
1	III
2	IV and V

The subratings on slope length is made as below:

Rating	Length (metres)
1	>200
2	50–200
3	< 50

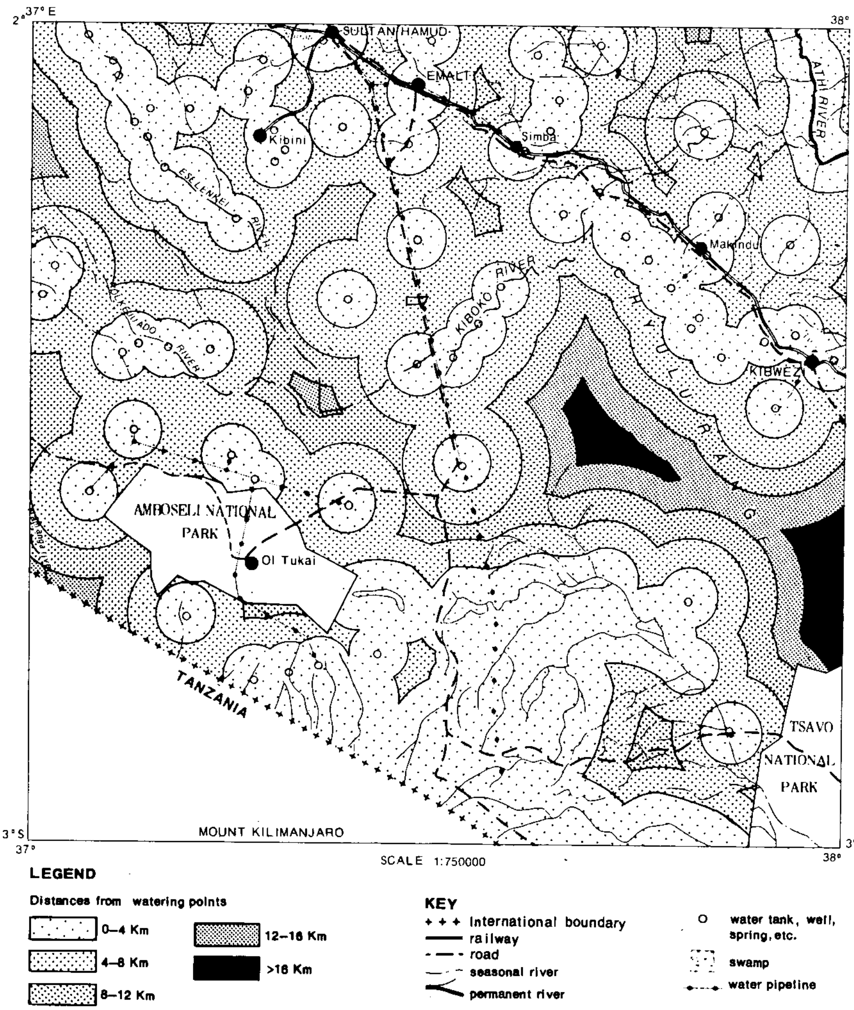
Three subratings are assigned to each of the four subratings (i) to (iv) above on soil erodibility, rating 1 being highest and rating 3 the lowest. The subratings (i) to (iv) are then summed up to obtain the final subratings on soil erodibility.
The final rating on susceptibility to erosion is given by summing up all the subratings in five rating classes ranging from 1 to 5.

B. Land qualities directly affecting the animals

The land qualities in this category are more decisive in their influence on suitability of land for a specific LUT. The qualities include availability of drinking water (the quality, quantity and distance to watering points); hindrance by vegetation; treadibility; the nutritive value of forage; availability of shade (climatic hardships) and the incidence of pests and diseases.

(i) Availability of drinking water

Different animals will manage to travel for specific distances in search of water without affecting their performance. For example the camel will travel much longer and stay without water for longer durations than cattle. There are few ratings, if any, on this land quality. Pratt and Gwynne (1977) observed that for (beef)cattle a distance of four kilometres is the furthest distance an animal can travel without affecting its performance. The use of availability of drinking water as a criterion poses some difficulties. Touber (1983) observed the use of distance to drinking water causes subdivision of mapping units in different suitability ratings. This subdivision is evident from Figure 1. A possible solution on how to use distances to watering points is yet to be found. Due to this difficulty, availability of drinking water has not been used as a diagnostic criteria by the KSS.



Drawing No. 82049

Fig. 1 Availability of permanent drinking water for cattle *(ii) Hindrance by vegetation*

Animals are affected differently by the density of bushes and shrubs. Browsers are more suited to vegetation with shrubs while pure grazers have difficulties. The KSS uses the density of shrubs for rating this land quality as shown below for cattle in the Kiboko area:

Rating	Degree of hindrance	Physiognomic units
1	none to slight	G, BG, WB, WBG, W
2	slight	B
3	moderate	Bd – B
4	high	Bd
5	very high	Bt

The physiognomic units are defined on the attached key to physiognomic classes (Fig. 2).

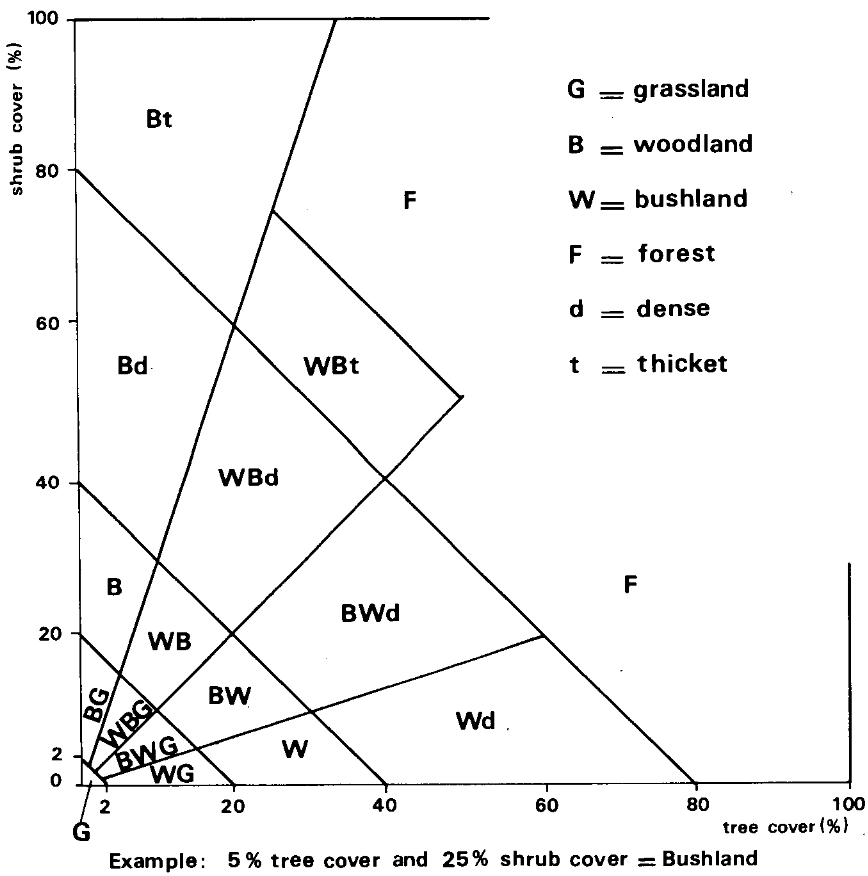


Fig. 2 Key to physiognomic classes

(iii) Treadibility

Treadibility of land affects the distances which an animal may cover in a given time in search of pasture or drinking water. This quality may be assessed from various factors including surface rockiness or stoniness, consistence of the topsoil, both dry and wet. In the Amboseli-Kibwezi area the consistence of topsoil was used to assess this quality, however, in other areas ratings have not been defined for this quality, e.g. in the Kiboko area.

(iv) The nutritive value

Nutritive value is one of the very important parameters used to determine the carrying capacity. In recent years more data on nutritive value of forage has become available. The nutritive value has been estimated from ash content, crude protein (CP), crude fibre (CF), other extractives (EE), nitrogen free extractives and also from analysing the forage contents of phosphorus, calcium, magnesium and other major or minor elements (Bogdan, 1977). The nutrient balance in the forage is also important. For example, a poor balance between magnesium and potassium can be toxic to animals due to hyper-magnesium.

The KSS, however, does not carry out these analyses, therefore a simple rating is used based on species composition and physiognomy.

For example, in Kiboko the following ratings are used:

Rating	Description	Species or physiognomy
1	excellent grasses	Pennisetum cladestinum
2	good grasses	Digitaria milanjiana, Bothriochloa, Sporobolus
3	moderate grasses	Themeda sp., Chloris spp.
4	poor grasses/herbs	annuals and herbs
5	no grasses	bushland thickets with shrubs and herbs

There are other land qualitites which, although important, have not been used as criteria in the evaluation for various reasons. These include incidence of pests and diseases and palatability of grasses,which have only been qualitatively used in Amboseli-Kibwezi.

C. Land qualities affecting management

Rational utilization of rangelands is dependant on the management practices applied. Two land qualities are of particular importance, viz. the present state of overgrazing and the susceptibility to burning. Other qualities e.g. regeneration of vegetation are also important. The present declining trend is attributed to, among other qualities, overgrazing and bush fires, which are common in rangelands. The KSS has not developed a suitable rating system for susceptibility to burning. The rating proposed by Thomas and Pratt (1967) (cited by Pratt and Gwynne, 1977) based on the percentage kill for rating susceptibility to fire is appropriate here.

Fire susceptibility	% Kill
tolerant	< 10
semi-tolerant	10 – 39
sensitive	40 – 70
intolerant	> 70

In addition Pratt and Gwynne (1977) suggest that the response of plant species to the frequency of burning and the nature of fires should also be taken into account if the ratings are to be meaningful.

The present state of overgrazing is rated on the basis of percentage basal cover as given below:

Rating	State of overgrazing	% Ground cover by grass
1	none	80 – 100
2	slight	60 – 80
3	moderate	40 – 60
4	severe	20 – 40
5	very severe	< 20

Conclusion

Once all these land qualities are rated, the specification of the diagnostic criteria defining the suitability classes of land for various LUTs is made. These specificaitons are called 'conversion tables' and present the most difficult step in the evaluation procedure. The construction of these tables requires a multidisciplinary team which is often difficult to assemble. The conversion table for the Kiboko area specifying the suitability classes for the LUT 'cesented as an example Appendix 2. The qualities used as diagnostic criteria include availability of moisture, climate, availability of nutrients and oxygen, resistance to soil erosion, nutritive value of grasses and present state of overgrazing.

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Appendix 1 – Rating of availability of nutrients

R1 – Cation Exchange Capacity

Rating	CEC me/100g s
1	>16
2	12–16
3	6–12
4	2– 6
5	0– 2

R2 – Exchangeable cations, available P and % carbon.

Subrating R2	Exch. K me%	Avail. P (ppm)	%C
1	>0.6	>60	>2.5
2	0.2–0.6	20–60	1.5–2.5
3	<0.2	<20	>1.5

The final subrating of R2 is obtained by summing up the individual ratings:

R2	Final rating R2
0– 5	1
6–10	2
11–15	3

R3 – 25% HCl extractable.

Subrating R3	Ca (me %)	Mg (me %)	K (me %)	P (ppm)
1	>75	>40	>25	>500
2	25–75	10–40	5–25	250–500
3	0–25	0–10	0– 5	0– 25

The final rating R3 is obtained by summing up subratings of R3.

Appendix 2 – Conversion tables for the LUT cattle in the Kiboko area

Land quality / Suitability Class	climate	soil moisture storage capacity	availability of nutrients	resistance to erosion	hindrance by vegetation	availability of oxygen	nutritive value of grazing land	present state of overgrazing
1.1 Highly Suitable	IVb–V	1	2	1	1	2	1	1
1.2 Moderately Suitable	IVb–V	2	3	2	2	3	2	2
1.3 Marginally Suitable	IVb–V	3	4	3	3	4	3	3
3 Not Suitable								

* Source: Michieka, D. O. and Braun, H. M. H., 1977.

A land evaluation study in the Mount-Kulal-Marsabit Area, Northern Kenya *

by A.J. van Kekum,
UNESCO, Abidjan, Ivory Coast

1. Introduction.

The land evaluation was carried out as a follow up to a soil survey conducted in the area. The survey was executed on behalf of the MAB Programme of Unesco, while the soil research programme was a joint undertaking between Unesco's Ecological Division and the International Soil Museum in Wageningen.
The present survey belongs to the Intergrated Project of Arid Lands (IPAL) of the Man And Biosphere (MAB) Programme and was initiated in 1976. The aim of IPAL is to find direct solutions to the most urgent environmental problems associated with desert encroachment and ecological degradation of arid lands. The results of the investigations are integrated in an area management plan, which concentrates on the improvement of the natural environment with the aim to raise the existence level of the pastoralists.

2. The Environment

2.1. Location, administration, communication and population.

The Mount Kulal-Marsabit survey area, which covers 15 630 square kilometres, lies in the north of the republic of Kenya between 2 and 3°N and 37° and 38°E. (Figure 1). In the southwest it is bounded by the Ndoto mountains (2838 m), in the west by an outlier of the 01 Donyo Mara (2224 m) and Lake Turkana. In the northwest a volcanic mountain, Mt. Kulal (2295 m) forms a distinct landmark. In the east another volcanic mountain, Mt. Marsabit (1710 m) forms the boundary of the survey area. Between the mountains lies an extensive plain at an altitude between 400 and 700 m above sea level.

The main administrative centre is Marsabit with the offices of the District Commissioner and District Officers. Marsabit further provides many important facilities for the people of the area.
Three National Forest Reserves are located in the survey area: the Kulal Forest Reserve which is also a MAB Bioshere Reserve, the Marsabit National Reserve and the Ndoto's Forest Reserve.
Only one main road crosses the area: the Isiolo-Moyale road. The other roads are mere tracks and all roads may become impassable in wet periods.
Almost the whole Rendille tribe lives in the survey area. In the north some Gabra people occupy the land. These people are nomadic pastoralists who

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* This paper represents an edited version of the original document which is entitled: A soil survey and land evaluation study in the Mount Kulal-Marsbit Area, Northern Kenya.

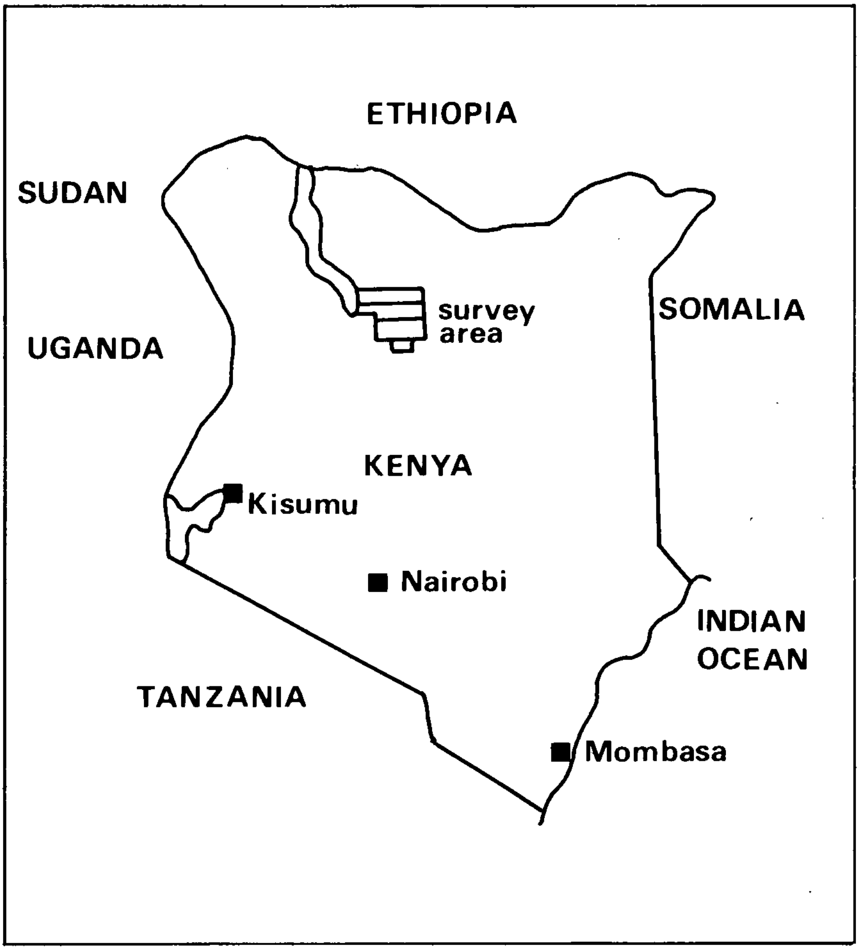

Fig. 1 Location map of the survey area

keep camels, sheep and goats. Small numbers of Boran and Samburu occupy the mountainous fringes of the survey area. They are basically cattle-keeping nomadic pastoralists. As a rule, the different tribes do not use the same geographic area because of an tagonism and fear of inter-tribal raiding of stock. The mainstay of their diet is milk from camels or cattle, often mixed with blood, and the meat of small stock. Some Turkana and El Molo people are living along the shore of Lake Turkana. The Turkana supplement their milk and meat diet with fish, while the El Molo almost entirely rely on fish. The Rendille utilize the largest part of the survey area and they are pure pastoralists, mainly dependent on the camels for their livelihood. Like other groups in the study area, the Rendille have been subject to various pressures on their territory. It is estimated that the Rendille occupy only 8.000 square kilometres of a former home range of 57.600 square km of their present range, over 40% is not ulitized due to poor security and the fear of raids from neighbouring Turkana and Samburu.

According to the 1979 census the Rendille number amounts to approximately

13.000, which means that they have doubled in the last 40 years (the information about the Rendille is after Lusigi, 1981).

2.2. Climate

The annual rainfall in the survey area shows clearly a bimodal pattern. (Figure 2). The main wet season normally starts in March/April and lasts till May, the short rainy season starts in October/November and lasts about two months. In the annual mean Mt. Marsabit receives more than 700 mm, which is the highest for the study area. As a supplementary source of water

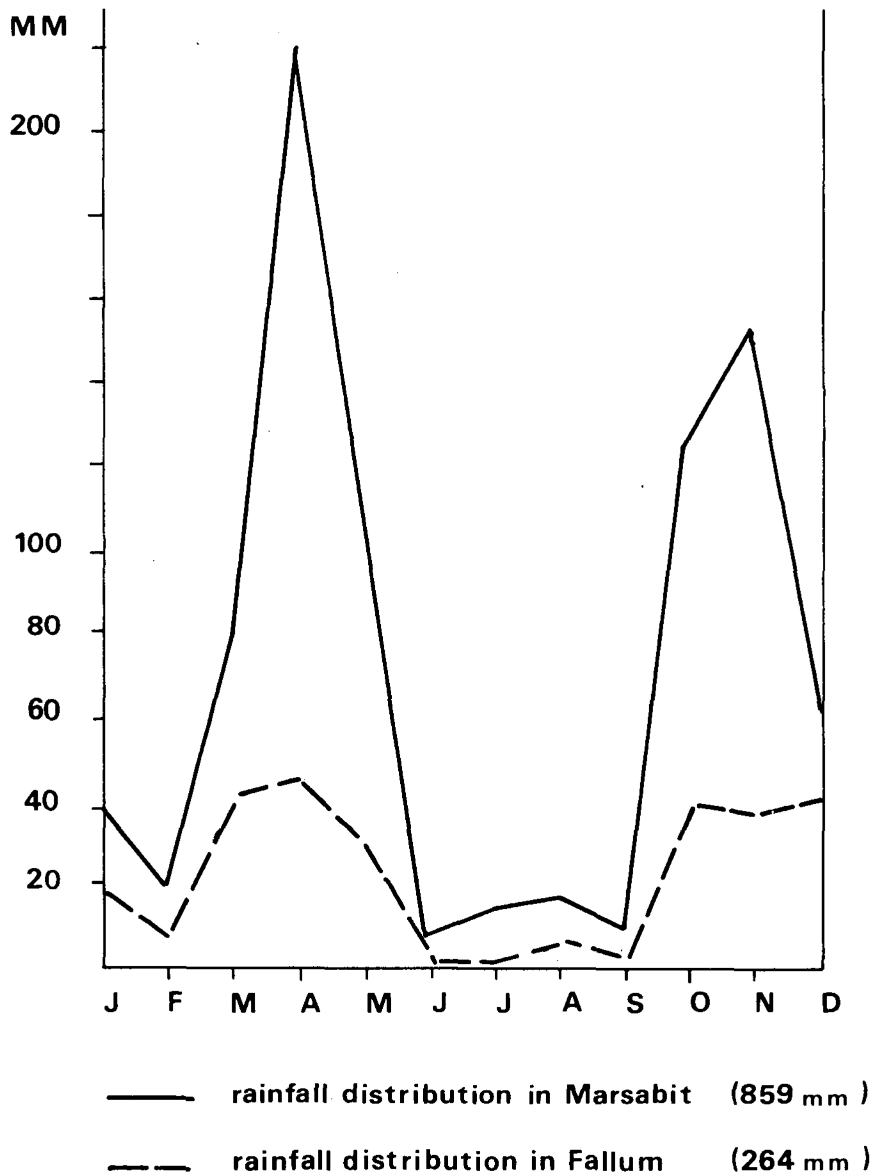

Fig. 2 Rainfall distribution patterns

there is an outcombing of clouds and fog. All the other places in the area receive less rain. The mean annual rainfall for the plains is around 225 mm. An important characteristic is the high variability of the rainfall in the area. The variation may be as high as 200%. Also the variation in spatial distribution is high. Generally speaking, there is a clear relation between rainfall and altitude, the higher places receiving the highest amount.
In figure 2 the mean monthly rainfall data for Marsabit are given. The figures are based on more than 50 years of observations. Marsabit represents about the wettest place in the area. In Figure 2 also the mean monthly rainfall for Fallam, which represents the rainfall in the dry lowlands, is given. The figures have to be handled with care as they are based on only five years of observations.
The monthly rainfall variability is very high. This has of course a big influence on the way of life of the pastoralists: they follow the rains, but can never rely on them completely.
The evaporation rates are very high in northern Kenya. The measured potential evaporation in a place with similar conditions as the survey area is well above 3.000 mm/year. Calculated figures vary between 1.800 (Marsabit mountain) and 2.280 mm (in the lowlands) using Woodhead's methodology (Woodhead, 1968).
The mean monthly temperatures vary little throughout the year. The mean annual temperature for the mountains is around 19°C, while in the lowlands the temperature is around 28°C. The differences in mean monthly maximum and mean minimum are about 10°C.
The winds come mainly from an easterly direction, are often present and wind speeds over 4 m/s are very common (Edwards et al., 1979).

2.3. Geology

The survey area falls mainly in the East African Rift Valley Zone, which is clearly demonstrated in the western part of the area where major fault systems in a SSE-NNW direction occur, accentuated by the occurrence of scarps.
Tectonism and denudation led to the development of a number of mountain ranges and isolated mountains. Some rise well above 2.000 m.
The oldest rock dates from the Pre-Cambriam, e.g. the Basement System Rocks. These rocks have been subject to folding and metamorphism. They are encountered in the south and southwestern part of the survey area and exposed as the Ndoto's, Ol Donyo Mara, Bayo and Ilim mountains.
The Basement System Rocks mainly consist of felsic gneisses with bands of migmatites and limestone. Occasionally ferro-magnesian rich gneisses occur, e.g. in the Korr and Elgess areas. The rocks are indicated on Figure 3 as 'U'. Reddish quartzitic sandstones ('S') occur in the northern part of the area, south of Maikona. They are overlain by volcanic rocks ('V).
The major part of the area is underlain by volcanic rocks of the late Tertiary to early Pleistocene age, which are frequently exposed.
Distinct landmarks are the two volcanos Mt. Kulal (2.295 m) and Mt. Marsabit (1.730 m). They are mainly composed of basalt, however, pyroclastics occur also.
Various lava plateaus are present in the survey area, commonly of basalt, interchanged with pyroclastic hills.

The intermonane basins are mainly filled with a mixture of volcanic rocks. Lacustrine sediments are present in the area around the Chalbi desert, at the foot of the mountains in Olturot and Ilaut, as well as along Lake Turkana. The sediments are mainly derived from the undifferentiated Basement System Rocks with an admixture of volcanic materials.
The lacustrine sediments are dated late Miocene/Pliocene to Recent ('X').

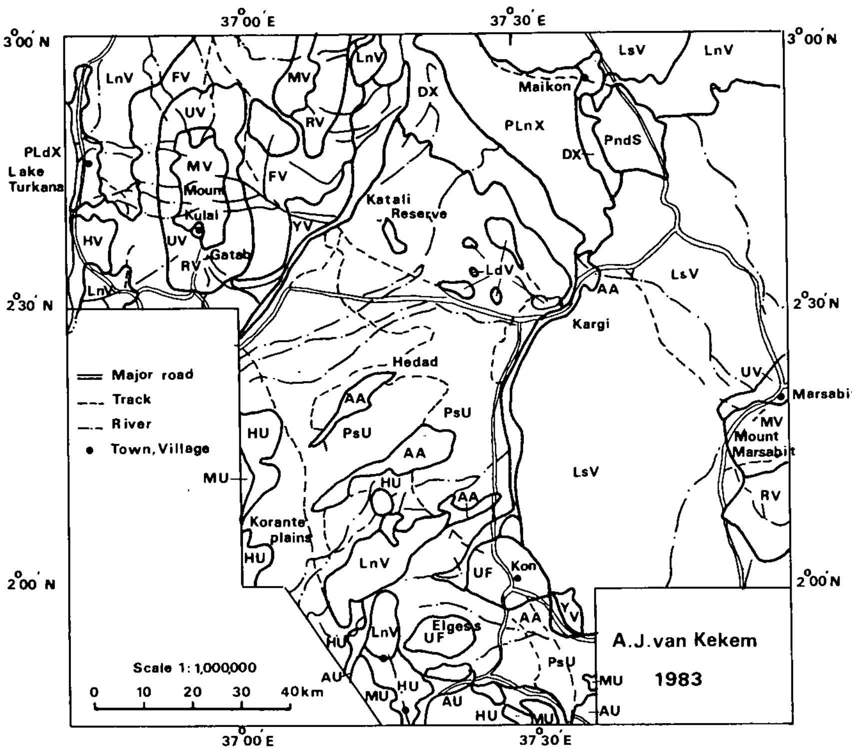

Fig. 3 Physiographic map

Legend to Figure 3

M	: MOUNTAINS (relief intensity 300-1000 m, slopes from 8 to over 30%).
MU	: Mountains of undifferentiated Basement System rocks (Precambrian).
H	: HILLS (relief intensity 50-300 m, 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).
U	: UPLANDS (relief intensity 10-100 m) HIGH LEVELS (relief intensity 10-100 m, slopes from 2 to over 16%).
UV	: Uplands of various volcanic rocks (Plio-Pleistocene) LOW LEVEL (relief intensity 10-50 m, slopes 1-8%).
UF	: Uplands of gneisses rich in ferro-magnesian minerals (Basement System, Precambrian).

L : PLATEAUS
Ls : Stepped plateaus (relief intensity less than 10 m, steps of 10-20 m, slopes 0-3%).
Ln : Non-dissected plateaus (relief intensity less than 20 m, slopes 0-5 %).
Ld : Dissected plateaus (relief intensity 10-60 m, slopes 1-10%).
LV : All plateaus of various volcanic rocks (Plio-Pleistocene).

R : FOOTRIDGES (dissected middle slopes of volcanic mountains, relief intensity 50-200 m, slopes of crests 2-8%, slopes of valley sides over 16%.
RV : Footridges of various volcanic rocks (Plio-Pleistocene).

F : FOOTSLOPES (at the foot of mountains, hills and plateaus, relief intensity less than 10 m, slopes 1-8%).
FV : Footslopes of colluvium derived from various volcanic rocks (Pleistocene).

Y : PIEDMONT PLAINS (relief intensity less than 10 m, slopes 0-2%).
YV : Piedmont plains of colluvium and alluvium derived from various volcanic rocks) (Pleistocene).
P : PLAINS
Pv : Volcanic plains (relief intensityy 5-10 m, slopes 0-2%).
PvV : Volcanic plains of various volcanic rocks (Plio-Pleistocene).
Pnd : Non-dissected and dissected erosional plains (relief intensity 0-20 m, slopes from 0 to over 16%).
PndS : Erosional plains of quartzitic sandstones (Miocene).

Ps : Sedimentary plains (relief intensity less than 5 m,, 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 5 m, slopes 0-2%).
Pld : Dissected lacustrine plains (relief intensity 5-20 m, slopes 0-8%).
PlX : All lacustrine plains of sediments derived from various parent materials (Pleistocene).

A : FLOODPLAINS (relief intensity less than 5 m, slopes 0-2%).
AU : Floodplains of alluvial deposits derived from undifferentiated Basement System rocks (Pleistocene-Holocene).
AA : Floodplains of alluvial deposits (Pleistocene-Holocene).

D : DUNES (relief intensity 2-10 m, slopes from 0 to over 16%).
DX : Dunes of aeolian deposits overlying various parent materials (Pleistocene).

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

N.B.: All geological times are tentative.

2.4. Hydrology

Permanent surface water is very rare in the area. Exceptions are the summits of Mt. Kulal and Mt. Marsabit and some springs at the foot of lava flows (e.g. the Kirole spring, NE of Largi). The springs are merely waterholes dug in the sandy riverbeds. After prolonged droughts they may dry up as well. Aquafers may be recharged after rains and temporary water sources are shallows filled up during rainshowers after which water may be available for a few days.
The Chalbi desert forms the erosion base for a large part of the area and the desert may be flooded for a few weeks in the rainy season. The largest intermittent river is the Balesa Kulal which drains into the Chalbi. Secondly the Ngurunit is important as it flows for about six months every year.
In the northwest Lake Turkana serves as a local erosion base.

2.5. Soils

The soils are classified according to the FAO-Unesco (1974), results are summarized in the following table. The symbols are corresponding to those on Figure 3, indicating the major landform and the geology.
In general, aspects on the soil chemical properties indicate the following trends for the top 0-20 cm:

P-Olsen	is generally between	5 -10	ppm,	occasionally	10 - 20	ppm
Available P	is generally between	20 -80	ppm,	occasionally	80 -100	ppm
Available K	is generally between	1.0- 2.0	me/100g	occasionally	2.0- 3.5	me/100g
Available Ca	is generally between	6 -10	me/100g	occasionally	10 - 20	me/100g

The nitrogen content is low, however, many plant species are leguminous.
The pH-H 0 varies between 7 and 8.
The organic matter content is generally below 1%. The C/N ratio is between 5-7 in the drier parts of the area and around 10 in the wetter parts.
The CEC of the soils is generally above 16 me/100g, except in coarse textured soils.

Some physical aspects concern the available water holding capacity and infiltration. The total available moisture for a sandy clay loam is 10-15 volume %. Infiltration of (rain)water is hindered by sealing (crust formation) and by degradation of the structure by cattle trampl- ing particulary around water holes.

Table 1: General properties of the soils (summarized).

Soil Classification, Landform	Limitations
Soils of the Mountains (MU):	
eutric Lithosols	shallowness, stoniness, coarse texture
ferralo-chromic Luvisols	low fertility
luvic Phaeozems	stoniness
eutric Cambisols	stoniness, shallowness

Table 1: (Contd.)

Soil Classification, Landform	Limitations
Soils of the Hills and Minor Scarps (HU & HV):	
eutric Lithosols	shallowness, stoniness, coarse texture
haplic Yermosols	rockiness/stoniness/sodicity
eutric-calcaric Regosols	stoniness, shallowness, sodicity
Soils of the Uplands (UF):	
eutric Nitosols	occ. stoniness
chromic Luvisols	occ. stoniness
chromic Cambisols	occ. stoniness
eutric Cambisols	stoniness, shallowness
luvic & haplic Yermosols	salinity
cambric Arenosols	stoniness, shallowness
Soils of the Plateaus (Ls, Ln, Ld & LV):	
chromic Luvisols	occ. stoniness
chromic Cambisols	occ. stoniness
chromic Vertisols	stoniness, low fertility, poor workability
haplic Yermosols	rockiness/stoniness, salinity, sodicity
calcaric Regosols	rockiness/stoniness, salinity, sodicity
Soils of the Footridges (RV):	
chromic Cambisols	bouldery =
haplic & calcic Xerosols	stoniness, shallowness
chromic Luvisols	bouldery
haplic & calcaric Phaeozems	stoniness
Soils of the Footslopes (FV):	
luvic & cambic Arenosols	stoniness, coarse texture
luvic Yermosols	low fertility, sodicity
calcic Yermosols	stoniness, salinity, sodicity, shallowness (occ.)
haplic Yermosols	bouldery/stoniness, sodicity/salinity (occ.)
haplic Xerosols	stoniness, shallowness
orthic Solonchaks	stoniness, sodicity
Soils of the Plains (P). Volcanic Plains (Pv):	
luvic & calcic Yermosols	stoniness, sodicity
Erosional Plains (Pld):	
eutric Lithosols	stoniness
cambric Arenosols	sodicity, low fertility
orthic Solonetz	sodicity, salinity, poor drainage

Table 1: (Contd.)

Soil Classification, Landform	Limitations
Sedimentary Plains (Ps):	
cambic Arenosols	petrocalcic, low fertility
luvic/vertic/haplic Yermosols	sodicity, salinity (occ.)
orthic Solonetz	sodicity, low permeability, salinity (occ.)
Lacustrine Plains (PlX):	
orthic & takyric Solonchaks	salinity, sodicity, poor drainage
Soils of the Floodplains (AA & AU):	
calcaric Fluvisols	sodicity, variable properties
Soils of the Dunes (DX):	
cambic Arenosols	sodicity, coarse texture
orthic Solonchaks	salinity, sodicity, poor drainage

3. Land evaluation

3.1. Introduction

The FAO methodology is used as explained in 'the Framework for Land Evaluation' (FAO, 1974).

The following stepwise approach is adhered to:

1) definition of the relevant LUTs in the area;
2) determination of those land qualities that have a direct influence on the production of the LUT;
3) rating of these land qualities by means of single or a set of land characteristics;
4) matching the land use requirements and the land qualities to arrive at the land suitability for each tract of a land for the present condition (current land suitability classification).

As a result of an integrated approach of range ecologists and livestock experts and soil scientists the preliminary carrying capacity for the carrying tracts of land is calculated (first production level), see Van Wijngaarden (1984). The input of the soil scientist concerns the rating of a number of land qualities that influences this first second production level, e.g. accessibility, erodability, flooding hazard, natural fertility and soil moisture availability*.

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* The paper does not make a clear differentiation in land qualities applicable to first and second production levels as outlined in other papers, particulary by Van Wijngaarden. However, the first three led to an assessment of the carrying capactiy, why the combined land quality rating concerns the suitability for the LUT extensive grazing and browsing.

3.2. Land Utilization Types (LUTs)

Relevant land utilization types for the area are:

- Nomadic to semi-nomadic, small scale, extensive grazing and browsing. The products are milk, blood, hides, skins and some meat for local consumption. Some meat, hides and skins are marketed at very low prices. The capital investiment per ha is extremely low. Labour input per ha is also very low. Technology is traditional. The land is tribally owned and the family income is also extremely low. The present infrastructure is very poor. Veterinary input is very low.

- Protected forest or game reserve. At present only in Marsabit some capital is invested and tourist revenues are gained. This land utilization type is important for the mountain summits.

- Small scale, rainfed, mixed farming (agriculture with dairy farming). Low level of technical knowledge. This land utilization type is only possible in areas that are rather flat, have deep soils and receive enough rain for a crop to complete its growing cycle. These requirements are only fulfilled in a small area near Marsabit and on some parts of Mt. Kulal. In this paper attention is mainly given to the first LUT, namely nomadic to semi-nomatic, small scale, extensive grazing and browsing. In places where other LUTs are applicable, it is mentioned as well.

3.3. The rating of the land qualities

The influence of each land quality on land use is determined by a single or a set of land characteristics, according to the grade of its availability or absence of risk as follows:

Rating	Description			
1	very high	grade of	-availability/	-absence of risk
2	high	,,	,,	,,
3	medium	,,	,,	,,
4	low	,,	,,	,,
5	very low	,,	,,	,,

Generally the most limiting factor is conclusive, exceptions to this rule are explained in the text.

The grades have a relative meaning only, e.g. qualitative approach.

3.3.1. Accessibility

The land quality accessibility is composed of the following land characteristics:

- percentage slope
- surface stoniness
- occurence of flooding

As the requirements vary for the different animals commonly used in the area (camels, cattle, sheep and goats) a separate rating is given for the different species (Table 2).

Table 2: Subrating for 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		

Key: A (0-2%), B (2-5%), C (5-8%), D (8-16%), E (16-30%)
* cm = camels, ct = cattle, sg = sheep and goats

In Table 3 the subrating for the surface stoniness or boulder cover are given.

Table 3: Subrating for surface stoniness/boulder cover.

Subrating	Cover with stones (%)			Cover with boulders (%)		
	cm*	ct*	sg*	cm	ct	sg
1	0–50	0–50	50–80	0–50	0–50	0–80
2			>80			>80
3	50–80	50–80		50–80	50–80	
4	>80					
5		>80		>80	>80	

* see Key table 2.

In Table 4 the subratings for the occurrence of flooding are given. Flooding is limited to a few areas and to the Chalbi desert. The period of flooding varies from a few days to a maximum of 4 to 6 weeks per year. The subratings do not vary with the animal species.

Table 4: Subratings for the occurence of flooding.

Subrating	Flooding
1	absent
2	present

The rating for the accessibility is determined by the most limiting factor of any of the subratings. So, if for example the subratings are 1, 5, 1 respectively, the final rating will be 5. Only in case of a combination of 3 with 3, the final rating will be 4. A combination of 4 with 4 will end up in 5. The significance of the figures on the scale of 1 to 5 is as follows: 1 means excellent accessible, 5 means not or very difficult accessible.

3.3.2. *Erodibility*

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 be greatly influenced by the different animal species. The density of the livestock population is very low and consequently the surface area influenced is very low. However, the effect of trampling around water points and villages cannot be neglected and although the surface area is relatively small it warrants special attention. In Table 5 the subratings for slope class are given.

Table 5: Subratings for slope class.

Subrating	Slope class
1	A
2	AB, B
3	C
4	D
5	E, >E

In Table 6 the subratings for the texture of the topsoil are given. The subrating for texture will be upgraded with one class if the surface is exceedingly stony or exceedingly bouldery.

Table 6: Subrating for texture of topsoil.

Subrating	Texture
1	sand, loamy sand
2	sandy loam, sandy clay loam
3	loam, clay loam and finer

Another land characteristic influencing the resistance to erosion is the cover of the vegetation. In this aspect the perennial grasses and the dwarf shrubs play the most important role. Annual grasses, however, should not be overlooked. It was decided to use as parameter the aerial cover with perennial grasses and dwarf shrubs plus 50% of the annual grasses and herbs. Table 7 shows the subratings for the vegetation cover.

Table 7: Subratings for the vegetation cover.

Subrating	Cover (%)
1	>50%
3	20–50%
5	0–20%

The rating for the resistance against erosion is composed of the sum of the subratings given above. Table 8 shows the final ratings for the resistance against erosion.

Table 8: Ratings for resistance against erosion.

Class	Rating	Sum of subratings (slope class, texture, cover)
highly resistant	1	3– 7
moderately resistant	2	8–11
slightly resistant	3	>11

The ratings for accessibility and resistance to erosion can be combined to a final rating or suitability classification for the different soil mapping units in the survey area, based on the two land qualities, treated above. The combinations for the suitability classification are given in Table 9. A proposal is given in the same table for the subtraction of a certain percentage from the carrying capacity as the results of limitations caused by the accessibility and the erodability.

Table 9: Suitability classification with conversion table based on the land qualities accessibility and erodability.

Suitability class	Final rating	Ratings for Accessibility	Ratings for Res. to erosion	reduction carrying capacity
highly suitable	1	1, 2	1	0%
moderately suitable	2	1, 2	2	
		3	1,2	25%
marginally suitable	3	1, 2, 3	3	
		4	1,2	50%
not suitable	4	5	all	
		4	3	100%

To arrive at the assessment of the suitability of the various map units for the LUT extensive (semi-)nomadic grazing and browsing two additional land qualities are considered e.g. soil moisture availability and salinity/sodicity.

3.3.3. *Soil moisture availability*

The following land characteristics are used for the calculation of the soil moisture availability:

- rainfall (effective rainfall, infiltration minus run-off and evaporation)
- evaporation (from land and vegetation)
- waterholding capacity of the soil (soil depth, soil texture/ structure, pF values).

As no water balance studies were carried out, the ratings concern estimates of the various land characteristics in which extensive use was made of existing information on the agro-climatology in Kenya.
The soil moisture availability is subsequently expressed as the length of the growing period as follows:

Table 10: Ratings for the soil moisture availability.

Rating	Length of growing period (in days)
1	more than 150 days
2	100–150 days
3	60–100 days
4	40– 60 days
5	less than 40 days

Note that the occurrence of flooding has a positive effect on the soil moisture availability. The flooding, except for the Chalbi desert, is never so long that it inhibits plant growth completely. (Usually 2 to 6 weeks per year as a maximum). If flooding occurs the final rating will be upgraded with one class.

3.3.4. *Salinity/sodicity*

The land quality salinity/sodicity influences in a negative way the production of the vegetation. The composition of the vegetation will change as well: on saline soils halophytic plant species appear. This can be beneficial for the diet of the livestock, but even halophytic plants grow better in a non-saline environment.
Only highly tolerant plants can tolerate an ECe of more than 15 mmho/cm (U.S. Salinity Laboratory Staff, 1969). So, it is supposed 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 boundary criterium. However, in this area it was observed that roots penetrate layers with an ESP of 20 or more. The limit is therefore put at an ESP of 30. The influence of a very high salinity and/or sodicity is thus reflected in the soil moisture availability. In Table 11 the subratings and the ratings for the salinity and the sodicity are given.

Table 11: Ratings for the salinity and/or the sodicity of the soil.

Depth	ECe (mmho/cm)		E S P (%)	
Subrating	0–50 cm	50–100 cm	0–50 cm	50–100 cm
3	8–15	>15 or higher	10–15	>15 or higher

Table 2: (Contd.)

2	4–8	8–15	6–10	10–15
1		less than above		

Final rating	Sum of subratings
1	2, 3
2	4, 5
3	6

The land quality rating for some individual map units is presented in Table 12.

Table 12 Land quality rating for some individual land mapping units.

Land quality	Map Unit					
	MV1	HU	UV1/2	PsU1/2	LsVIP	LsV2
I) *Accessibility*						
cm (camels)	2-5	3-5	1	1	3	1
ct (cattle)	1-4	3-4	1	1	3	1
sg (sheep & goats)	1-3	1-3	1	1	1	1
II) *Resistence to erosion*						
cm & st & sg	2	3	1-2	1	1	1
Combined I & II						
cm	4	3-4	1-2	1	2	1
ct	2-3	3-4	1-2	1	2	1
sg	2-3	3	1-2	1	1	1
III) *Moisture availability*						
various l.q. (see text)	1	4	1	3	5	2
IV) *Salinity/Sodicity*						
salinity & sodicity	1	1	1	1	1	1

3.4. The conversion table

The conversion table is designed to specify the suitability classes for a particular land utilization type.
The conversion table shows the worst conditions that can be accepted within each class for each limitation (or land quality).
The adjudication of the class limits requires a detailed knowledge about the requirements of the land utilization type. This information is often not or only scanty available and the link between the suitability and the actual performance of the LUT is therefore more a qualitative than a quantitative one.

The conversion table for the LUT extensive, (semi-)nomadic grazing and browsing is given in Table 13.

Table 13: Conversion table for the land suitability classification for the land utilization type: Extensive nomadic to semi-nomadic grazing and browsing.

Suitability class	Rating accessibility and res. to erosion	Soil moisture availability	Salinity sodicity
1. highly	1	1, 2	1
suitable	2	1	1
2. moderately	1	1, 2, 3	2
	1	4	1
suitable	2	2	1, 2
	1,2	3	1
	3	1, 2	1
3. marginally	1, 2	3	2
suitable	1	5	1, 2
	1	4	2
	2	4, 5	1, 2
	3	1, 2	2
	3	3, 4, 5	1, 2
	4	1	1
4. unsuitable	1	5	3
	2	4	3
	4	all (except 4,1,1)	all

No conversion tables were constructed for the other two LUTs recognized in the area, viz. forest reserve/protected forest and small holder, rainfed mixed farming, traditional to intermediate technology.
To maintain the forest reserves a strict policy for their conservation is needed, otherwise other land uses may effect their existence in negative way. Forest reserves not only fulfil a crucial role as water catchment areas, but in addition preserve an unique collection of floral and faunal species, which on their turn attract researchers and tourists alike.
The LUT mixed farming can only be carried out if the growing period numbers at least 100 (consecutive) days. Consequently areas with sufficient moisture are concerned which coincide largely with the LUT mentioned above. In drier areas irrigation must be practised to obtain and sustain reasonable yields, also the application of fertilizer may be necessary.

3.5. The Land suitability classification

Matching the land use requirements with the land qualities (Table 12) by means of the conversion table (Table 13) leads to the land suitability classification of each tract of land. An example for a limited number of map units is outlined in Table 14.

Table 14: Matching land use with land; the suitability classification.

Map unit	Land	suitability classification for extensive grazing					
		S1	S2	S3		NS	Remarks
MV1	cm					x	too cold
	ct			x			
	sg			x			
HU	cm				x		
	ct				x		
	sg			x			
UV1/2	cm			x			too cold
	ct	x					
	sg	x					
PsU1/2	cm		x				
	ct		x				
	sg		x				
LsV1P	cm			x			
	ct			x			
	sg			x			
LsV2	cm	x					
	ct	x					
	sg	x					

As was explained a flexible approach was needed to accommodate the herd mixture (cm, ct and sg) with regard to the land accessibility.
With regard to the area as a whole, only the Chalbi Desert is considered unsuitable for all groups of animal species.
Regardless of the unsuitability of an area on the basis of the presented bio-physiographic data, it has been observed that the local people do sometimes use these areas for various reasons. On the other hand, highly suitable areas may not be used or are avoided. Often social, religious or safety reasons underlie these desicions.

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