Landforms and Soils of Turkana District, Kenya

A site evaluation for rangeland use

L. Touber

Report 41

(The Netherlands), 1991

Landforms and Soils of Turkana District, Kenya

Survey carried out for:
The Republic of Kenya; Ministry of Livestock Development, Range Management Handbook Project, G.T.Z., Nairobi, Kenya.

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ABSTRACT

Touber, L., 1990. Landforms and Soils of Turkana District, Kenya; a site evaluation for rangeland use. Wageningen (The Netherlands), The Winand Staring Centre. Report 41. 63 p.; 7 figs.; 6 tables; 1 map and legend; 3 annexes.

Within the framework of the Range Management Handbook Project, Kenya, an inventory has been carried out of landforms and soils of Turkana District at a scale of 1 : 1 000 000. It concerns a site evaluation for rangeland use, which is based on a limited amount of field observations, and relies heavily on visual interpretation of satellite imagery. The physical data of landforms and soils are interpreted for aspects of primary production (fertility and soil-water relationships) and for management aspects (erosion status and -hazard; accessibility for livestock; flooding hazard; possibilities for the construction of dams and waterpans). Attention is paid to local names (Turkana language) of landforms and soils.
Annex I deals with the organisational and logistic aspects.

Keywords: Kenya, Turkana District; Landforms, Soils, Range Management, Satellite image interpretation; vernacular soil names

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The WINAND STARING CENTRE is continuing the research of: Institute for Land and Water Management Research (ICW), Institute for Pesticide Research, Environment Division (IOB), Dorschkamp Research Institute for Forestry and Landscape Planning, Division of Landscape Planning (LB), and Soil Survey Institute (STIBOKA).

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CONTENTS

1 INTRODUCTION

The Range Management Handbook Project is a collaboration project between the Ministry of Livestock Development of Kenya and the German Organisation for Technical Cooperation (GTZ). It aims at the inventory of the potential for extensive rangeland use of the dry northern and northeastern regions of Kenya, through studies on climate, landforms, vegetation, soils and hydrological and socio-economic aspects.

It is the purpose to present the results of these inventories per District in the form of 1 : 1 million scale maps and their interpretation. Maps and reports should be easily intelligable to staff of the extension services and planning division of the Ministry of Livestock Development.

The Winand Staring Centre (formerly STIBOKA) already participated in the inventory of landforms and soils of Marsabit, Wajir, Mandera, Samburu, Baringo and Isiolo Districts. The present report deals with the landforms and soils of Turkana District. As was the case with former district surveys, the present one is based on satellite image interpretation and a restricted amount of field observations. Field checks were directed towards the assessment of range potential rather than towards the execution of a conventional "multi-purpose" soil survey. Hence it is preferred to use the term "Site evaluation for rangeland use" as subtitle for these land inventories.

Acknowledgements are contained in the mission report, Annex I.

2 METHODS

2.1 General

Survey methods have been described in a separate volume, dealing with the general approach to small-scale inventories of soil and vegetation resources in the context of the Range Management Handbook Project (Touber, 1988). Aspects of this methodology, as far as specific for the present survey, will be only dealt with here.

2.2 Materials

All existing previous studies concerning the area were consulted as much as possible during the interpretation of satellite imagery. These comprise mainly the Exploratory Soil Map of Kenya (Sombroek et al., 1982) and all available geological maps and reports. The literature list contains these publications. In the framework of rehabilitation projects in Turkana District, various resource surveys have been carried out recently (Adams, 1989; Amuyunzu, 1988; Ecosystems, 1985; Norconsult 1990).

When preparing field surveys, much emphasis is given to the interpretation of remote sensing material. Use was made of 1 : 500 000 scale Landsat Tematic Mapper images taken during the months July/August 1985 and 1986. A 1 : 500 000 scale map was drawn, showing landforms as interpreted from this satellite imagery. In addition to the rather outdated 1 : 250 000 scale topographic sheets of the Survey of Kenya, information on the location of oil company exploration lines was used.

2.3 Survey activities

Field survey took place in September and October 1990. The number of actual field survey days that were spent on field data gathering amounts to forty. A total of 150 observation points were established, at which points both the soil surveyor and the vegetation scientist recorded their data simultaneously. Apart from recording field data at these points, vegetation and soils were viewed while travelling between points. Fig. 1 gives these locations and a reliability diagram. It may be clear that not all landform/soil/vegetation types have been covered by field visits as one would judge necessary for a 100% reliable description. This is however inherent to the scale at which the Project operates, and not in conflict with the planned projects output, which calls for a general overview of the natural resources of each District.

The vegetation scientist interviewed local people, knowledgeable as to plant species and the performance of the rangeland. Vernacular soil and landform names were collected by the soil surveyor, using the same procedure.

During the survey two reconnaissance flights were made over the District, in order to view areas that were inaccessible.

2.4 Map and report preparation

Map and legend have been prepared according to the standard procedure as described in Volume I of the Handbook. The 1 : 500 000 scale satellite image interpretation map has been corrected and amended according to the field data. The final basic document is a landforms and soils map at scale 1 : 1000 000.

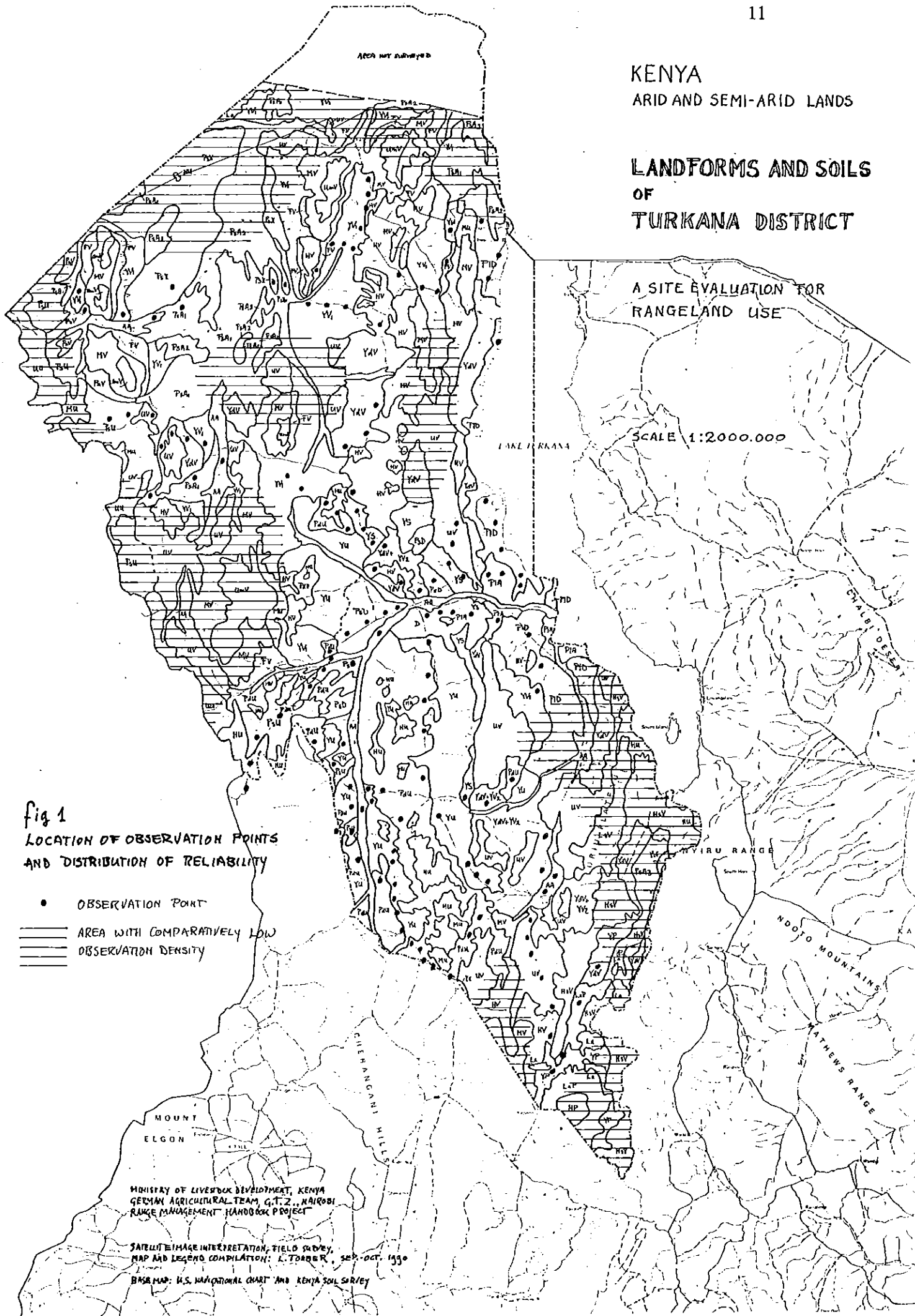


fig 1
LOCATION OF OBSERVATION POINTS
AND DISTRIBUTION OF RELIABILITY

- OBSERVATION POINT
- AREA WITH COMPARATIVELY LOW OBSERVATION DENSITY

3 SURVEY RESULTS

3.1 Summary of landforms, rock types and soils of Turkana District

The arid climate of northwestern Kenya is one of the dominating factors that have shaped and developed its landforms and soils.
Under arid circumstances, the so called physical weathering of rocks prevails; i.e. rocks are desintegrated by mechanical forces (heating, cooling; swelling, shrinking) rather than by chemical processes (solution, alteration of minerals). The latter play a much reduced role, due to lack of rains.
"Skeletal" soils prevail, i.e. soils that are rocky, shallow and stony and/or contain much gravel, sand and stones.
Strong and dry winds dominate under these climatic conditions. Going east, towards lake Turkana, wind erosion and deposition become increasingly important land characteristics. Dune formation takes place at present, and has happened in the past. Wind erosion has also contributed to the development of desert pavements. This concerns a relatively stable "end-stage" in erosion, which is easily attained on skeletal soils.

Tertiary volcanic rocks are most widespread in Turkana District. These rocks consist of hard erosion resistant basalts and the usually softer, stratified pyroclastic rocks (ashes, cinders). Metamorphic rocks of the Precambrian Basement System prevail in the southern half of the District, and along the Ugandan border.
An important part of the District is covered by unconsolidated sediments, which are partly lake deposits of a formerly much larger lake Turkana.
In these sedimentary areas, dune formation is a common feature.

The Landforms and Soil map (See Annex in folder) separates thirty one different types of land.

To summarize the physiography of the District the following major groups of landforms should be highlighted (See Fig. 2).

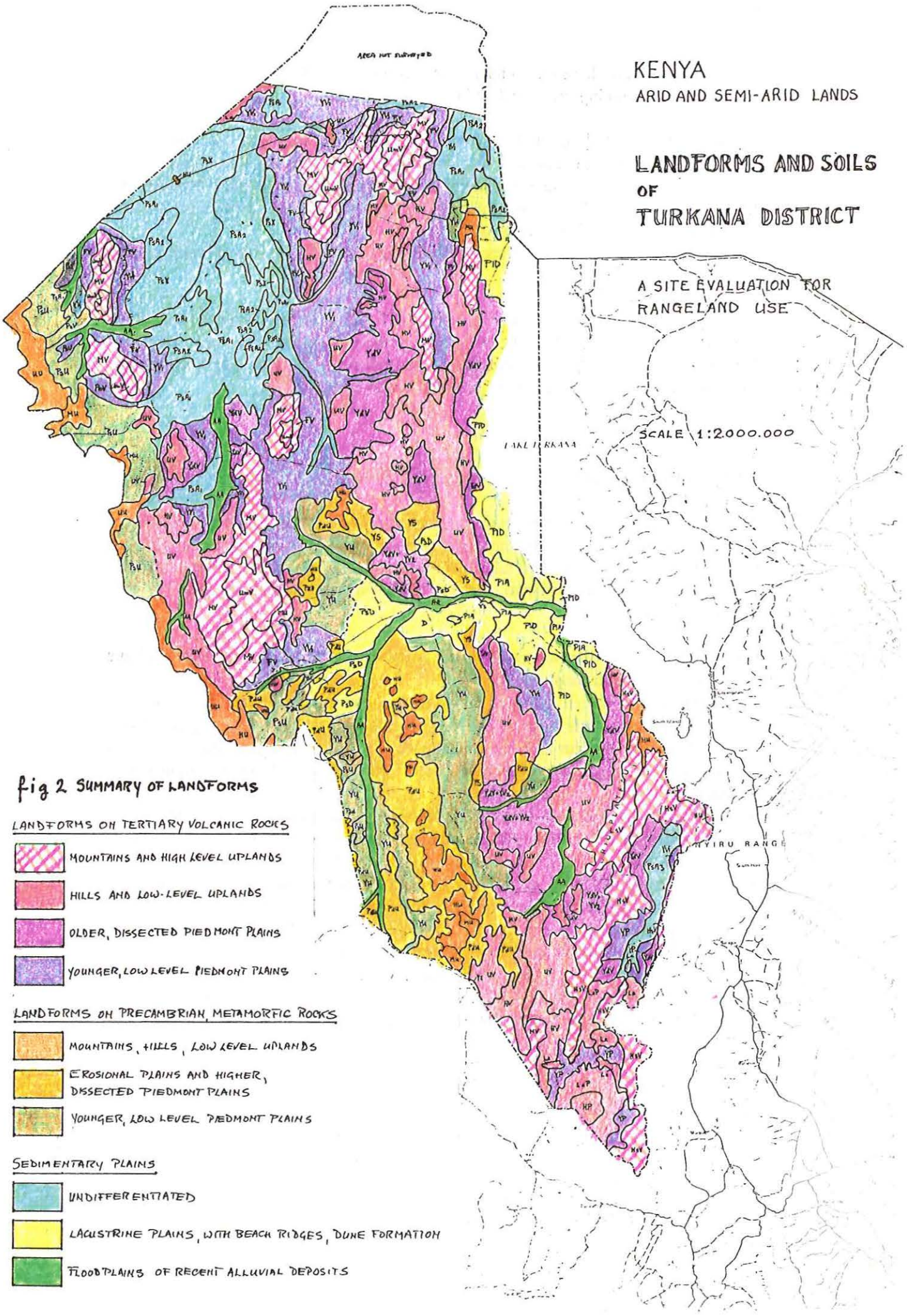
a. Mountains and high-level uplands developed on volcanic rocks.
b. Hills, uplands, dissected and non-dissected piedmont plains developed on volcanic rocks.
c. Hills, uplands, dissected and non-dissected piedmont plains developed on metamorphic rocks.
d. Sedimentary plains and floodplains.

a. Mountains, developed on Tertiary volcanic rocks, have a steep rugged topography with largely rocky and shallow soils (Mapping unit 2: MV). These contain part of the dry season grazing areas.
Within these mountain ranges, high-level uplands and top - regions are separated on the 1 : 1 000 000 scale map (Mapping unit 8: UmV). These are situated at an altitude of over 1200m, and fall mostly in a sub-humid (to semi-arid) climate zone. They are the most important dry season grazing areas, in somuch as they are accessible. The Loima Hills forest is included in this unit, but not typical of it. Open wooded and bushed grassland is more common.

b. Hills and uplands developed on a complex of basalts and partly unconsolidated pyroclastic rocks form a steep to rolling topography. The hills have mostly bare rocky and stony soils . The uplands have shorter and gentler slopes, exist mostly of unconsolidated ashes, with a dense surface layer of stones and gravel.
Around these hills and uplands extensive piedmont plains have formed. An important separation is to be made among these very long and gentle slopes: Older piedmont plains that have been subject to erosion and dissection, have a characteristic desert pavement, i.e. a cover of residual black basaltic gravel (mapping unit 12: YdV). These dissected piedmont plains, like the uplands and hills, show an almost bare surface, whereby all vegetation concentrates along the incised drainage lines.
The equally extensive lower level, younger piedmont plains bear shallow to moderately deep dark clay soils over unconsolidated pyroclastic volcanics (and/or older lake bed deposits). Here Acacia reficiens shrubland prevails, together with Duosperma dwarfshrubs.

c. An analogous sequence of landforms has developed in the Basement System rocks. Hills (Mapping unit 3: HU) have steep irregular slopes, that largely consist of rock outcrops. These hills are surrounded by piedmont plains and low uplands (Mapping unit 19: PdU) which are dissected by a dense network of numerous drainage lines. Soils are absent, or very shallow, over weathered rock, and have a surface layer of white angular quarts gravel ("desert pavement").
Also here the soils are (over large parts of the unit) practically devoid of vegetation, except for the shrubs and trees along the incised drainage lines.
Downslope of this dissected older surface, younger piedmont plains have developed at a lower level (Mapping unit 16: YU). These exist of deep sandy and loamy sediments, that support mostly a dwarfshrub vegetation (Indigofera) and that incidentally have the potential to support Sorghum shamba's in downslope position.

d. Large parts of Turkana District are occupied by almost flat extensive plains of sediments of various origin.
The Lotikipi plains contain the local drainage basin for most of the northem half of the District. The Tarach, Oropoi, Anam and many other rivers drain into these plains. However their waters (apart from the Tarach) normally do not reach the Lotikipi plains proper, but disappear in their own sediments. Sandy micaceous deposits associated with braiding river channels with scattered riverine woodland and shrubland form a large part of the plain (Mapping unit 22: PsA1 and 28:AA). The formation of riverine dunes is a characteristic feature there.


KENYA
ARID AND SEMI-ARID LANDS
LANDFORMS AND SOILS
OF
TURKANA DISTRICT
A SITE EVALUATION FOR
RANGELAND USE
SCALE 1:2.000.000
AREA NOT SURVEYED
LAKE TURKANA
NYIRU RANGE
fig 2 SUMMARY OF LANDFORMS
LANDFORMS ON TERTIARY VOLCANIC ROCKS
MOUNTAINS AND HIGH LEVEL UPLANDS
HILLS AND LOW-LEVEL UPLANDS
OLDER, DISSECTED PIEDMONT PLAINS
YOUNGER, LOW LEVEL PIEDMONT PLAINS
LANDFORMS ON PRECAMBRIAN, METAMORFIC ROCKS
MOUNTAINS, HILLS, LOW LEVEL UPLANDS
EROSIONAL PLAINS AND HIGHER, DISSECTED PIEDMONT PLAINS
YOUNGER, LOW LEVEL PIEDMONT PLAINS
SEDIMENTARY PLAINS
UNDIFFERENTIATED
LACUSTRINE PLAINS, WITH BEACH RIDGES, DUNE FORMATION
FLOODPLAINS OF RECENT ALLUVIAL DEPOSITS

Further downstream these river channels merge into a flat featureless plains, devoid of vegetation (Mapping unit 23: PsA2).

Around Lodwar and along the lake Turkana coast, as well as along the downstream part of the Kerio river, extensive flat plains have been formed by lake bed deposits. South east of Lodwar an extensive field of rather stable subrecent dunes (mapping unit 29: D) merges gradually into an area of active wind erosion and -deposition towards Lake Turkana and the Kerio river delta.
Old beach ridges and old mud flats are locally clearly recognisable (Mapping units 26 and 27: PlA and PlD).

Floodplain and low terrace riverine deposits are found along the major rivers. These exist of stratified, fine sandy and clayey micaceous sediments of high natural fertility. The permanently green strip of riverine Acacia woodland that it supports, features as a red ribbon along the river course on the satellite imagery.

3.2 Local landform and soil names and mapping units

As indicated in the chapter on methodology, data have been gathered at each observation point concerning the local herdsmens appreciation of the soil and vegetation type encountered. Also vernacular soil names were collected at each point and the Turkana word for the surrounding landform. These were listed against the mapping units in which the observation took place.

Unlike surveys in the northwestern Districts, it proved very difficult to correlate Turkana names with landform mapping units.
The problem encountered is largely due to an apparent incompatibility between these local terms and the scale of the survey. It appears as if the Turkana language has a wealth of terminology for rather minute, small extent, differences within land types that the exploratory surveyor otherwise would regard as a well defined, homogeneous landform.
A good example for this situation gives the higher level piedmont plains developed on volcanic rocks. These long and gentle slopes are covered by a blackish gravel or stone pavement, and are more or less strongly dissected by a dense drainage network. Turkana have various terms for the intensity and steepness of this incision, as this has an implication e.g. for the access for camels. Also the type of stoniness/gravelliness of the desert pavement has a variety of terms, that partly imply damage to hooves, or, on the contrary, an appreciated hoof - trimming function.
Thus, within the dissected, gravel covered piedmont plains, a number of Turkana landform terms were recorded. Of these some appeared to apply also to landforms, other than piedmont plains, such as dunes, slightly undulating plains, or even rather relief-rich uplands.

Table 1. Turkana landforms/soils terminology

MAJOR LANDFORM	Turkana landform name	Approximate meaning/translation
MOUNTAINS	Emoru	Mountain, hill
	Emoru ekokonyo	Black, stony mountains, hills
	Emoru lokoyen	Mountain-, hill slopes, too steep for cattle
	Ng'inya	Mountain range with dry season grazing
HILLS	Emoru	Steep, stony hill
	Ng'aukon	Hilly area, range of small hills
	Ng'aukon a ng'amor kirionok	-Do- of black rock ontcrops
	Aukot	One small, singular hill
	Aukot ataba	Kopje, koppie
	Ng'imor	Small, isolated hill, without dry season farge
	Epeta mugei	Hilly area, black stony slopes
UPLANDS (AND HILLY AREAS)	Ng'itela	Hilly, rolling uplands
	Ng'itela a ng'amor kirionok	-Do- of black rock ontcrops
	Epeta mugei	Black, stony undulating plain
	Ng' ikamukumukui	Undulating land, dissected upland
	Ng'achurro	Steeply dissected land
	Ng'ari	Rounded landforms
	Ng'ir	-Do- at smaller scale, shorter distances
DISSECTED ERIOSIONAL PLAINS; DISSECTED PIEDMONT PLAINS; DISSECTED PEDIMENTS	Ekitela	Raised, undulating area
	Ekitela ekokonyo	-Do- with gravelly surface
	Ekitela ngasinyono	-Do- with sandy ridges, dunes
	Ekitela a ng'acharra	-Do- with many gullies
	Ekitela a ng'akoges	-Do- with (rounded) gravel
	Ekitela a ng'amor	Upland with rock outcrops
	Ng'ikamukumukui	Undulating land (dune land)
	Ng'ikamukumukui a ng'akoges	-Do- with (rounded reddish) gravelly surface
PLAINS, SEDIMENTARY AREAS	Ng'aratin	Plain with small undulations
	Ng'aratin a ng'amor	-Do- with black rocky ontcrop
	Aro	Plain "where one can see far": flat extensive plain
	Aro nateleng	-Do- with ridges
	Aro asinyen	undulating sandy plain
	Kalapatan	Flat plain (synonimous with Aro) Locally: plain with wet season ponding
	Kalapatan aregai	Plain with Acacia reficiens shrubland
	Elapat	Flat area
	Apero	Flat area with raised land in distance
	Epokor	Sedimentary area
	Etupat	Rise; swale; where water drains away
	Ngatotin	Flat, sloping area
	Ngatotin ng'angasinyono	-Do- sandy

Table 1 (cont.)

MAJOR LANDFORM	Turkana landform name	Approximate meaning/translation
FLAT PLAINS, BOTTOMLANDS	Ng'ataparin	Flat area, dusty in dry season, ponded in wet season; "devil's lake", plain of mirages
SANDY AREAS	Ngasinyono	Sandy dune soils, sandy areas
	Ngakate leengoi	Sandy ridge, beach ridge

Table 2 Turkana names of land units/land types according to soil characteristics

Turkana names	Soil characteristics
Alup	Soil (general term)
Ng'arengaak	Reddish brown soil
Echoto	Black soil, clay soil
Alup ongora	Brown soil
Ng'arabat	Lava
Ng'amor	Stony, rocky, rock outcrop
Ng'atabab	Bouldery
Ng'akoges	Gravelly, stony
Ng'asinyono	Sandy
Kirionok	Black (of stones, rocks)
Ekokonyo	Black (of stones, rocks)
Apua	Dust, dusty
Lokhakungon	Hard stony surface
Echukule	Bare soil; no grazing; scaled surface

Table 3 Turkana (landform) names according to vegetation type, dominant species

Turkana names	Vegetation type
Amoni	Dense bushland
Aoi	Plain with tall, open Acacia tortilis woodland
Atir	Wooded bushland of young Acacia tortilis
Napetet	Alluvial/colluvial downslope fringe of piedmont plains dominated by Acacia nubica
Aregai	Plains dominated by Acacia reficiens

Obviously, and naturally, Turkana criteria for landform classification differ from those in use by the Kenya Soil Survey (KSS). But also, on the other hand, the KSS classification is difficult to apply to the volcanic landforms of the District, as for instance the separation between volcanic hills and uplands and between uplands and dissected plains seems arbitrary.

It is believed, that a clearer picture of the Turkana landform/soils categorisation may emerge in more detailed surveys, and by questioning more informants independently on the same locations.

In order to give an overview of terms recorded, Turkana words are listed according to major landform categories in the broadest sense. See tables 1, 2 and 3.

3.3 Evaluation of soil properties relevant to primary production and range management aspects

3.3.1 General

Methods of interpretation of data gathered, are contained in a separate volume (see Touber, 1988). The system followed is based on the Framework for Land Evaluation (FAO, 1987).

Which parameters play a role and how these data are interpreted is briefly summarized here.

Within a given climatic zone the availability of soil water and of nutrients are the land qualities that have a prevailing influence the primary production of rangelands. Land qualities that are related to aspects of management are erosion hazard, accessibility for livestock and possibilities for the construction of pans and dams.

In reality more parameters are of influence of course, but data on these are not obtainable in the context of the present site evaluation. The land qualities are rated in the following sections, in order to establish a comparison among the various mapping units. The figures given (ratings) do not pretend to have any absolute value or quantitative connotation.

3.3.2 Water availability

Soil moisture availability depends on the course of the rainfall /evaporation ratio through the seasons; the infiltration capacity of the surface soil; the available water capacity (AWC) of the soil material and the depth of the rooting zone.

We will use the term Water Holding Capacity here for the combined effect of the three main soil characteristics concerned: Infiltration capacity, AWC, and Rooting space.

Infiltration capacity depends on the porosity of the surface soil, which in turn is influenced by such parameters as soil texture, soil structure and organic matter content. Important is that the surface soil is not "sealed". This is the case on certain soil types that are "overutilized", and where due to too frequent grazing and trampling the vegetation cover, the organic matter content and hence structure stability and porosity have diminished. A low infiltration capacity causes (part of) the rainwater to runoff along the surface. This water will not become available to the vegetation on the soil where the rain falls.

Available water capacity is estimated according to its connection with the soil texture (see separate volume on methodology).

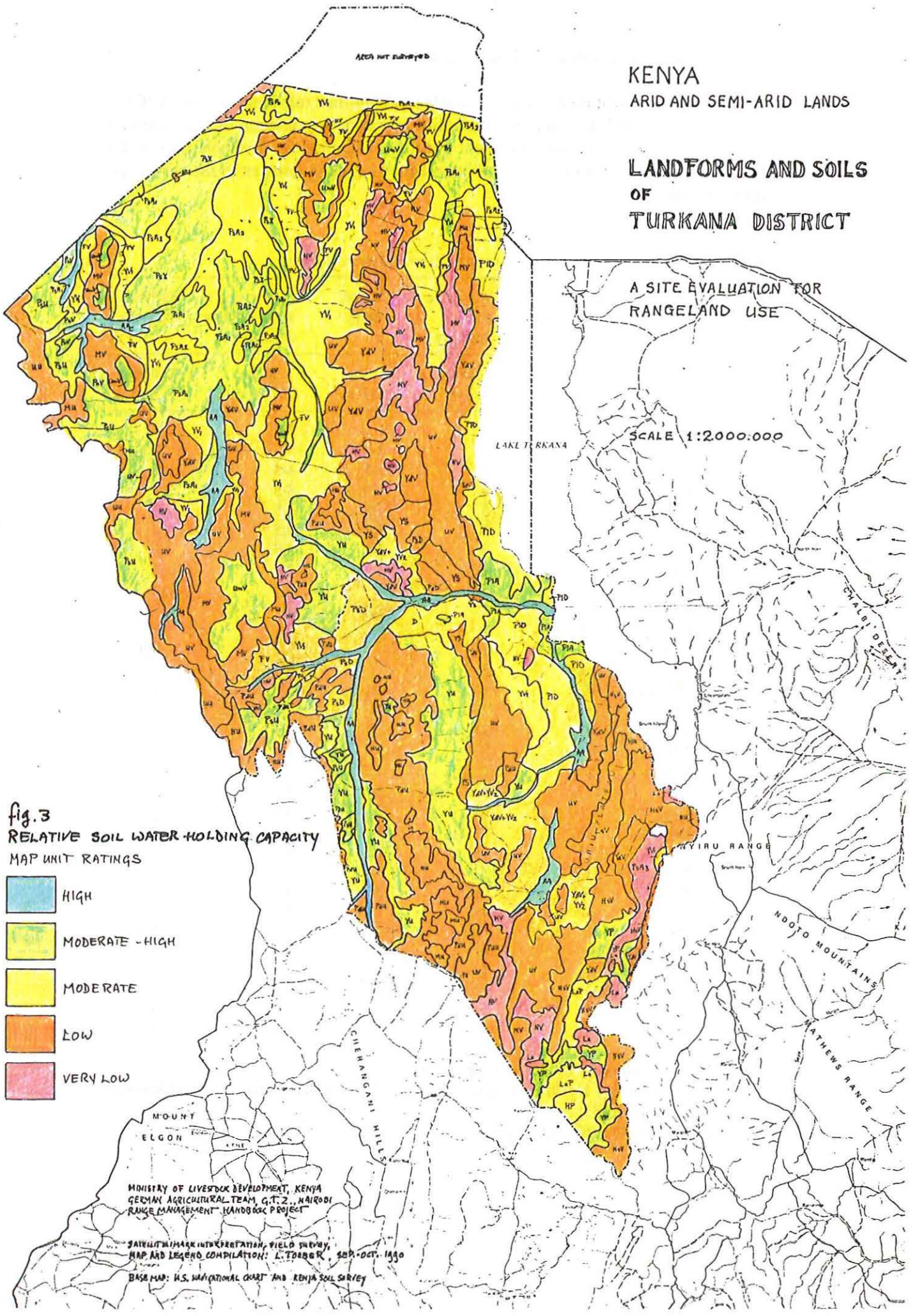
The depth of the rooting zone may be limited by shallow rocks or an abrupt change in texture or a change in chemical composition, such as a strong increase with depth in salinity or sodicity.

Table 4 gives a comparison among the mapping units concerning effective soil depth, available soil water capacity and eventual runoff losses. A combination of these is given as "final rating", of water holding capacity in a separate column. These ratings are expressed on the map of figure 3.

All mapping units with stony and rocky surface have been rated of low water holding capacity. These concern all Mountains, Hills, Plateaus, Uplands and dissected older Piedmont plains and Lava's. However, these rocky and stony areas may support, relatively speaking, in view of the extreme dry climatic conditions, yet an appreciable amount of vegetation: this is mainly due to a natural system of "water harvesting"; runoff water from the bare surface collects in drainage lines, rock crevasses and between boulders, where a good shrub vegetation can develop. Also, on stony surfaces perennial grasses may be protected from being extinguished under high grazing pressure conditions.

All landforms with sandy soils, wich do not recieve floodwaters from elsewhere are rated as moderate in water holding capacity: the low AWC (available water capacity) is counteracted favourably by good infiltration rates. A healthy, evenly distributed cover of Indigofera dwarfshrub is maintained.

A favourable rating has been attributed to landforms with good soil properties, and that also receive floodwaters from elsewhere (Mapping units 15 and 16: YP and YU; parts of 22: PsA1; 28: AA and the low component in 14: YdV + YV2).


KENYA
ARID AND SEMI-ARID LANDS
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TURKANA DISTRICT
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SCALE 1:2000.000
AREA NOT SURVEYED
LAKE TURKANA
CHALBI DESERT
NYIRU RANGE
NDOTO MOUNTAINS
MATHEWS RANGE
CHEHANGANI HILLS
MOUNT
ELGON
fig.3
RELATIVE SOIL WATER-HOLDING CAPACITY
MAP UNIT RATINGS
HIGH
MODERATE - HIGH
MODERATE
LOW
VERY LOW
MINISTRY OF LIVESTOCK DEVELOPMENT, KENYA
GERMAN AGRICULTURAL TEAM, G.T.Z., NAIROBI
RANGE MANAGEMENT HANDBOOK PROJECT
SATELLITE IMAGE INTERPRETATION, FIELD SURVEY,
MAP AND LEGEND COMPILATION: L. TOBBER, SEP.-OCT. 1990
BASE MAP: U.S. AERONAUTICAL CHART AND KENYA SOIL SURVEY

3.3.3 Soil chemical fertility; salinity; sodicity

The mineral composition of the soils can play an important role in identifying different types of range land. It is not so much differentiating in amounts of standing crop expected, but rather in mineral content (nutritive value) of the available forage. The last column in Table 4 presents a comparison of mapping units as to the richness in mineral content of the soils.

*Table 4 Rating of soil characteristics, relevant to productive capacity**

Unit no.	Mapping unit	Effective soil depth	Available water capacity	Runoff losses	Final rating water holding capacity	Richness in minerals
		1: large 5: small	1: high 5: low	1: low 5: high	1: high 5: low	1: high 5: low
1	MU	2-5	3	1	2-4	3
2	MV	3-5	3	2-4	3-5	2
3	HU	3-5	3	3-5	4-5	3
4	HV	5	3	2-4	4-5	2
5	HsV	4/5	3	4/5	4/5	2
6	HP	2/5	3	2/5	2/5	2
7	LsV	3/5	3	3/5	3/5	2
8	UmV	3	2	2	2	2
9	UV	5	3	4	4	2
10	UU	4	3	2-4	4	3
11	FV	2-3	3	2	3	2
12	YdV	3-4	3	3	3-5	2-3
13	YV_1	3-2	3	2	3	2
14	$YdV+YV_2$	4/3	3/2	3/1	5/2	3/2
15	YP	2	2	2	2	2
16	YU	2/1	3/1	3/1	3/1	3/1
17	YS	4	3	4	4	4
18	PnV	2	2	2	2	2-3
19	PdU	4	3	3	4	3
20	PsU	1	3	2	3-2	4
21	PsX_1	2	3	2	2	2
22	PsA_1	1/3	1/4	1	1/3	1/5
23	PsA_2	1(3)	3	3	3	2
24	PsA_3	1(5)	3(5)	3	5	5
25	PsD	1	4/2	1/4	3/4	3/4
26	PlA	1	4/2	2	2	3-2
27	PlD	2	4	1	3	3
28	AA	1	2	1	1	1
29	D	1	4	1	3	3
30	La	5	-	-	5	2
31	LaP	5/3	-/2	-/2	5/2	2

*) a) Figures connected by hyphen indicate a range of ratings;
b) Figures separated by ./. indicate ratings for different soil types within one unit in up- and downslope position respectively;
c) Figures between brackets represent inclusions.

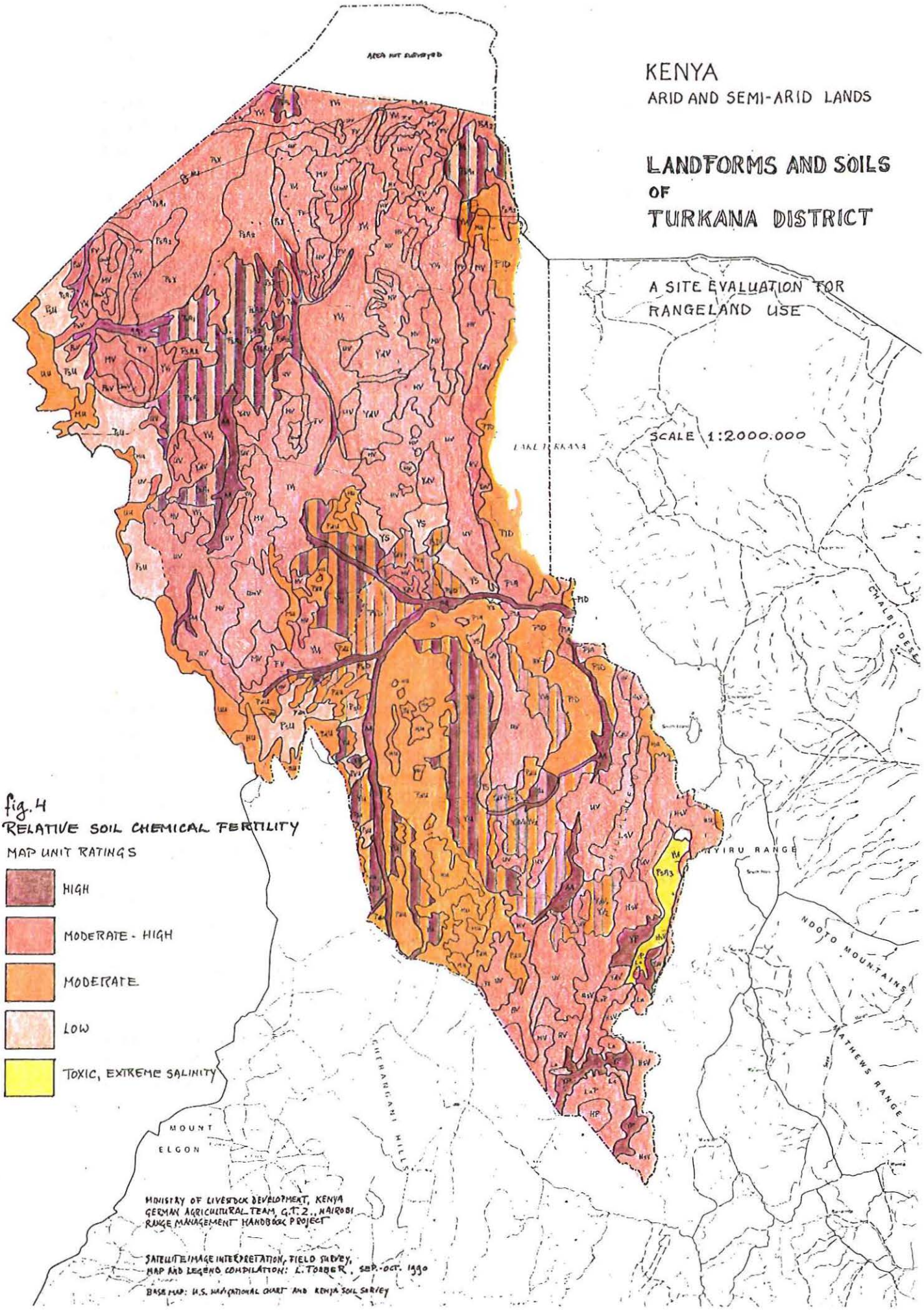

fig. 4
RELATIVE SOIL CHEMICAL FERTILITY

Restrictions in productive capacity of soils in arid and semi-arid areas, due to chemical properties, are posed by toxicity (salinity, sodicity), rather than by lack of certain minerals.

The Suguta valley bottom (Mapping unit 24: PsA3) has extremely saline soils: the surface is formed by a salt crust. Also parts of mapping unit 22: PsA1 have a very high salinity, revealed by stands of the salt-bush Salsola kali. High salinity has further been observed along the incisions of drainage lines in most older Piedmont plains: mapping units 12: YdV, 14: YdV+YV2, 17: YS and 19: PdU; and also locally in volcanic Uplands in the Lokori area (mapping unit 9: UV).

Ratings of relatively low chemical fertility have been attributed to mapping unit 17:YS and 20: PsU, because of the relatively poor mineral content of the soil parent material.

High chemical fertility is attributed to all soils developed on recently deposited alluvial material. These cases concern of course the riverine deposits of mapping units 28: AA, 22: PsA1 and the downslope component of unit 16: YU.

3.3.4 Erosion

As has been explained in the volume on methodologies, it is useful to give ratings of the three main types of erosion hazard. In addition, possibilities for recuperation of the vegetation cover should be estimated as this constitutes to some extent the resistance to erosion. Terminology, factors and criteria involved are discussed in the volume on methodologies.

Table 5 contains the conclusions for Turkana District.

The detachment, removal and transportation of soil particles is a characteristic feature of areas whith arid climatic conditions. In fact the arid climate is the cause of the vulnerability of soils to easy detachment: There is hardly a protective vegetation cover, and the soils have a very low level of organic matter in the topsoil. Both water and wind erosion and -deposition have been, and still are very active since the (semi-)arid climate prevailed, of course. At present, however, it is very difficult to establish criteria by which human induced accelerated erosion can be separated from erosion that takes place due to physiographically natural conditions.
Hence, there is no attempt made here to do such separation: the ratings in Table 5 and on Fig. 5 just indicate a relative "instability" of the land under present conditions.
Secondly, as a consequence of intense and long term erosion, several landforms are dominated by a stony or gravelly surface. This layer of gravels or stones has been residually concentrated at the surface as a consequence of the removal of finer particles by sheet and/or wind erosion. This process has advanced to the present state, at which no material can be removed any more: a "desert pavement" has formed. This, now, can be regarded as a stable "end-stage" of sheet- and wind erosion, as the impact of rainsplash has no effect; water and wind cannot remove any substantial amount of soil material. The gravelly/stony surface layer protects against further degradation.

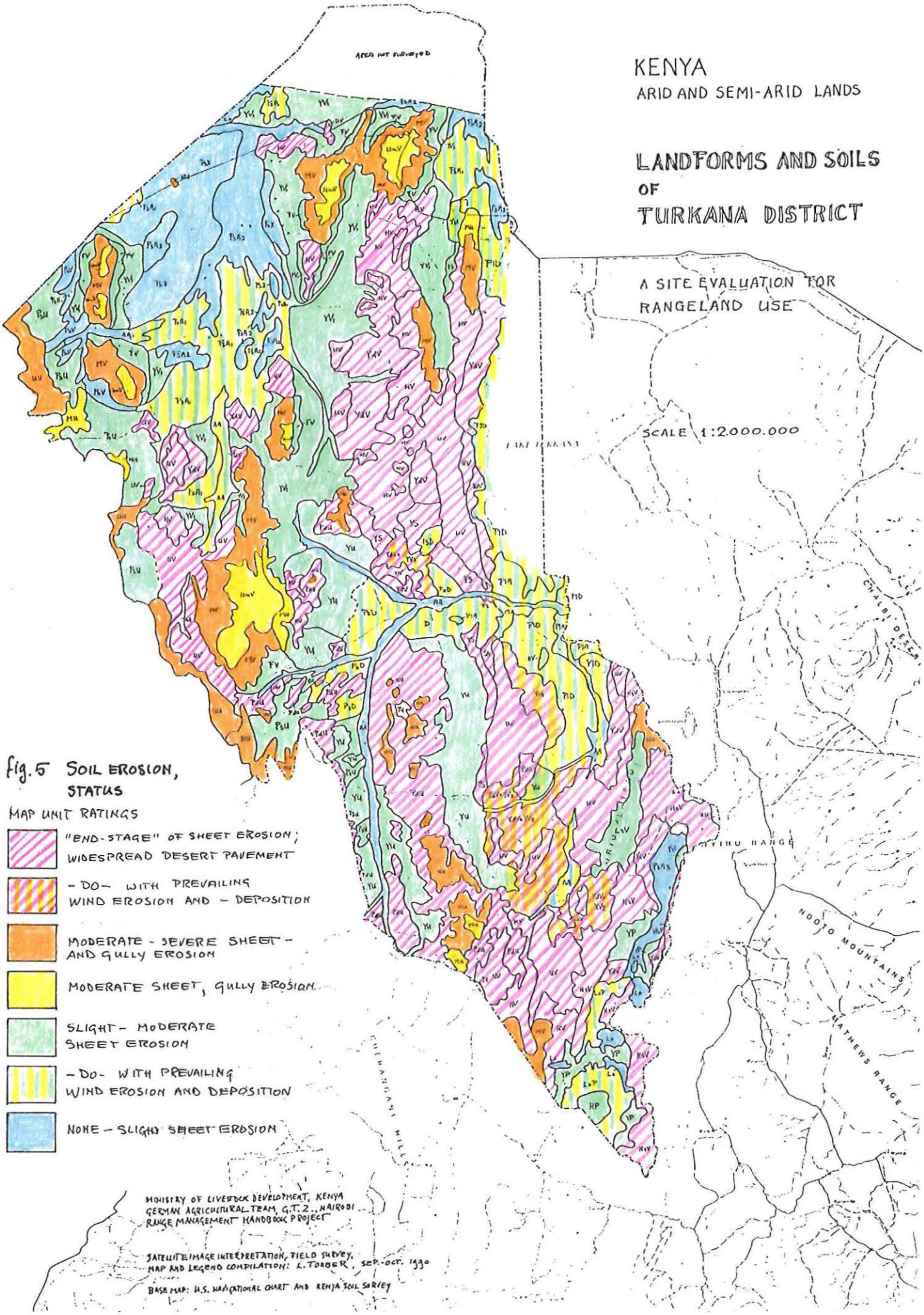
KENYA
ARID AND SEMI-ARID LANDS
LANDFORMS AND SOILS
OF
TURKANA DISTRICT
A SITE EVALUATION FOR
RANGELAND USE
SCALE 1:2.000.000
Fig. 5 SOIL EROSION, STATUS
MAP UNIT RATINGS
"END-STAGE" OF SHEET EROSION; WIDESPREAD DESERT PAVEMENT
- DO- WITH PREVAILING WIND EROSION AND - DEPOSITION
MODERATE - SEVERE SHEET - AND GULLY EROSION
MODERATE SHEET, GULLY EROSION
SLIGHT - MODERATE SHEET EROSION
- DO- WITH PREVAILING WIND EROSION AND DEPOSITION
NONE - SLIGHT SHEET EROSION
MOYIRO RANGE
NDOTO MOUNTAINS
MATHEWS RANGE
MINISTRY OF LIVESTOCK DEVELOPMENT, KENYA
GERMAN AGRICULTURAL TEAM, G.T.Z., NAIROBI
RANGE MANAGEMENT HANDBOOK PROJECT
SATELLITE IMAGE INTERPRETATION, FIELD SURVEY, MAP AND LEGEND COMPILATION: L. TORBER, SEP.-OCT. 1990
BASE MAP: U.S. AERONAUTICAL CHART AND KENYA SOIL SURVEY

*Table 5 Rating forms of actual erosion**

Unit no.	Mapping unit	Sheet erosion 1: none,slight 5: severe	Gully erosion 1: none,slight 5: severe	Wind erosion + deposition 1: none, slight 5: severe	Possibilities for recuperation 1: good 5: poor	Final rating (see fig. 5) 1: slight (risk) 5: severe (risk)
1	MU	3	3	1	3	3
2	MV	4	4	1	2	4
3	HU	4	3	1	3	3-4
4	HV	E	2	1	5	E
5	HsV	4	2	1	3	3
6	HP	2	1/4	2	1/3	2/4
7	LsV	3	2	2	2	2
8	UmV	3	2	1	1	3
9	UV	E	2-3	1	5	E
10	UU	4	2	1	3	4
11	FV	3	2	1	1	2
12	YdV	E	2-3	2	4	E
13	YV_1	1-3	2	2	1	2
14	$YdV+YV_2$	E/2	3/1-2	2/3	4/1	E/2
15	YP	1-2	1/3	2	1	2
16	YU	3-4/1	1/2	2/1	2/1	2
17	YS	E/3	3/1	2	4	E/3
18	PnV	1	1	1	2	1
19	PdU	E/3-4	3/1	2	4	E/4
20	PsU	3	1	1/2	3-2	2
21	PsX_1	1	1	1/2	1	1
22	PsA_1	2	2	2-3	1	2
23	PsA_2	1	1	2	1	1
24	PsA_3	1	1	2	5	1
25	PsD	1/3	1	3-4	1/3	2/3
26	PlA	1	1	3	1	2
27	PlD	2	1/2	3-5	3	3-4
28	AA	1	2	2-3	1	2
29	D	2	1	2	1	2
30	La	-	-	-	-	-
31	LaP	2	-/1	2	1	-/2

*) A. Figures connected by hyphen indicate a range of ratings.
B. Figures separated by ./. indicate ratings for different soil types within one mapping unit, in up- and downslope position, respectively.
C. E = "End stage" of sheet erosion.

Most rainfall will disappear as runoff water towards drainage-lines. These are (partly because of this) deeply incised. Here, some active gully erosion can be observed, working its way in upstream direction.

"End-stage" of erosion has been indicated as a separate category in the ratings of this land quality: it is not relevant to give a rating such as "severely eroded" or "highly resistant to erosion", both of which qualifications would be applicable. This situation is indicated by an "E" in Table 5 and Fig. 5.

Areas of strong sheet erosion concern all mountains and steep hillslopes where the natural vegetation is removed (mapping units 2: MV; 3: HU; 5: HsV; and 10: UU).
A risk for further gully development is characteristic of most of the (older, high-level) piedmont plains: Mapping units 12: YdV; 13: YV1; 17: YS; and 19: PdU; and of course of areas of high relief (Mapping units 4: MV; parts of 6: HP; and 9:UV)

Relatively stable landforms as far as water erosion is concerned are most of the low relief mapping units: the (younger, low level) piedmont plains, the sedimentary plains, lacustrine plains and dune fields.

Wind erosion and -accumulation is a comparatively important feature in Turkana District. Deflation and the formation of sand ripples and small dunes is also characteristic and inherent to arid areas. Drought, strong winds and (soil)material suitable for wind transport (i.e. fine sand, loose, dry clay, volcanic ashes, etc.) are the three prerequisites for the process. These requirements are fully met in the area between Lodwar and Lake Turkana, along the Lake coast, the plains around the Kerio river, the Suguta valley, etc. Also in the case of wind erosion, it is impossible to identify to what extent the process has been enhanced by pastoralist landuse.
Wind erosion and deposition is presently highly active near the mouths of both the Turkwel and Kerio rivers, where older dunes are being eroded away by saltating sand, and new, low dunes are being formed. Also in mapping unit 22: PsA1 and locally along unit 28: AA (Kakuma) active dune formation takes place, out of freshly deposited fine sandy alluvium.

The rating "severe wind erosion" should be applied only for those situations where it is clear that primary production is being affected more than it used to be. This is possibly the case only where the re-establishment of Indigofera dwarfshrub cannot keep pace with the dynamics of deflation and accumulation, and where this situation is brought about by too frequent use of livestock.

3.3.5 Accessibility

Limitations in accessibility are determined by steepness of terrain forms and surface ruggedness, because of gullies and/or stones and boulders. Such conditions restrict livestock movements, limiting the daily "action radius" of herds and thus the actually available rangeland.
The less primary production per ha, the wider this action radius needs to be. This means that for example in a sub-humid ecozone a certain given stoniness (e.g. 30% cover of medium and large stones) is a less severe limitation as compared to the same stoniness cover in extreme, arid conditions.
With other words, accessibility is a land quality that "counts" more heavily under more arid conditions, as compared to conditions of milder climates. This aspect has not been taken into account in the present rating system.

Apart from such permanent, year round restrictions additional limitations to accessibility are posed during the wet season by flooding or ponding and/or stickiness/muddiness of the surface in certain areas. The ratings for these land characteristics are specified in the volume on methodology.

Areas of severely limited accessibility are largely confined to all mountainous and hilly landforms, including the high level uplands (mapping units 1 tm 8: MU, to UmV) and also the lava's (mapping units 30 and 31: La, LaP). Steep and long slopes, rocky and bouldery surfaces, deep gorges and cliffs confine the accessibility largely to old fixed routings of livestock tracks in these units.

Restrictions in accessibility on land of low relief is posed by gravelliness and stoniness of the surface and/or a dense network of more or less steeply incised drainage gullies. Gravelly surfaces are prominent in the dissected older piedmont plains and pediments (mapping units 12: YdV; 14: YdV+YV2; 17: YS and 19: PdU). In a number of cases this gravelliness was reported to cause damage to hooves of goats and cattle. Where gullies are steep-sided, camels are restricted in their progress.
Slight limitations have been attributed to units where active dune formation takes place and/or where a loose sandy surface prevails.

Additional wet season constraints due to flooding and ponding of large stretches of land, are mainly found in the northern half of the District.
The extensive drainage basin of the Tarach and Nanam rivers nearing the Kenya-Soudan border, features as a bottomland in the centre of the Lotikipi Plains. Flooding and ponding occur here in years of excessive rains. Seasonal flooding may happen only in the real swampy parts that this unit contains (a minor portion of mapping unit 23: PsA2).
Another extensively flooded area in periods of excessive rains is the bottom of the Suguta valley (mapping unit 24: PsA4)

Local ponding and muddiness of the surface during the wet season is found in extensive parts of the Lotikipi Plains. It concerns parts of unit 22: PsA1, most of unit 21: PsX; and all of unit 23: PsA2.
The lower level piedmont plains (mapping unit 13: YV1) are dominated by sticky and muddy surfaces and some local ponding. Muddiness in combination with surface stoniness is reportedly a factor in the cause of footrot.

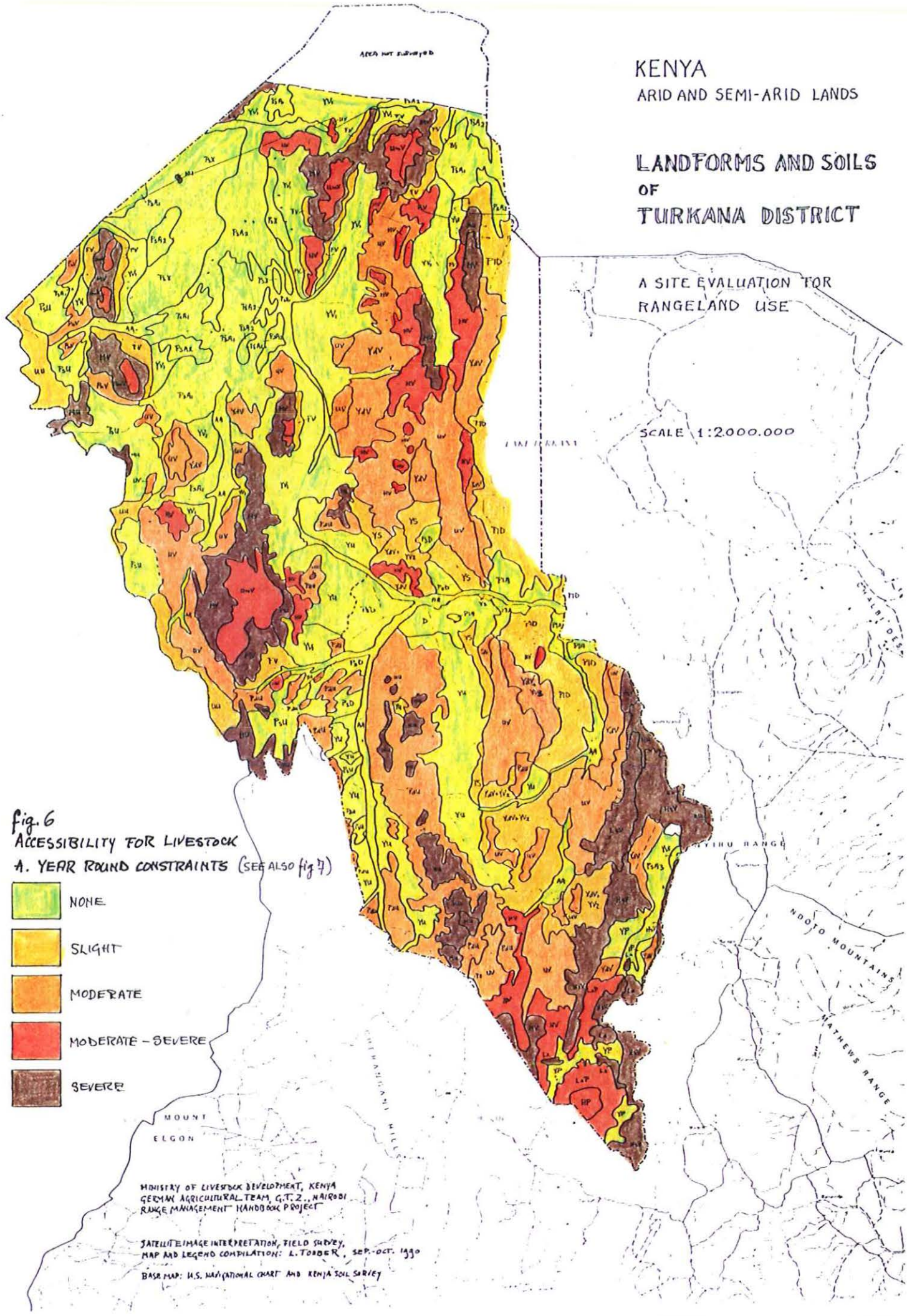
KENYA
ARID AND SEMI-ARID LANDS
LANDFORMS AND SOILS
OF
TURKANA DISTRICT
A SITE EVALUATION FOR
RANGELAND USE
SCALE 1:2000.000
Fig. 6
ACCESSIBILITY FOR LIVESTOCK
A. YEAR ROUND CONSTRAINTS (SEE ALSO fig 7)
NONE
SLIGHT
MODERATE
MODERATE - SEVERE
SEVERE
MOUNT
ELGON
MATHEWS RANGE
NDOTO MOUNTAINS
MINISTRY OF LIVESTOCK DEVELOPMENT, KENYA
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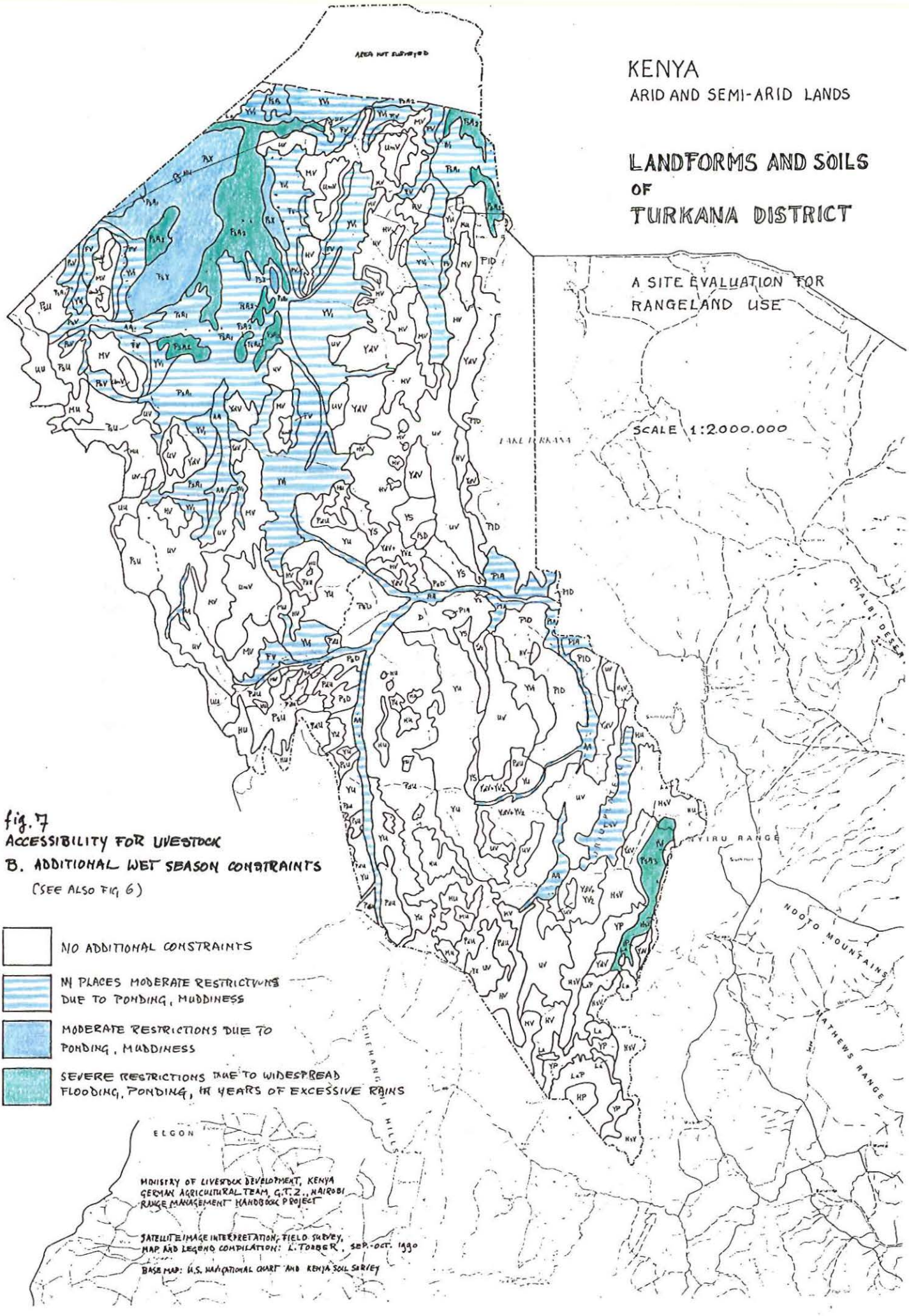
*Table 6 Ratings of limitations to accessibility**

Unit No.	Mapping unit	Constraints due to slope, topography 1: low 5: severe	Constraints due to surface rocks, sandiness, 1: low 5: severe	Permanent, year round constraints 1: low / 5: severe			Additional wet season constraints -: none 5: severe
				sheep/ goats	camel	cattle	
1	MU	4	3	3	4	5	-
2	MV	3	4	3	4	5	-
3	HU	4	3	3	4	5	-
4	HV	3	2	2	3	4	-
5	HsV	4	3	3	4	5	-
6	HP	1/4	1/3	1/3	2/5	2/5	-
7	LsV	1/5	4/5	2/5	4/5	5/5	3/-
8	UmV	3	3	2-3	4	4	-
9	UV	2	3	1	2	2/4	-
10	UU	2	2	1	2	2	-
11	FV	1	2	1	1	2	3/-
12	YdV	1-3	2-3	1	1-3	2-3	-
13	YV_1	1	2	1	1	1	3/-
14	YdV+YV2	2/1	2/1	1/2	1	2/3	-
15	YP	1	2	1	1	1	-
16	YU	1	1	1	1	1	-/(3)
17	YS	3/1	3/2	1	3/1	2	-
18	PnV	1	3	1	3	3	(3)
19	PdU	3/1	3	1/4	1/2	1/4	-
20	PsU	1	1	1	1	1	-
21	PsX	1	1	1	1	1	3
22	PsA_1	1	1	1	1	1	3/-
23	PsA_2	1	1	1	1	1	3-(5)
24	PsA_3	1	1	1	1	1	3-(5)
25	PsD	1	2	1	1	2	1/2
26	PlA	1	2	1	1	1	-/3
27	PlD	1	3	2	1	2	-
28	AA	1	1	1	1	1	(3)
29	D	1	2	1	1	1	-
30	La	3	5	3	4	5	-
31	LaP	3	2	2	2	4	-

* a. Figures connected by hyphen indicate a range of ratings;
b. Figures separated by ./. indicate ratings for different soil types within one unit, in up- and down slope position respectively;
c. Figures between brackets reflect situations expected in years of "above average" rainfall.


KENYA
ARID AND SEMI-ARID LANDS
LANDFORMS AND SOILS
OF
TURKANA DISTRICT
A SITE EVALUATION FOR
RANGELAND USE
SCALE 1:2.000.000
AREA NOT SURVEYED
LAKE TURKANA
CHALBI DESERT
NYIRU RANGE
NDOTO MOUNTAINS
MATHEWS RANGE
CHERANGANI HILLS
ELGON
fig. 7
ACCESSIBILITY FOR LIVESTOCK
B. ADDITIONAL WET SEASON CONSTRAINTS
(SEE ALSO FIG 6)
NO ADDITIONAL CONSTRAINTS
IN PLACES MODERATE RESTRICTIONS DUE TO PONDING, MUDDINESS
MODERATE RESTRICTIONS DUE TO PONDING, MUDDINESS
SEVERE RESTRICTIONS DUE TO WIDESPREAD FLOODING, PONDING, IN YEARS OF EXCESSIVE RAINS
MINISTRY OF LIVESTOCK DEVELOPMENT, KENYA
GERMAN AGRICULTURAL TEAM, G.T.Z., NAIROBI
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MAP AND LEGEND COMPILATION: L. TOBER, SEP.-OCT. 1990
BASE MAP: U.S. NAVIGATIONAL CHART AND KENYA SOIL SURVEY

3.4 Evaluation of soils and landforms for irrigated agriculture

It is a widespread belief that areas of the dry Northeastern parts of Kenya can be put into some kind of productive arable land, if only an irrigation infrastructure would materialize.

As the realisation of irrigation schemes involves considerable investments, the land mapping units will be evaluated here as to their suitability for (small scale) irrigation, in order to see whether such investments are justified. Requirements that are important in the suitability assessment of land for irrigated agriculture are:
- availability of sufficient irrigation water of suitable quality
- low levels of soil salinity, and the possibilities to prevent increased salinization by an effective drainage system.
- Soils of good water holding capacity, and which are otherwise suitable as arable land.

Another (most) important requirement is that the local population would be prepared and able to maintain and manage such irrigation schemes.

Soils should be non-saline and non-sodic. They should be sufficiently permeable to enable irrigation water to percolate through the soils, thus preventing a constant capillary rise (evaporation!). This would cause soil salinity in the rooting zone.

Land that has no obvious limitations to irrigation potential among their soil characteristics are: Mapping unit 11: FV; part of mapping unit 15:YP; the downslope component of 16: YU; mapping unit 18: PnV and 20: PsU; parts of 22: PsA1 and parts of mapping unit 28: AA.
In view of the restrictions in water availability it seems natural that the latter two mapping units (AA and PsA1) deserve further detailed surveying for the assessment of irrigation potential.
All other land is too steep and rocky (Mapping units 1-6: MU - HsP); have too shallow and/or too gravelly and stony soils (mapping units 7-10: LsV - UU; 12: YdV; parts of 14: YdV+YV2; 17: YS; 19: PdU; and 30: La); have too saline soils or have soils with a high risk to develop salinity under irrigation (mapping units 13: YV1; parts of 14: YdV+YV2; the upslope part of 16: YU; 17: YS; 21: PsX; 23: PsA2; and 24: PsA3) or have soils that are too sandy and permeable for irrigation practices (mapping units 29: D; 25-27: PsD-PlD; and parts of 22: PsA1 and of 28: AA)

4 MAPPING UNIT DESCRIPTIONS

Mapping unit 1: **MU**

Surface area: 702 km^2; 1.0% of the District.
Landform, relief: Mountains; long slopes, generally irregular, slope steepness over 30%; relief energy generally over 300 m.
Rock type, soil parent material: Undifferentiated metamorphic rocks; predominantly gneisses.
Soils: Well drained, shallow and deep, loamy sands to sandy clay loams of various colours, with frequent rock outcrops and pockets of well developed A-horizons.
Productive capacity: In general low, due to frequent rock outcrops, and generally shallow stony soils. Locally high, where deep soil pockets with well developed A-horizon occur. These have a good infiltration capacity and chemical fertility.
Erosion status/hazard: Rainfall runoff is a normal feature, inherent to this steep and rocky landform. Removal of natural woody vegetation has intensified this process. This has also marked consequences for the lower surrounding plains (mapping units 16: YU and 19: PdU).
Accessibility: Severe restrictions for cattle and camels due to steepness of topography and stoniness of the surface.
Obs.: Information inferred from similar landforms elsewhere, satellite imagery, and from survey flight.

Mapping unit 2: **MV.**

Surface area: 3229 km^2; 4.6% of the District.
Landform, relief: Mountains; long, steep, irregular slopes; generally over 30%; often of "escarpment"-like character.
Rock type, soil parent material: Undifferentiated Tertiary volcanic rocks, including basalts, rhyolites and pyroclastic rocks.
Soils: Well drained, shallow, very gravelly, stony and rocky, very friable clay loam of various colours.
Productive capacity: Very low due to the dominantly rocky and bouldery character of the land, with low soil moisture reserves.
Erosion status/hazard: Due to the steep and rocky landform, runoff and erosion is a natural feature. Soil material of this unit is sensitive to rainsplash impact. However, there is little soil left, that can be eroded: rocks and stones provide a protective cover for further severe erosion.
Accessibility: Severe restrictions for camels and cattle due to steepness and rockiness of the terrain.
Obs.: Information inferred from similar landforms elsewhere; and from reconnaissance flights.

Mapping unit 3: **HU.**

Surface area: 1334 km^2; 1.9% of the District.
Landform, relief: Singular isolated hills, or groups of hills and hill ranges. Steep, irregular slopes of variable %.
Rock type, soil parent material: Undifferentiated metamorphic rocks; mostly banded gneisses, poor to moderately rich in ferromagnesian minerals.
Soils: Well drained, shallow, rocky and stony, friable loamy sand to sandy clay loam, of various colour; locally over deeply weathered rock; locally with humus-rich top soils.
Local landform/soil name: Emoru ekokonyo (hills of dark stones); Emoru lokoyen (hills that are too steep for livestock).
Productive capacity: Mainly low, due to shallowness and consequently low water holding capacity of the soils; this is somewhat counteracted by a fair chemical fertility.
Erosion status/hazard: Soils are prone to strong sheet erosion. Runoff is high, mainly due to stoniness, rockiness and sealing of the soil surface.
Accessibility: Severe restrictions for camel and cattle due to steepness and stoniness.
Obs.: Information inferred from similar landforms elsewhere.

Mapping unit 4: **HV.**

Surface area: 2808 km^2; 4.0% of the District.
Landform, relief: Moderate, irregular slopes, with moderate to high relief energy in hill ranges.
Rock type, soil parent material: Undifferentiated Tertiary volcanic rocks, Basalts, Rhyolites and Pyroclastic rocks.
Soils: Well drained, very shallow, yellowish brown, friable, locally calcareous, extremely gravelly and stony clay loam to silty clay loam.
Local landform/soil name: Ng'amor mugeik (black, stony areas); Epeta mugei (hilly area, black stony slopes);Ng'aukon a ng'amor kirionok (black stony, hilly land).
Productive capacity: Mainly low, due to low water holding capacity (stoniness) and only moderate soil chemical fertility.
Erosion status/hazard: Over large areas, the surface exists of closely packed stones and gravel. This "desert pavement" can be regarded as an "end stage" of erosion; there is no soil left to be eroded away; elsewhere, deep gullying and/or slumping of unconsolidated pyroclastic rock is common. It is not clear to what extent these erosional processes are accelerated, human induced, or natural geomorphological features.
Accessibility: Moderate to severe restrictions to cattle; to certain extent to goats due to steepness, also due to damaging effects of stony surface to hooves.
Obs.: 10, 59, 109.

Mapping unit 5: **HsV.**

Surface area:2246 km^2; 3.2% of the District.
Landform, relief: Hills of the step-faulted Rift Valley escarpments (Suguta Valley). Complex of small, broken and tilted table lands, separated by scarps and steep valleys.
Rock type, soil parent material: Undifferentiated volcanic rocks: Basalts capping pyroclastic (tuffaceous) rocks with interbedded older lava's.
Soils: Predominantly well drained, very shallow, yellowish brown, rocky, stony and gravelly soils of clay to fine sandy clay loam texture, mostly strongly calcareous. On somewhat larger table lands also bouldery red clay.
Productive capacity: Low to moderate, due to very low water holding capacity, and in spite of a moderate to high mineral content.
Erosion status/hazard: Soils are shallow due to the predominant steepness of the landform. Rainsplash impact has little effect on the predominantly gravel covered soils.
Accessibility: Moderate restrictions for small stock; moderate to severe restrictions for cattle and camels.
Obs.: 110, 111.

Mapping unit 6: **HP**

Surface area: 140 km^2; 0.2% of the District.
Landform, relief: Volcanoes, cone-shaped hills; overall slope moderate; locally step-faulted; locally terraced due to lavaflow sequences; locally smooth slopes of ash deposits.
Rock type, soil parent material: Recent basalts (lavaflows), partly covered by pyroclastic material and ashes.
Soils: Complex of rock outcrops and somewhat excessively drained fine-gravelly sandy clay loams: soils comparable to parts of mapping unit 31:LaP, except for a higher humus content in the topsoils.
Productive capacity: Within this climatic zone these soils are (apart from the rock outcrops) of a comparatively high productivity due to a fair soil moisture storage, good infiltration capacity and high soil fertility.
Erosion status and hazard: Along major tracks soils may be deeply gullied. Erosion hazard depends largely on the soil texture (coarseness of Pyroclastic material) and slope, but is estimated as generally low, due to favourable infiltration capacities.
Accessibility: Moderate restrictions due to local steep slopes and rugged rocky terrain.
Obs.: Information inferred from satellite imagery and knowledge of similar landforms elsewhere.

Mapping unit 7: **LsV.**

Surface area: 562 km^2; 0.8% of the District.
Landform, relief: Step-faulted (Loriyu) plateau of gently undulating relief, broken by minor escarpments and steep gorges, in a N - S orientated pattern.

Rock type, soil parent material: Undifferentiated tertiary volcanic rocks, mainly basalts.
Soils: Association of:

1. Well to moderately well drained, shallow to moderately deep, yellowish brown to dark red, extremely stony and bouldery clay loam to clay. The deeper soils have a more or less dense cover of surface stones and boulders.
2. Rock outcrops.

Local landform/soil name:
Productive capacity: Low, due to shallowness, stoniness and rockiness. Locally moderate, where soils attain some depth.
Erosion status/hazard: On the almost flat to gently undulating plateau component, water erosion is negligible; the "end" stage of (sheet)erosion is reached on plateau rims and steep parts.
Accessibility: Severe restrictions due to the surrounding escarpments, only a few access roads to the flat top parts exist. On the plateau level itself fields of huge boulders are an additional severe restriction in access to grazing for most stock.
Obs.: Aerial survey flights; information inferred from satelite image and similar landform elsewhere.

Mapping unit 8: **UmV**.

Surface area: 1334 km^2; 1.9% of the District.
Landform, relief: Hilly upland areas in the summit regions of the larger mountain- and hill-ranges. Generally at an altitude of more than 1200m above sea level. Slopes of varying steepness; undulating to rolling and hilly relief.
Rock type, soil parent material: Undifferentiated tertiary volcanic rocks, basalts, trachytes and pyroclastic rocks.
Soils: Well drained, shallow to deep, dark reddish brown, gravelly and stony clay loam.
Local landform/soil name:
Productive capacity: This unit comprises the dry season grazing areas. It falls in a sub-humid climate zone. Dry season satelite imagery (Landsat Eosat) reveals a year round greenness of vegetation. Not regarding this climatic aspect, the soils are considered of moderate productive capacity due to good infiltration rates, moderate soil water holding capacity and chemical fertility, and relatively high organic matter in the top soil, insofar erosion has not degraded the land.
Erosion status/hazard: Overall rating for sheet erosion is assumed as moderate; gully erosion locally severe. The generally steep relief is a unfavourable factor, but this may be counteracted by other conditions, especially the higher organic matter content in the top soil, and a relative good vegetation cover. Erosion hazard is high, once the natural vegetation is affected
Accessibility:
Moderate restrictions due to steepness and stoniness, especially for cattle.
Obs.: Information inferred from survey flights and satellite images.

Mapping unit 9: **UV.**

Surface area: 7862 km^2; 11.2% of the district.
Landform, relief: Uplands of undulating to rolling, occasionally hilly relief. Mainly short, irregular or straight slopes. A dense drainage network prevails, that is deeply incised, so that lower slopes tend to be steep towards the drainage channel.
Rock type, soil parent material: Undifferentiated tertiary volcanic rocks; mainly (strongly tilted) strata of basalts, and less consolidated pyroclastic materials.
Soils: Well drained, very shallow, yellowish brown, calcareous, locally saline, extremely gravelly and stony clay loam, in many places with a desert-pavement surface.
Local landform/soil name: Ng'iri (small sized hills); Ng'ari (rounded, undulating land); Ng'ikamukumukui (undulating land, short abrupt slopes); Emunyen (soils of various colour); Kapèrperè (soft rocks of purple, bluish and white colours); Ng'aukon a ng'amor kirionok (hill range of black stones); Ng'itela a ng'amor kirionok (uplands of black stones); Ng'achurro (gullied land); Ng'acharra (land with steep gullies)
Productive capacity: Low to very low; very shallowness of the soils combined with high runoff rates render water holding capacity very low. Yet these areas are appreciated as wet season goat and camel areas, mainly due to the evergreen woody vegetation concentrated in drainage lines.
Erosion status/hazard: Largely the "end" stage of erosion has been reached: the resulted concentration of residual gravel at the surface acts as a protective layer against further deterioration. Locally gully erosion extends from drainage line incisions.
Accessibility: Locally the incised rainage lines are a severe limitation to camels and to a lesser extent for other livestock. Surface gravel, if very angular/sharp, may cause damage to hooves of goats and cattle.
Obs.: 39, 42, 46, 55, 76, 106, 107, 108.

Mapping unit 10: **UU.**

Surface area: 1123 km^2; 1.6% of the District
Landform, relief: Uplands.
Rock type, soil parent material: Undifferentiated metamorphic rocks.
Soils: Well drained, shallow to moderately deep, yellowish brown to yellowish red, gravelly and stony coarse sandy loam.
Obs.: No field data; no coverage by clear satellite image. Information derived from Sombroek et al (1981).

Mapping unit 11: **FV.**

Surface area: 1264 km^2; 1.8% of the District.
Landform, relief: Footslopes. Long, gentle, somewhat irregular slopes of 5 - 3%, at the foot of mountains and hills (both colluvial footslopes and pediments with shallow rock).
Rock type, soil parent material: Undifferentiated tertiary volcanic rocks and derived colluviated material.

Soils: Well drained, deep and shallow, dark reddish brown, calcareous, stony, clay loam and clay, in places saline.
Local landform/soil name: Agule arii; Agule emor (almost flat slope from mountain towards valley).
Productive capacity: Moderate.
Erosion status/hazard: Presently a moderate sheet erosion is observed; the overall rating for degradation is favourable. Hazard of gully erosion development is rather high, due to the position at the foot of steep hill masses, and the presence of layers of cracking clay in the subsoil of this unit.
Accessibility: No restrictions, except for locally stoniness which, during the rainy season, in combination with wet clay soils, can cause problems for goats and cattle.
Obs.: (68), 69, (77).

Mapping unit 12: **YdV**.

Surface area: 3510 km^2; 5.0% of the District.
Landform, relief: Piedmont plains, dissected by a more or less deeply incised drainage system. Overall slope extremely long and very gentle; due to incised local drainage lines with very short, convex, gentle to very steep slopes.
Rock type, soil parent material: Undifferentiated volcanic rocks (largely pyroclastic deposits with interbedded layers of basalt) and derived colluvium and alluvial deposits.
Soils: Well drained, shallow to moderately deep, dark reddish brown to dark grayish brown, calcareous, locally saline, very friable clay to loam, with a densely packed layer of residual gravel at the surface. Locally, at downslope position, extremely saline.
Local landform/soil name: Etupat (well drained land, where water flows off; good for rainy season settlement); Ekitela a ng'amor (stony upland); Ekitela a nachik (gravelly upland); Ng'aratin a ng'amor (plain, covered by black stones).
Productive capacity: Low, mainly due to a low water holding capacity as a consequence of rain water runoff, combined with unfavourable germination/rooting conditions for annual grasses.
Erosion status/hazard: The "end-stage" of sheet erosion has been reached, as the resulted concentration of residual stones and gravel at the surface acts as a protection against rain-splash impact. Drainage lines show active stream-bank erosion. Some gully erosion develops from these drainage lines.
Accessibility: No restrictions, except where drainage lines are too deeply incised; in these cases camels are restricted in their movement. Locally sharp gravel may cause damages to hooves of cattle and sheep.
Obs.: 9, 43, 44, 45, 47, 75, (77), (81).

Mapping unit 13: **YV1.**

Surface area: 7301 km^2; 10,4% of the District.
Landform, relief: Piedmont plain; extremely long, very gentle to almost flat slopes, with locally very gently undulating relief.
Rock type, soil parent material: Colluvium and alluvium derived from undifferentated volcanic materials, mainly (water lain?) pyroclastic rocks and thin basalt layers.
Soils: Moderately well to imperfectly drained, moderately deep to deep, very dark grayish brown to dark brown, firm, strongly calcareous, locally saline, gravelly clay loam over heavy clay, probably strongly sodic in the deeper subsoil.
Local landform/soil name: Aro; Kalapatan (plain "where one can see far"); Agule arii (slope between mountains and plains); Ng'atotin; Nikalapatan (plain where water is stagnant); Etupat (higher ground between stream channels, relatively good for wet season manyatta settlement); Amoni (dense shrub land); Nasurkeny (area "of many birds" in rainy season).
Productive capacity: Moderate; good infiltration conditions combined with low to moderate water holding capacity and moderate soil fertility.
Erosion status/hazard: No obvious signs of present sheet or gully erosion have been observed. However the soils have conditions for a rapid and deep gully erosion development. A slight wind erosion takes place; this is inherent to the hot and dry climate.
Accessibility: No restrictions; in the wet season goats and cattle experience limitations: the combination of sharp gravel and moist clay may cause hoof-damage and footrot.
Obs.: 16, 17, 48, 60, 61, 62, 63, 64, 66, 68, 72, 73, 74.

Mapping unit 14: **YdV+YV2.**

Surface area: 2036 km^2; 2.9% of the District.
Landform, relief: Association of dissected, higher level piedmont plains (as in mapping unit 12: YdV) and non dissected lower level piedmont plains of low and almost flat relief, locally with dune formation (YV2 component).
Rock type, soil parent material: Undifferentiated volcanic rocks and mainly alluvial sediments (YV2 component) that are partly wind blown and probably enriched with volcanic ashes (Kerio river sediments and Suguta valley deposits).
Soils: Association of:
1. soils as described under mapping unit 12: YdV
2. Well drained, very deep, pale brown, very friable to loose, saline, fine sandy loam.

Local landform/soil name: YdV-component: Epeta muge (plain with black stones); YV2-component: Aro (plain, "where one can see far").
Productive capacity: Extremely low on the dissected older piedmont plains, due to the desert pavement (closed gravelly - stony surface layer) and its generally high salinity (and probably sodicity). The vegetation occurs only along drainage lines.
The lower fine-sandy component has a moderate to high water holding capacity and high chemical fertility. It supports a variety of vegetation types, among others due to numerous drainage lines present.

Erosion status/hazard: The upper component has reached the "end stage" of sheet erosion. Rainwater runoff is of course an important continuing process. The lower component suffers locally from stream-bank erosion and a slight to moderate wind erosion.This is however a normal natural feature that fits in the climatic/geologic environment.
Accessibility: Locally the presence of loose, windblown sediments in the second component poses a constraint in accessibility, especially in the end of the dry season.
Obs.: (32), 104, 105.

Mapping unit 15: **YP**

Surface area: 702 km^2; 1.0% of the District.
Landform, relief: Piedmont plain. Long gentle slopes, partly terraced due to underlying lavaflows. Locally badland topography due to advanced gully erosion.
Rock type, soil parent material: Subrecent volcanic ashes, partly redeposited by alluvial processes.
Soils: Well drained, very deep, very friable, strong brown (calcareous) fine-gravelly coarse sandy clay loam, locally stony and coarse-gravelly.
Productive capacity: High, due to favourable infiltration, moisture storage and high chemical fertility.
Erosion status/hazard: Locally the area shows a badland topography. However, these concern stabilized gullies. Sheetwash erosion is widespread, in spite of the good infiltration.
Accessibility: No restrictions.
Obs.:

Mapping unit 16: **YU.**

Surface area: 4072 km^2; 5.8% of the District.
Landform, relief: Piedmont plain, very gentle to almost flat, very long slopes, with numerous parallel drainage lines. These are more or less deeply incised in the upslope parts of the piedmont plain.
Rock type, soil parent material: Colluvial and alluvial deposits derived from undifferentiated metamorphic rocks.
Soils: Complex of:
1. Well drained, very deep, yellowish brown, compact sandy clay loam; in places calcareous, saline, and/or sodic; with a fine gravelly surface layer.
2. Well drained, very deep, brown to dark brown, loose to very friable, stratified loamy sand to sandy clay loam, in places calcareous.
The second component occurs mostly in a downslope position in relation to the first. Also the stratified "younger" deposits dominate the southern part of the unit, while the "older" compact sandy loams are more common towards the north.
Local landform/soil name: Epokor (sandy area, many gullies); Asinyonoit (coarse sands); Ngatotin ngangasinyono (flat, tilted sandy plain); Ngasinyono (sandy area); In downslope parts :Napetet (land of Acacia nubica shrubs).

Productive capacity: 1. soils of the first component have a low productive capacity, due to reduced moisture storage as a consequence of soil sealing. Vegetation is mostly scattered dwarfshrubs (Indigofera).
The 2nd component has a high productive capacity, due to its good infiltration conditions and high chemical fertility. The unit also receives runoff water from elsewhere. The latter component is locally used for opportunistic sorghum cultivation. [Alup nganyangayek (dusty soil)]
Erosion status/hazard: The first component suffers a moderate to strong sheet erosion. The second "younger" component is subject to some slight wind erosion.
Accessibility: There occurs locally some flooding in the 2nd, lower, component of the unit.
Obs.: 78, 93, 98, 100, 101, 120, 121, 122, 128, 132, 133, 138, 139, 142.

Mapping unit 17: **YS.**

Surface area: 913 km^2; 1.3% of the District.
Landform, relief: Piedmont plain: long, very gentle overall slope, that is intricately dissected in the upslope parts, and shows an undulating meso-topography of short convex slopes.
Rock type, soil parent material: Turkana grits, i.e. early Tertiary sandstones and conglomerates. These are formed before the volcanic activities took place and are composed of sediments derived from metamorphic rocks.
Soils: Well to moderately well drained, very shallow to deep, pale brown to yellowish brown, calcareous, extremely gravelly clay to loam; with a pink coloured quartz-gravel pavement on the surface; in places extremely saline.
Local landform/soil name: Ekitela ekokonyo (upland, well drained undulating plain of rough surface, with gravelly, stony surface); Ekitela a ng'acharra (raised land with many gullies); Ng'ikamukumukui a ng'akoges (undulating area with pink gravels); Ekitela a ng'akoges (plain, raised land, with pink gravels)
Productive capacity: Very low, due to very low soil moisture storage (runoff losses) and low chemical fertility.
Erosion status/hazard: The higher areas (up-slope areas) have reached an "end stage", where the land is capped by a firm desert pavement and dissected by numerous gullies. However, in a position lower down slope sheet erosion is a strong and ongoing process.
Accessibility: In the strongly dissected parts of this unit, the drainage incisions are a limitation to the access of camels.
Obs.: 12, (29), 33, 40, 41.

Mapping unit 18: **PnV**

Surface area: 421 km^2; 0.6% of the District.
Landform, relief: Volcanic plain, non dissected, almost flat.
Rock type, soil parent material: Undifferentiated volcanic rocks, mainly basalts.
Soils: Moderately well drained, moderately deep, greyish brown, calcareous, firm, stony and bouldery clay.

Productive capacity: Moderate to high, due to a moderate water holding capacity and moderate soil chemical fertility.
Erosion status/hazard: Sheet erosion hardly takes place due to the almost flat topography in combination with the clay soil.
Accessibility: Surface stones and boulders are the cause of moderate restrictions for camel and cattle. In the wet season stickiness and muddiness of the surface is an additional constraint.
Obs.: Information inferred from geological maps (Walsh and Dodson, 1969) and satellite imagery.

Mapping unit 19: **PdU.**

Surface area: 2948 km^2; 4.2% of the District.
Landform, relief:Intricately dissected erosional plain (peneplain or piedmont plain). Overall slope is very gentle to gently undulating. The meso-topography is rolling to undulating due to the deep incisions of the densely distributed drainage system.
Rock type, soil parent material: Undifferentiated metamorphic rocks, mainly gneisses, moderately rich in ferromagnesian minerals (quartz-biotite and hornblende gneisses)
Soils: Well drained, very shallow, yellowish red to dark brown, gravelly loamy coarse sand to coarse sandy clay loam, in places calcareous and saline, and with an extremely gravelly surface of angular quartz.
Local landform/soil name: Ekitela lokhakungon (upland of hard ground); Ekwakwa (where plants easily germinate, mixture of stones and soil); Ngitela a ng'amor (uplands with stones).
Productive capacity: Low, due to a very low moisture storage. This is slightly counteracted by a moderate soil chemical fertility. The area produces a short lived wet season grazing, and reportedly a perennially good browse, which almost exclusively occurs in and along drainage lines.
Erosion status/hazard: The "end stage" of sheet erosion has been reached. There is little soil material left to be eroded away. Runoff percentage of rainfall is high; the drainage line gullies are being deepened and are extending.
Accessibility: Steep drainage incisions are locally a limitation to camels. The angular quartz gravel causes damage to hooves of cattle and goats.
Obs.: 13, 15, 22, 89, 90, 94, 95, 96, 97, 123, 124, 126, 127, 129, 130, 131, 135, 136.

Mapping unit 20: **PsU.**

Surface area: 2668 km^2; 3.8% of the District.
Landform, relief: Sedimentary plain, almost flat to very gently undulating. Locally a gently undulating meso-topography, due to subrecent dune formation.
Rock type, soil parent material: Strongly weathered older sediments (probably Pleistocene or older), derived mainly from undifferentiated metamorphic rocks.
Soils: Well drained, very deep, dark reddish brown, compact, sandy clay loam,with a friable to coarse sandy loam top soil.

Local landform/soil name: Amoni (dense bush, productive land); Alup ng'arengaak (reddish brown soil); Ekitela aregai (undulating plain of Acacia reficiens, i.e. bad, unproductive soil); Aregai ng'akalapatan (plain of Acacia reficiens bush); Alup ongora (brown soil)
Productive capacity: Moderate to low, due to runoff losses of rain water (surface sealing) and a low soil chemical fertility.
Erosion status/hazard: Soil sealing and runoff are wide spread, but of moderate intensity. Locally some wind erosion.
Accessibility: No restrictions (apart from dense Acacia reficiens bush, and bush-thicket with numerous Euphorbia species).
Obs.: 25, 54, 83, (91, 92), (141)

Mapping unit 21: **PsX.**

Surface area: 2457 km^2; 3.5% of the District.
Landform, relief: Almost flat, extensive, sedimentary plain.
Rock type, soil parent material: Mostly clayey sediments, derived from both undifferentiated volcanic and metamorphic rocks.
Soils: Imperfectly drained, very deep, drak brown, calcareous, saline and sodic, friable to firm clay.
Local landform/soil name: Aro= Kalapatan (flat plain); Echoto (clay soil); Ekitela (very gently undulating plain).
Productive capacity: The almost flat topography combined with good infiltration conditions and moderate to high soil chemical fertility render the productive capacity relatively high within this climatic zone.
Erosion status/hazard: Little or no erosion takes place.
Accessibility: No restrictions, except in the wet season, when the area is locally ponded. This is reportedly no restriction to wet season grazing, however.
Obs.: 49, (71) and information derived from Sombroek et al.,(1981).

Mapping unit 22: **PsA1.**

Surface area: 3931 km^2; 5.6% of the District.
Landform, relief: Sedimentary plain, almost flat, with (subrecent) braiding river channels and recent dunes of various size.
Rock type, soil parent material: (Sub)recent sandy and clayey riverine alluvium.
Soils: Well drained, very deep, pale brown to dark brown, stratified micaceous fine sand to fine sandy loam, locally calcareous, saline and sodic in the deeper subsoil.
Local landform/soil name: Atoot (yearly flooded area of many river channels, with Asinyen = sandy, stratified soils); Epokor (as Atoot, but higher ground, not flooded, and with frequent riverine dunes, and lacking groundwater supply in the dry season); Etupat (rise between river channels)

Productive capacity: Varying, but in general high: due to a high chemical fertility, a moderate to high water holding capacity, and due to occasional floodwaters that reach the area. The unit contains land that is suitable for micro catchment constructions and suitable patches of land for sorghum shamba's.
Erosion status/hazard: Winderosion and -deposition, and streambank erosion are natural features in this unit.
Accessibility: Occasional slight restrictions due to steep streambanks and/or loose sandy surface. Wet season flooding may pose locally some restrictions of short duration.
Obs.: 56, 57, 67,

Inclusion: Locally extremely saline soil conditions are encountered in the valleys south west of Kakuma. These have a very low productive capacity, are subject to strong sheet-, gully- and wind erosion, and should be excluded from micro-catchment construction activities.

Mapping unit 23: **PsA2.**

Surface area: 2527 km^2; 3.6% of the District.
Landform, relief: Sedimentary plain, flat riverine drainage basin of the Lotikipi plains
Rock type, soil parent material: Subrecent clayey alluvium.
Soils: Imperfectly to poorly drained, very deep, dark brown, calcareous, saline and sodic, firm clay loam; locally cracking clay. Locally flooded. Ponded only in years of excessive rainfall.
Local landform/soil name: Alaireng; Ngataparin (flat area, dark soil, where water collects).
Productive capacity: Apparently very low, judging from the lack of vegetation. It is not understood why this area appears as one large plain of bare ground.
Erosion hazard: None.
Accessibility: Inaccessible when flooded/ponded.
Obs.: 70, no sufficient data.

Inclusions: local semi-permanent swamps are included in this unit.

Mapping unit 24: **PsA3.**

Surface area: 491 km^2; 0.7% of the District.
Landform, relief: Sedimentary plain, almost flat bottomland of the Suguta Valley.
Rock type, soil parent material: Alluvial and lake-bed deposits derived from recent and subrecent volcanic sources.
Soils: Imperfectly to poorly drained, very deep, olive brown, extremely saline, sodic and calcareous silt loam to clay, with a salt crust at the surface.
Productive capacity: None, due to toxic levels of salt concentration and sodicity.
Erosion: None.
Accessibility: Inaccessible in wet season due to ponding/flooding.
Obs.: Information inferred from survey flight and derived from Sombroek et al.(1981).

Mapping unit 25: **PsD**.

Surface area: 1053km^2; 1.5% of the District.
Landform, relief: Sedimentary plain, very gently undulating, with an undulating meso-topography of low dune ridges.
Rock type, soil parent material: Older alluvium and sub-recent wind blown deposits.
Soils: According to meso-topography an association of 1: dune ridges (accumulation), and 2: dune valleys (deflation):

1. Somewhat excessively drained, very deep, pale brown to brown, loose loamy sand to sand.
2. Imperfectly drained, very deep, brown to dark brown, friable to compact, calcareous and saline sandy loam with a bare, strongly sealed surface.

Local landform/soil name: Nateleng (undulating plain); Aro ekitela (plain with small undulations); Aregai aro (plain of Acacia reficiens bushland); Aro nateleng (plain with tall ridges).
Productive capacity: Lower component (2) is unproductive due to the strong surface sealing and runoff (see also Hemming and Trapnell, 1957). The dune ridges have a high infiltration rate, but low water holding capacity. These support a steady cover of Indigofera dwarfshrub.
Erosion status/hazard: Wind erosion and deposition is a natural feature, inherent to the climate and this landform. Sealing and sheet erosion in the valleys between the ridges should not be regarded as a human induced degradation.
Accessibility: No restrictions, or temporary slight restrictions in the wet season due to local ponding.
Obs.: 18, 19, 20, 21, 26, 28.

Mapping unit 26: **PlA**.

Surface area: 562km^2; 0.8 % of the District.
Landform, relief: Almost flat lake bed terrace (lacustrine plain), locally with meso-topography of small dune ridges, and extensive flat bottomlands, devoid of vegetation.
Rock type, soil parent material: Fine sandy, silty and loamy lake bed deposits.
Soils: Very deep, yellowish brown, very friable, stratified loamy fine sand; in places slight saline; somewhat excessively to imperfectly drained, according to topographic position.
Local landform/soil name: Aoi (open woodland of tall Acacia tortilis); Ng'ataparin (flat, seasonally ponded bottomland; "devil's lake": dusty plain with mirage)
Productive capacity: Area with aquifer near to surface as must be concluded from the widespread presence of Acacia tortilis woodland. Good area for camels and goats, not suited for cattle, due to lack of grazing.
Erosion status/hazard: Wind erosion and deposition is, going from west to east, increasingly active. Water erosion does not take place.
Accessibility: Slight to moderate wet season restrictions.
Obs.: 5, 31, 34, 37.

Mapping unit 27: **PlD.**

Surface area: 2668km^2; 3.8% of the District.
Landform, topography: Almost flat lake bed terrace (lacustrine plain) and gently undulating mesotopography due to former and present beach ridges and dune formation.
Rock type, soil parent material: Fine sandy to clayey, partly consolidated, lake bed deposits, mostly with thick, windblown sand cover.
Soils: A complex of:

1. Somewhat excessively drained, very deep, pale brown, very friable to loose stratified sand.
2. Well to imperfectly drained, very deep, dark brown to grayish brown, stratified sandy loam to fine sand, locally calcareous, locally saline.
3. Well drained shallow, saline, gravelly loam to gravel.

Local landform/soil name: Ekitela ng'asinyono (sandy undulating plain); Ekitela aabei (undulating plain with Balanites); Ngakate leengoi (sandy beach ridge).
Productive capacity: Variable; the more stable sands, i.e. those that are not subjected to strong wind action, supports a good cover of Indigofera dwarfshrub, and scattered Balanites.
Erosion status/hazard: Wind erosion and deposition is an important feature in this area of extreme dry climate. Average wind speed is apparently highest near lake Turkana. Sandy deposits of Kerio river and Turkana beach ridges provide a source of the sands. Also, older dunes are broken down, while new sand accumulations take place. These dynamics are too fast for the establishment of Indigofera dwarfshrub vegetation. Streambank erosion is active along the numerous rivers that flow towards the subsiding Turkana lake level.
Accessibility: Loose - sandyness poses a hardship towards the end of the dry season. The heat is avoided by travelling at night during that period.
Obs.: 6, 7, 8, 30, 35, 36, 38, 65, 79, 80.

Mapping unit 28: **AA.**

Surface area: 2176 km^2; 3.1% of the District.
Landform, relief: Floodplain and low terrace of major rivers, with (sub)recent braiding river channels. Locally small river dunes are common.
Rock type, soil parent material: Recent, and (sub)recent sandy, loamy and clayey riverine alluvium.
Soils: Well to moderately well drained, very deep, pale brown to dark brown, loose to very friable and firm, stratified, micaceous, fine sands to light clay. In places calcareous, saline.
Local landform/soil name: Ekanyapunyapu (riverine soil of fine dusty texture (apua = dust), good for sorghum shamba); Ng'ataparin (where water stagnates); Ngasinyono (sandy area); Emuria aro (plain with Salvadora persica); Agule ng'itamutonan (zone along riverbank, many trees); Aoi (open woodland of tall Acacia tortilis).

Productive capacity: High, due to good infiltration rate; generally high water holding capacity; supply of ground- and flood water; and a relatively high natural soil fertility (mica's, organic matter). This unit contains suitable areas for irrigation and "micro-catchment" practices. This unit supports all riverine Acacia tortilis/ Salvadora persica woodland of Kerio, Turkwel, Tarach and other larger rivers.
Erosion: Riverbank erosion is a natural geomorphological feature. Wind erosion and dune formation (in the Tarach valley) can be harmful to irrigation/ micro - catchment activities.
Accessibility: No restrictions, except for periods of flooding.
Obs.: 23, 27, 99, 58, 102, 103, 137.

Mapping unit 29: **D**.

Surface area: 562 km^2; 0.8% of the District.
Landform, relief: Stabilized dune fields, gently undulating, moderately long regular convex - concave slopes.
Rock type, soil parent material: Wind blown deposits derived from undifferentiated sources.
Soils: Somewhat excessively drained, very deep, pale brown, very friable to loose, fine to medium sand, locally calcareous.
Productive capacity: Low water holding capacity, but good infiltration capacity of rain water, and moderate soil fertility. The unit supports an evenly distributed stand of dwarfshrubs (Indigofera spinosa). The soil surface is loose, does not suffer any sealing or capping, so that seedlings can germinate and develop.
Erosion status/hazard: Sheet or gully erosion has not been observed (except locally along the Turkwel river incision, where Turkana grit hardrock occurs at shallow depth, here a badland topography has developed). Wind erosion and deposition is a continuous process, but not of such intensity that natural vegetation cover can develop with the renewed surface.
Accessibility: No restrictions. In the end of the dry season the loose sandy surface can pose some constraints.
Obs.: 1, 3, 4.

Mapping unit 30: **La**.

Surface area: 281 km^2; 0.4% of the District.
Landform, relief: Lavaflow; flat to undulating, with extremely irregular rugged stony and rocky meso topography.
Rock type, soil parent material: Sub recent volcanic rocks, Basalts.
Soils: Rock outcrops, stones, boulders.
Local landform/soil name: Emor ng'arabat.
Productive capacity: Natural vegetation is largely of woody nature. It finds its foothold in rock crevasses, where apparently rain water runoff collects. In spite of severe restrictions, the area is reportedly good for wet season goat herding over an eight month period, in which manyatta's have to be shifted after every one or two months.

Accessibility: Severe restrictions due to irregular surface.
Obs.: Inormation inferred from satelite image and information on similar landforms elsewhere (Marsabit district).

Mapping unit 31: **LaP.**

Surface area: 702 km^2; 1.0% of the District.
Landform, relief: Lavaflows of locally extremely irregular mesotopography, or with "terraced" topography due to infills of volcanic ashes.
Rock type, soil parent material: Recent basalts, partly covered by volcanic ashes and pyroclastic rocks.
Soils: Association of:
1. rock outcrops
2. Well drained fine gravelly ash soils of varying depth.

Productive capacity: very low on rock outcrops. Moderate to high on volcanic ash soils, due to moderate to high waterholding capacity, high soil chemical fertility and fair top soil conditions.
Erosion status/hazard: Probably locally gully development, to a limited extent. In general soil of high infiltration capacity and resistance to erosion.
Accessibility:
Moderate to severe restrictions locally, due to lava outcrops.
Obs.: None, information inferred from satellite image interpretation.

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ANNEX I:
Mission report

CONTENTS

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1 INTRODUCTION

The GTZ-funded Range Management Handbook Project aims at the inventory of the natural resources of the arid and semi-arid lands of Kenya, and the interpretation of these data in terms of recommendations for sustained forms of range land use. Results will be presented in the form of reports and maps at a 1 : 1M scale for each district separately. These are to be used by the Ministry of Livestock Development for both planning at ministerial level, as well as a first orientation for extension officers at district location or grazing block level.

The study is essentially a multidisciplinary one, in which are engaged a climatologist; a vegetation/range ecologist; a landforms/soils specialist; a hydrologist and a livestock agronomist.

The Winand Staring Centre participates in the project by providing the expertise for the landforms and soils inventory and for its interpretation in terms of productive capacity of rangelands and limitations to range land use.

The RMH-project started in 1986 and will be on-going to at least December 1991. Of the nine districts concerned, so far the survey of the Marsabit, Wajir, Samburu, Mandera, Baringo and Isiolo Districts, have been completed.
The present report concerns Turkana District, and results from the sixth consultancy to the Range Management Handbook Project.

The consultant travelled to Kenya on the 1st of September 1990 to carry out the above mentioned survey in Turkana District.
See Annex II for the Itinerary. Annex III contains the terms of reference.

2 ACHIEVEMENTS AND CONSTRAINTS OF THE TURKANA DISTRICT SURVEY

2.1 Survey preparation

In field surveys of large areas for which only a short time period is available (70,000 km^2 in six weeks time in the present case), the interpretation of remote sensing material is of crucial importance. Prior to field survey, a few days were spent on the production of an interpretation map at scale 1 : 500 000 of the whole District. Thirty five different interpretation mapping units were identified with the help of a 1 : 500 000 scale satellite images (EOSAT Tematic Mapper of 1984 and 1985). A base map was kindly provided by the Kenya Soil Survey. More than half of the District is covered by geological maps. These provide very valuable information in addition to the Exploratory Soil Map of Kenya at scale 1 : 1 000 000 by Sombroek et al. (1982).

The interpretation map, a copy of which was provided to each of the participating consultants prior to the field survey, proved useful as a general overview and appeared sufficiently accurate in most salient physiographic boundaries.

2.2 Field survey

The survey team consisted of a teamleader/technical adviser (Dr. Walther) and his counterpart of the ministry of Livestock Development (Mr. Shabaani), a vegetation/range ecologist (Dr. Herlocker), a landform/soils specialist (Touber) and a hydrologist (Dr. Bake). An anthropologist (Dr. Mueller-Demf) and a livestock marketing specialist (Dr. Shabari) also visited the survey area in approximately the same period.

Field checks were located at points identified beforehand as representative according to the satellite image interpretation map. The vegetation scientist and soil surveyor conducted their observations simultaneously at the same sites in most of the area. Soil and landform characteristics that play a role in the performance of rangeland were recorded, i.e. topography, steepness, drainage condition, soil moisture availability, rooting space, degree of surface sealing, signs of rainwater run-off, flooding, ponding, humus content of the top soil, calcareousness, salinity and pH (at the standard depths of 10, 40 and 90 cm), soil consistence and texture. At most of the sites soil fertility samples were taken. These were delivered at the N.A.L. for a "Mehlig" analysis, i.e. major nutrients, carbon content, pH and salinity. Unfortunately, results of these analyses were not available as yet by the time of report preparation.

The cooperation between the soil surveyor and the vegetation scientist is to ensure that the existing correlation between landforms/soils and vegetation is expressed in the maps to be produced. The vegetation scientist, as was the case in the previous surveys, initiated interviews with local people which not only revealed aspects on vegetation status and trend. It also provided the surveyors with local soil and landform names. In fact these vernacular names stand for landform-soil-vegetation complexes with their inherent production capacities and management aspects throughout the various seasons. In most

of the previous district surveys it appeared no problem to correlate this local information to the delineated physiographic mapping units.

Unfortunately, a drawback was experienced in this respect, as the Turkana soil and landform terminology is not always compatible with the Kenya Soil Survey classification of physiography in its concepts throughout the District. Also criteria for separating one soil type from the other were not altogether clear in a number of cases.

Field survey took place between 5 September and 19 October, with a short break in the first week of October. Some time was spent on surveying parts of Elgeyo Marakwet and West Pokot Districts during the second field work period.

2.3 Map and report preparation

After the field survey period a re-interpretation was done of the Landsat Imagery. Field data were put together on the basis of which thirty one units were identified. These have been presented on a 1 : 1.000 000 scale map that forms a final draft map and legend for publication in the handbook. Finalisation of the complete technical report materialized in November 1990 / January 1991, Wageningen.

ANNEX II:
Itinerary

Sat	1 Sep	Travel Amsterdam - Frankfurt - Nairobi. Meet Project Chief Technical Adviser Dr. Walther.
Sun	2 Sep.	Assemble field trip necessities; shopping.
Mon	3 Sep.	Meet Mr. Wokabi, Acting Head, Kenya Soil Survey. Arrange for Survey equipment. Meeting with Project team members, Drs. Walther, Shabaani, Herlocker, Bake at Ministry of Livestock Development.
Tue	4 Sep.	Collect field equipment KSS, arrange photocopies of topographic maps, complete shopping, collect petty cash at GTZ office, load vehicle.
Wed	5 Sep.	Travel Nairobi - Kitale - Lodwar.
Thu	6 Sep.	Visit Mr. Chumakemer, act. District Livestock Development Officer. Attempts to meet various related institutions , ao the Turkana Drought Contingency Planning Unit (TDCPU), part of Turkana Rehabilitation Project (TRP); the Turkana District Planning Unit, Mr. Kersten.
Fri	7 Sep.	- Sun 9 Sep. Carry out field observations in Lodwar area.
Mon	10 Sep.	Visit Turkana Planning Unit Info Centre; Visits to various ministries; Visit Turkana Resource Evaluation and Monitoring Unit, Dr. Macheti, acting head, and Dr. Gufu Oba, Range Ecologist.
Tue	11 Sep.	Carry out field observations in Lodwar area.
Wed	12 Sep.	Survey flight over northern Turkana District.
Thu	13 Sep.	- Fri 14 Sep. Carry out field observations in Lodwar area.
Sat	15 Sep.	Shift base camp to Kakuma. Field observations.
Sun	16 Sep.	- Mon 17 Sep. Carry out field observations in Kakuma-Lokichoggio area.
Tue	18 Sep.	Shift base camp from Kakuma to Kaikwor.
Wed	19 Sep.	- Fri 21 Sep. Carry out field observations in the Kaikwor-Lokitaung area.
Sat	22 Sep.	Travel Kaikwor - Lokitaung - Loruth Kaado - Todenyang - Kalokol - Lodwar.
Sun	23 Sep.	Measure EC samples, review data.
Mon	24 Sep.	Survey flight over the Lotikipi Plains.
Tue	25 Sep.	Survey flight over southern Turkana; Loriyu Plateau; Suguta valley; Turkwel dam and river course. Observations Lorugumu area.
Wed	26 Sep.	Carry out field observations in Lorugumu area.
Thu	27 Sep.	Travel Lodwar - Lokichar - Lokori.
Fri	28 Sep.	Carry out field observations in the Lokori area.
Sat	29 Sep.	Carry out field observations Lokori - Kapedo area. Travel Kapedo - Nairobi.
Sun	30 Sep.	Measure EC samples, review field data.
Mon	1 Oct.	Petty cash accounts at GTZ office; shopping; review data at KSS.
Tue	2 Oct.	Review satellite imagery. Bring vehicle to garage for service.
Wed	3 Oct.	Review data and satellite imagery at KSS.
Thu	4 Oct.	Meet mr. von Boguslawsky, team leader, German Assisted Settlement Project (GASP), GTZ, on possible consultancy. Meeting with Dr.Walther on further field trip planning. Collect petty cash at GTZ office. Load vehicle.