LANDSCAPE-ECOLOGICAL RISK INFORMATION SYSTEM (LERIS) FOR NAMIBIA

Atlas of the project areas
NORTHERN GROOTBERG FARMS (Kunene Region)
and UUVUDHIYA CONSTITUENCY (Oshana Region)
(Situation at the end of the dry season 1996)

LERIS

DEPT. OF GEOGRAPHY & ENVIRONMENTAL STUDIES (UNAM)
RESEARCH
ETOSHA ECOLOGICAL INSTITUTE
AGRICULTURE LABORATORY
EDUCATION & TRAINING
RESEARCH COOPERATION

SARDEP
UNIVERSITY OF REGensburg
NAPCOD

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PD Dr. Manfred W. Buch
Dr. Harald Beugler-Bell and
Dr. Christian Trippner

University of Regensburg

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NORTHERN GROOTBERG FARMS

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NORTHERN GROOTBERG FARMS

by Dr. Harald Beugler-Bell

1. THE STUDY AREA

The study area ‘Northern Grootberg Farms’ is communal farm land situated in the south-eastern Kunene Region adjoining the reference area Etosha National Park towards south-west (Fig. 1). The LERIS Pilot Area West comprises the northern part of the so-called ‘Grootberg Farms’, a target region of several rural development and anti-desertification projects in northern Namibia (NAPCOD, SARDEP, CAWS). The Grootberg Farm area extends southwards including the upper Huab catchment with the local centres Khorixas in the south and Fransfontein in the south-east.

The LERIS Pilot Area West has a size of 103,708 ha and includes the following 14 farms: Marienhoche, Kamdesha, Quo Vadis, Dorslan, Oortrek, Waterbron, Keiserfontein, Eendrag, Atlanta, Condor, Neuland, Emanuel, Deo Volento and Grootberg (Fig. 1).

A terrain classification of the area was done by using map and aerial photo interpretation techniques (Fig. 2). The landscape units (Terrain Mapping Units TMUs; Fig. 3) were mapped according to the definitions given in Appendix A. The TMUs provided the basis for the soil map of the study area (Fig. 4) and the evaluation of the soil and relief (erosion/flood) risks (Fig. 5 and Fig. 7).

The following source maps were used: Topographical maps Sheets 1:50,000 1914AD Swartskamp, 1914CA Omumborombongo, 1914CB Atlanta, 1914CC Grootberg, 1914CD Grootberg-Oos, 1914DA Bruno; Vegetation maps Sheets 1:100,000 (Dept. of Forestry) 1914A, 1914C, 1914D and the Geological map 1:250,000 Sheet 1914 Kamanjab.

2. INDIVIDUAL LANDSCAPE-ECOLOGICAL RISKS (see also Appendix B)

2.1 SOIL RISK (Fig. 5)

data source: field survey 1996 (soil survey and laboratory analyses), Etosha Soil Data Base
data files: grosoil.dbf, soilfac.xls
The soils in the study area are generally poor in nutrients with sandy to sandy-loamy texture and predominantly shallow and rocky, esp. in hilly and mountaineous terrain (Leptosols) (Fig. 4). In these areas which comprise more than 60% of the study region the soil risk is ‘moderate to high’ (class 4) and ‘high’ (class 5). The extremely shallow and rocky soils of the Etendeka table mountains in the south-west are grouped into class 6. Due to more favourable physical properties the soils of the undulating plains (Dystric Cambisols, Fluvisols and Leptosols) show only moderate limitations (class 3). The most favourable soils (class 2) are the Fluvisols in the river valleys and fluvial basins.

2.2 WATER RISK (Fig. 6)

Data source: field survey 1996 (measurement of water quality, interviews of farmers)
Data files: growat96.xls

The water risk is a synthesis of chemical water quality, water availability from the aquifer and distance from the waterhole (spatial availability). The access of cattle and small stock to waterholes was supposed to be limited by farm boundary fences\(^1\). As elephants have been

\(^1\) Although there are fences within the farm boundaries, they were not considered as there are no recent maps of existing fences available for the study area. However, with some exceptions, the old farm boundaries adapted from the 1:50000 topographical maps still seem to be generally valid in terms of demarcating major management units.
reported to continuously destroy pumps and pipes, the ‘Elephant Risk’ was included in the evaluation of the water risk. The chemical water quality is, with some locally confined exceptions, generally good (class B according to DWA) and water availability from the aquifer is also favourable except in some central western parts where water flow is weak (Condor, Emanuel). Elephant impact is high in the north (Kamdesha, Marienhoehe), along the Honib River (Waterbron) and in the southwest (Makalan, Grootberg, Libra). Especially the good water quality and a strong water flow is responsible that more than 40% of the study area shows a ‘low’ and ‘moderate to low’ water risk. About one third of the study area shows a ‘moderate to high’ water risk (class 4), especially in the central western part and in the south where the water supply by boreholes is limited.

2.3 RELIEF RISK (EROSION AND FLOOD RISK) (Fig. 7)

data source: field survey 1996 and map interpretation (1:50,000 topographical maps & 1:100,000 vegetation maps, Dir. of Forestry, MET 1994)

rainfall simulation tests

data files: grorrel.xls, grorrisk.xls

The relief risk is predominantly ‘low to moderate’ and ‘moderate’ although sheet erosion risk is very high in the mountaineous and hilly areas and also wind erosion risk is generally high due to the sandy topsoils and the low mean vegetation cover. However, as gully erosion risk and flood risk is limited to some fluvial basins and river valleys and is not apparent in the other regions, the combined relief risk factor is relatively favourable in more than 90% of the study area. Only in some fluvial basins in the north (esp. on the farms Kamdesha and Quo Vadis), where high gully erosion risk, wind erosion risk and flood risk occurs in combination, ‘moderate to high’ and ‘high’ relief risks were evaluated.

Relief Risk - Class distribution

![Relief Risk - Class distribution](image-url)
2.4 CLIMATE RISK (Fig. 8)


data files: gauges.xls

There is no first order weather station situated in the study area. Although it was observed that rainfall is collected at some farms (Grootberg, Kamdesha) there are no rainfall data available. As the longterm mean precipitation ranges between 300 mm in the northeast and less than 200 mm in the southwest and rainfall variability is higher than 40%, the entire region is grouped into risk class 6 'very high'. Like observed in adjacent areas in the ENP, where rainfall is recorded by a set of finely distributed rainfall gauges, high spatial variations of rainfall have to be assumed for the study area. The situation might locally, esp. in the northeast, be more favourable in over-average rainy seasons than represented by the longterm (interpolated) mean.

2.5 VEGETATION RISK (Fig. 9)

data source: field survey september 1996 by members of the AL, MAWRD Windhoek

data files: grov0996.xls

At the climax of the dry season 1996 the vegetation risk was found to be 'very high' in the whole study area. Basal cover and standing crop of annuals and perennial grasses was extremely low or totally missing due to excessive grazing, especially in the undulating plains, fluvial basins and river valleys. Only in a small area between Erwee and Libra on the farm Grootberg the standing crop of perennials was just low to very low. As this area was excluded from grazing by fencing, a 'low' cover of standing crop seems to be the best situation to be achieved in this dry area (for comparison see Fig. 10: Biomass for northern Namibia, 10/95-03/96).

3. COMBINED LANDSCAPE-ECOLOGICAL RISKS

3.1 SOIL, WATER and RELIEF RISK combined (Fig. 11)

Soil, water and relief are those landscape-ecological factors which do not show any (or very little) short-term or seasonal changes such as climate and vegetation in relation to rainfall and grazing pressure. The latter have to be updated continuously (seasonally) in order to understand ecosystem processes and resilience and to include actual conditions into management decisions. However, some parameters have to be adjusted to the actual situation if necessary (e.g. mean vegetation cover, groundwater flow, elephant impact, fencing).

Nearly 50 % of the study area show a 'moderate' risk of combined soil, water and relief risk. The risk is 'low to moderate' in the undulating plains, fluvial basins and river valleys, where the soil conditions are favourable, relief risks are 'low to moderate' and water of good chemical quality is supplied (esp. central parts of Grootberg, Atlanta and northern Marienhoche). In the mountainous and rocky areas, where the soils show high limitations, relief risk is 'moderate' and water supply is limited, the actual risk is 'moderate to high' or 'high' (western mountain ranges, table mountains, Granite koppie areas).
3.2 SOIL, WATER, RELIEF and RAIN RISK combined (Fig. 12)

When the ‘very high’ climatic risk is included in the rating, more than 90% of the study area are shifted towards a ‘moderate to high’ and ‘high’ risk. Generally the situation is better, i.e. the risk factors are lower, in the vicinity of waterholes predominantly due to lower water risks. The most favourable regions with a higher percentage area of ‘moderate’ risk are found on the farms Grootberg (central part) and Atlanta.
3.3 SOIL, WATER, RELIEF, RAIN and VEGETATION RISK combined (Fig. 13)

![Soil, Water, Relief, Rain and Vegetation Risk](image)

The situation gets even worse when both the actual vegetation conditions and the climatic situation are integrated in the risk evaluation. More than 80% of the region show a ‘high’ risk (class 5) and some remote mountaineous areas even have to be classified into class 6 (‘very high’ risk). The situation is more favourable only around some waterholes with good water quality and availability and better soil and relief conditions (undulating plains and fluvial basins, e.g. at Rodeon, Erwee, Atlanta Pos; a.s.o.).

Considering the high density of existing waterholes and the actual bad veld condition due to excessive grazing all over the area, the limited ressources in this harsh environment are already used to its upper limits. In combination with the actual climatic situation with a continuing period of under-average rainfall a serious decline of longterm regeneration capacity (=desertification) with far-reaching consequences for the rural population in this area has to be expected when land utilization pressure is maintained or even increasing.
Northern Grootberg Farms
TMU Identifier Numbers

farm boundaries
Terrain Mapping Units
61 TMU Identifier Number
Northern Grootberg Farms - Soil Associations

Soils and Topography
- B1 undulating plains
- B2 hills
- B3 mountains (igneous rocks)
- B4 mountains (sedimentary rocks)
- B5 granite castle koppies
- D1 river valleys and basins
- D2 major river valleys

- roads and pads
- farm boundaries

Terrain Mapping Units

Fig 4
## LERIS Pilot Area West ‘Northern Grootberg Farms’ Soil Mapping Units

<table>
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<tr>
<th></th>
<th>Associations of shallow to moderately deep sandy to sandy-loamy soils</th>
<th>Inclusions*</th>
<th>Lithology</th>
<th>Landscape Type</th>
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<td>B1</td>
<td>(Lithi) Dystric Cambisols</td>
<td>40**</td>
<td>Ferralic Arenosols</td>
<td>Granite, Gneiss</td>
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<td></td>
<td>(Rudi) Dystric Leptosols</td>
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<td>Eutric/Calcic Fluvisols</td>
<td>Granite, Gneiss, Andesite, Rhyolite, Tuffite</td>
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<td></td>
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<td>(Rudi) Dystric/Lithic Leptosols</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
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<td>60</td>
<td>Rudi Dystric Leptosols</td>
<td>Granite, Gneiss, Andesite, Rhyolite, Tuffite</td>
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<td></td>
<td>Bare Rock</td>
<td>30</td>
<td>Dystric/Eutric Fluvisols</td>
<td></td>
</tr>
<tr>
<td>B4</td>
<td>Lithic Leptosols</td>
<td>50</td>
<td>Rudi Eutric Leptosols</td>
<td>Basalt, Tuffite</td>
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<td></td>
<td>Bare Rock</td>
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<td>Eutric Fluvisols</td>
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<td>B5</td>
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<td>Calcaric Fluvisols</td>
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<td>Dystric Leptosols</td>
<td>Granite</td>
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<td></td>
<td>Bare Rock</td>
<td>50</td>
<td>(Lithi) Dystric Cambisols</td>
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## D Moderately deep to deep soils of fluviatile sediments

<table>
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<th></th>
<th>Inclusions</th>
<th>Lithology</th>
<th>Landscape Type</th>
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<tr>
<td>D1</td>
<td>(Areni) Dystric Fluvisols</td>
<td>80</td>
<td>Dystric Leptosols</td>
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<td></td>
<td></td>
<td></td>
<td>Calcaric/Eutric Fluvisols</td>
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<td>D2</td>
<td>Eutric/Calcic Fluvisols</td>
<td>85</td>
<td>(Areni) Dystric Fluvisols</td>
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</tbody>
</table>

* inclusions cover less than 20% of a mapping unit
** estimated percentage area of mapping unit
Water Risk (incl. Elephant Risk)

LERIS Risk Classes
- Low
- Low to moderate
- Moderate
- Moderate to high
- High
- Very high

- Roads and pads
- Farm boundaries
- Water points

Fig. 6
Erosion and Flood Risk

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high
- roads and pads
- farm boundaries
- water points
- Terrain Mapping Units

Fig. 7
Climate Risk (longterm mean precipitation)

LERIS Risk Classes

- low
- low to moderate
- moderate
- moderate to high
- high
- very high

- roads and pads
- farm boundaries
- Terrain Mapping Units
- water points

Fig. 8
Vegetation Risk (Dry Season '96)

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high

- roads and pads
- farm boundaries
- Terrain Mapping Units
- sites of veld condition assessment
LERIS PILOT AREAS
and
BIOMASS FOR NORTHERN NAMIBIA (10/95-03/96)
Soil, Water and Relief Risk combined

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high
- roads and pads
- farm boundaries
- water points
Rain, Soil, Water and Relief Risk combined

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- roads and pads
- farm boundaries
- water points

Fig. 12
Rain, Soil, Water, Relief and Vegetation Risk combined

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high
- roads and pads
- farm boundaries
- water points

Fig. 13
II. LERIS PILOT AREA NORTH
UVUDHIYA CONSTITUENCY

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II. LERIS PILOT AREA NORTH
UUVDHIYA CONSTITUENCY

by Dr. Christian Trippner

1. THE STUDY AREA

The study area "Uuvudhiya Constituency", situated north of the reference area Etosha National Park shows the geographic boundary coordinates S18°00'00" to S18°40'00" and E15°16'00" to E16°00'00". The Uuvudhiya Constituency covers an area of 3,192 km² (319,200 ha) with a low population density in the southern territories close to the Etosha National Park and high population densities in the north (Fig. 1). The LERIS Pilot Area North being a communal rural area with a high demographic pressure and limited natural resources is one of the target regions of SARDEP and of great importance for national planning strategies. The distribution of biomass as a first rough indicator of natural resources and the ecological status of the study area is given in Fig. 2. Within the study area, the SARDEP field office Onkani is situated close to the Uuvudhiya community in the north west.

A terrain classification of the Pilot Area North Uuvudhiya Constituency was done by using topographical maps and aerial photo interpretation techniques. The different landscapes were classified into landscape units (Terrain Mapping Units - TMU) and mapped according to the definitions given in Appendix A. The TMUs are the classified ground information of the study area and an important tool for soil mapping (Fig. 3) and the evaluation of the relief risk.

The individual landscape-ecological risks (i.e. soil risk, relief risk, etc.) were evaluated by using risk values ranging from 0 (low) to 5 (very high). The final classification (and presentation in maps) of landscape-ecological risks was done by using six risk groups which were classified as low (score 0-0.25), low to moderate (0.25-0.40), moderate (0.40-0.50), moderate to high (0.50-0.60), high (0.60-0.75) and very high (>0.75).

2. INDIVIDUAL LANDSCAPE-ECOLOGICAL RISKS IDENTIFIED BY LERIS

2.1 SOIL RISK (FIG. 4)

data source: field survey 1996 (soil survey and laboratory analysis), Etosha Soil Data Base
data files: uvuhiya.dbf, useoilest.xls
The soils in the study area can be characterized by a poor nutrient status, with high sodium and salt concentrations and a loamy sandy to clayey sandy texture. Most of the soils show medium soil depth, often with an extremely dense ‘hard pan’ at the lower parts of the profile (Planosols,Cambisols). Due to unfavourable soil physical and soil chemical properties, almost 40% of the soils in the Uuvudhiya Constituency (Arenosols,Cambisols) show ‘moderate to high’ soil risks (class 4) and nearly 60% of the soils (Planosols) are classified into the ‘high’ soil risk group (class 5). Only 1.2% of the study area show ‘moderate’ soil risks resulting from the somehow better nutrient status and lower sodium content of the fluvial soils (Fluvisols) of the Oshana system except the braided Ekuma channels.

2.2 RELIEF RISK (FIG. 5)

data source: field survey 1996 and interpretation of maps (topographical maps 1:50,000; vegetation maps 1:100,000, Dir. of Forestry, MET 1994)
data files: uvurelef.xls, uuvurisk.xls

The relief risk in the Uuvudhiya Constituency is ‘low to moderate’ (class 2) to ‘moderate’ (class 3) for more than 80% of the areas. These relatively favourable relief conditions are mainly due to the flat terrain with hardly any gully and sheet erosion. Some soils however (Arenosols,Cambisols), with a sandy topsoil show a tendency towards increasing wind erosion, especially where the coverage by vegetation is low. This can be observed at some locations (around pipeline outlets, water posts or hand-dug water wells) with bare ground, where micro dunes (wind ripples) occur due to overutilization by cattle. The ‘moderate’ (class 3) flooding risk is limited spatially to the Oshana system (Planosols,Fluvisols), the Etaka/Ekuma channel system (Fluvisols) and Lake Oponono (Solonchak). The only areas with a
II. LERIS PILOT AREA NORTH - UUVUDHIYA CONSTITUENCY

'moderate to high' relief risk (class 4) are restricted to the local clay and/or salt/sodium pans (Solonchaks) which are without any protective vegetation during most time of the year.

2.3 CLIMATE RISK (FIG. 6)

data source: Van der Merwe (1983); National Atlas of Namibia; Etosha Rainfall Data Base.
data files: gauges.xls

There is no first order weather station situated in the Uuvudhiya Constituency, thus no rainfall data were collected during the rainy season 1995/96.
To close this gap representative rainfall data of adjacent areas in the Etosha National Park, where rainfall is recorded for a long time by a set of finely distributed rainfall gauges, were taken as the basis for the climate risk assessment. The long-term mean precipitation ranges between 300-400 mm/a. But due to the under average rainfalls of the last years the worst case rainfall of 1995/96 was taken into account (= 200-250 mm/a) in order to describe the actual situation (to be 'on the save side' of a Climate Risk Evaluation). The Etosha Rainfall Data also indicate a high variability of rainfall between 30-40% for the Uuvudhiya Constituency. The combination of the assessment of rainfall in 1995/96 (risk factor 1.00 and the longterm variability of rainfall (risk factor 0.6) results in a total climatic risk of 0.8 (class 5, 'high').

2.4 VEGETATION RISK (FIG. 7)

data source: field survey September 1996 by members of the AL, MAWRD Windhoek
data files: uuvuv0996.xls

At the culmination point of the dry season 1996 the vegetation risk was evaluated as to be 'very high' all over the study area. Basal cover and standing crop of annual and perennial grasses were extremely low due to poor soil conditions and excessive grazing, especially in the flat and undulating plains. Due to the lack of significant grass species at this stage of the dry season the assessment of the forage factor was not done. Thus the most favourable situation of the veld condition in the Uuvudhiya Constituency can be described as 'very low', giving 'very high' vegetation risks (class 6). This bad situation of the vegetation status might be better if average or over-average rainfall would be available in the study area, which seems to be unlikely when regarding the high climatic risks in the Uuvudhiya Constituency.

2.5 WATER RISK (FIG. 8)

data source: field survey 1996 (measurements of water quality and interviews of farmers);
Department of Water Affairs (DWA), Windhoek
data files: uuvwa96.xls
The water risk is a combination of the individual factors chemical water quality, water availability and distance from the waterhole (spatial availability). Two aquifers with different water qualities occur in the study area: a natural upper aquifer (5-8 m [including artificial pipeline water with in general good water quality]; class A or B according to DWA) and a lower aquifer (>8 m) with bad water quality (class C, D, E according to DWA). Thus the chemical water quality is of great variation in the Uuvudhiya Constituency, resulting from what aquifer it is originating and what duration of time it was exposed to evaporation. As the local farmers reported, the water quality from the upper aquifer in a hand dug well, that originally has water quality of class A or B impairs by evaporation to class D or E within 4-6 weeks. Digging the well deeper so that new water can flow into the well improves the water quality to class B or sometimes A again. Additionally some hand dug wells fall dry during the dry season, so that the water availability and quality must be classified as very bad for most of the areas (86%) in the Uuvudhiya Constituency. Only small areas (approx. 13%) in concentric circles around pipeline outlets and hand dug wells show water qualities and availabilities that are sufficiently good, with a strong water flow.

3. COMBINED LANDSCAPE-ECOLOGICAL RISKS

3.1 SOIL, WATER AND RELIEF RISK (FIG. 9)

The landscape-ecological factors soil, water and relief do not show significant short-term or seasonal changes like the climate and vegetation factors, which might very dynamically react due to changes in annual rainfall and/or grazing pressure. Grazing activities and veld
condition have to be updated seasonally, in order to get an actual image of the ecosystem processes and to implement actual conditions into land management.

Due to the bad soil conditions and the high water risk, more than 70% of the Uuvudhiya Constituency show a combined soil, relief and water risk classified from 'high' to 'very high'. Only the areas around water outlets and wells (approx. 24% of the study area) are classified 'low to moderate', 'moderate' and 'moderate to high', because of the combination of often good water quality and high availability together with a low relief risk at these places.

3.2 SOIL, RELIEF, WATER AND RAIN RISK (FIG. 10)

![LERIS Soil, Relief, Water, Rain Risk](image)

Compared to the previous map the combination of soil, relief, water and rain risk categorizes most of the area of Uuvudhiya Constituency (74%) in risk class high (5). The locations around the water outlets and wells become worse, so that only 9% of the area can be grouped into class 2 to 3 ('low to moderate' to 'moderate').

3.3 SOIL, RELIEF, WATER, RAIN AND VEGETATION RISK (FIG. 11)

![LERIS Assessment 1996](image)

If in addition the vegetation risk is included into the evaluation, it becomes obvious that the whole landscape-ecological situation is very problematic. More than 90% of the study area are in risk class 5 and 6 ('high' to 'very high') and only the areas around the water places show a somewhat better condition (class 4, moderate to high). Regarding the combination of the five risk factors in Figure 11 one should always bear in mind that the only reason why some areas show "only" high risks is, that the relief risk in the Uuvudhiya Constituency is more or less favourable.
The landscape-ecological situation in the Uuvudhiya Constituency is mainly dominated by the soil properties, the water quality/availability, the vegetation status and the climatic conditions. These four risk factors show very high risks so that the recent utilization of natural resources must be considered to have reached its upper limit. This means the Uuvudhiya Constituency is close to over-exploitation, especially under the aspect that the impact of cattle and man was considered only indirect (by the vegetation status/veld condition) in this study because of a lack of data. If the recent climatic trend of under average rainfalls in the Uuvudhiya Constituency continues and the utilization pressure by cattle is increasing and focusing around some few water places, a serious decline in regeneration capacity with a long-term loss of range land has to be expected. If this happens, these areas are prone to desertification which will have far-reaching and catastrophic consequences for the rural population in the Uuvudhiya Constituency.
Fig. 1

Uuvuhiya Constituency - LERIS Pilot Area North

- Roads
- Tracks and Hiking Trails
- Game Reserve Boundaries
- Border of LERIS Pilot Area North
- Uuvudhiya

+ Settlements
□ Waterpoints
△ Trig. Beacons
_sprites
Flight Route/Waypoint
(Profile No.)
LERIS PILOT AREAS

and

BIOMASS FOR NORTHERN NAMIBIA (10/95-03/96)
Soils and Soil Associations - Uuvudhiya

Soil Mapping Units
- A1 (hilly areas)
- A2 (undulating plains)
- B1 (flat plains)
- B2 (flat plains/depres.)
- C1 (flat depressions)
- D1 (Omurambas)
- D2 (Oshanás)
- E1a (pan edge zone)
- E1b (recent pan floor)
- Seasonal Lake/E1b

Roads and pads (map sheet 1: 250 000)
- Roads and pads (GPS measurement)

Etosha N. P.
<table>
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<th>associations of deep to moderately deep sandy to sandy-loamy soils</th>
<th>inclusions (less than 20% area covering the soil assoc.)</th>
<th>Lithology</th>
<th>Landscape Type</th>
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<td>Sandstone, Siltstone</td>
<td>hilly areas with ridges (relief energy 5-10 m) and shallow depressions</td>
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<td>Para-Vertisols</td>
<td>Sandstone, Claystone, Hardpan</td>
<td>undulating plains with low height ridges (relief energy 1-5m) and shallow depressions</td>
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<td>Sali Dystric Fluvisols (20)</td>
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<td>flat plains with shallow depressions</td>
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<td>Sandstone, Limestone</td>
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<td>wide and flat ‘Omurumbas’, often with vegetation</td>
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<td>Sandstone, Siltstone</td>
<td>recent pan floor, mainly without vegetation</td>
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Classified LERIS Soil Risk - Uuvudhiya

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high

roads and pads (map sheet 1: 250 000)
roads and pads (GPS measurement)

Etosha N. P.
Classified LERIS Relief Risk - Uuvudhiya

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high

roads and pads (map sheet 1: 250 000)
roads and pads (GPS measurement)

Etosha N. P.
Distribution of Rainfall in the ENP for Selected Years

Periods 1986/87; 1988/89; 1995/96

Etosha National Park - Rainy Season 1986/87

Seasonal Rainfall
- <= 150 mm
- >150-200 mm
- >200-250 mm
- >250-300 mm
- >300-350 mm
- >350-400 mm

Below Average Rainfall

Etosha National Park - Rainy Season 1988/89

Seasonal Rainfall
- <= 150 mm
- >150-200 mm
- >200-250 mm
- >250-300 mm
- >300-350 mm
- >350-400 mm
- >400-450 mm
- >450-500 mm
- >500 mm

Average Rainfall

Etosha National Park - Rainy Season 1995/96

Seasonal Rainfall
- <= 150 mm
- >150-200 mm
- >200-250 mm
- >250-300 mm
- >300-350 mm
- >350-400 mm
- >350-400 mm

Worst Case Rainfall
(precipitation basic map of the 1996 LERIS assessment)
LERIS Vegetation Status Risk (STAND/BAS 09/96) - Uuvudhiya

LERIS Risk Values

- 0.4-0.5
- 0.5-0.6
- 0.6-0.7
- 0.7-0.8
- 0.8-0.9
- 0.9-1.0

Sample Point
Veld Condition Assessment

- roads and pads (map sheet 1: 250 000)
- roads and pads (GPS measurement)

Fig. 7
Classified LERIS WaterRisk (Qual., Avail., Dist.) - Uuvudhiya

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high

roads and pads (map sheet 1: 250 000)
roads and pads (GPS measurement)

Etosha N. P.
Combined LERIS Soil-Relief-Water Risk - Uuvudhiya

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high

roads and pads (map sheet 1: 250 000)
roads and pads (GPS measurement)

Etosha N. P.
Combined LERIS Soil-Relief-Water-Rain Risk - Uuvudhiya

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high

roads and pads (map sheet 1: 250 000)
roads and pads (GPS measurement)

Etosha N. P.

Fig 10
Classified LERIS Evaluation 1996 - Uuvudhiya

LERIS Risk Classes
- low
- low to moderate
- moderate
- moderate to high
- high
- very high

roads and pads (map sheet 1: 250 000)
roads and pads (GPS measurement)

Etosha N. P.
Appendix A:

DEFINITION AND CODING OF LANDSCAPE UNITS IN NORTHERN NAMIBIA
BASED ON MAP AND AIR PHOTO INTERPRETATION AT THE SCALE 1:50,000 TO 1:100,000

Harald Bengler-Bell, August 1996

1. LANDSCAPE TYPE, MESORELIEF

For the differentiation of landscape type morphogenetic (dominating processes), morphographic (landform shape) and morphometric (mean slope, relief energy) attributes of the relief are used. The performance of landscape type and landscape components on the map depends upon the mapping scale - the lower limit of a mapped component should not exceed a base width of 0.5 cm in the map (i.e. 500 m at the scale 1:100,000).

FLUVIAL AND ALLUVIAL LANDSCAPES

I. River Valleys, Alluvial Plains, Fans
   • esp. V-shaped valleys and saucer-shaped valleys with flat floor
   • +/- flat topography, mean slope <1°
   • clastic fluvial sediments, partly interrelated with colluvium at the valley sides
   • in alluvial plains dendritic pattern of superficial drainage lines, partly outcrops of hard rock as flat ridges (relief energy up to 5 m)

DENUDATION AND ACCUMULATION LANDSCAPES

II. Plains, Planation Surface
   • +/- flat to undulating topography (< 2° mean slope), low relief energy (absolute differences in height from drainage line to ridge top <10 m)
   • flat depressions and drainage lines

III. Pan Zone
   • extremely flat actual or relictic (=holocene) pan floor, including the pan margin zone with low pan margin (lunette) dunes
   • low woody vegetation cover and/or specially adapted grass, herb and shrub vegetation, active pan floors free of vegetation or with low grass cover
DENUDATION Landscapes

IV. Hilly Terrain, single Hills
- hilly to undulating landscape with mean slope of 1-5° and a relief energy (from drainage line to hill top) between 5 and 40 m
- dominating saucer-shaped valleys, partly V-shaped valleys (with flat floor)

V. Mountain Terrain, single Mountains, Cuestas and Escarpment
- mean slope > 5° and
- absolute differences in height energy (from drainage line to mountain top) > 40 m
- dominating V-shaped valleys, partly gorges

AC cumulation Landscapes

VI: Ridge Forms
- dune ridges or aeolian reshaped beach ridges with a base with of >0.5 cm in the map and relative heights of more than 5 meters (from the ridge top to the surrounding plain)

2. MICRO-TOPOGRAPHY, VEGETATION

The subclassification of the landscape type is done by a more detailed characterization and morphographic description of relief type and special landform features (meso- and microrelief). Also the vegetation can be used as a differentiating criteria, in case the morphology is very uniform or the relief intensity is less pronounced. Changes in vegetation are visible on the aerial photographs (1:50,000) by the variation of grey tone and structure. According to mapping scale and the size of the features a more detailed differentiation of the landscape type into single relief elements or physiotopes/ecotopes is possible (e.g. river valley → river channel, point bar, floodplain, low terrace, high terrace). New symbols should be defined for this purpose. The symbols listed below might be used in combination. A weakly developed attribute is marked by brackets.

Landscape Type I: (fluviial and alluvial landscapes)

a: valley floor: alluvial terrasses, floodplain, river bed (undifferentiated)
b: flat, partly slightly dipping alluvial plains and basins; broad drainage areas, partly divided by flat rock outcrops
v: alluvial fan
o: ‘Oshanas’: very broad, saucer-shaped valleys in central northern Namibia without incised river channel; mostly covered by grass vegetation
Landscape Type II: (denudation and accumulation landscapes)

l: flat plain (mean slope < 0.5°, relief energy < 1 m)
h: undulating plain (mean slope < 1°, relief energy 1 to 5 m)
n: small depressions without the special attributes of a pan
z: single Granite boulder koppies

Landscape Type III: (denudation and accumulation landscapes)

f: actual, extremely flat pan floor without vegetation or with highly (salt-)adapted grass cover after good rainy seasons
i: 'grass terrace': relict pan floor of holocene age with shallow sediment cover (<50 cm) and pure grass vegetation (e.g. Andoni Flats at the margin of the Etosha Pan); normally highly carbonatic and partly saline soils
k: 'acacia terrace': relictic pan floor of holocene age with moderately deep sediment cover (0.5 - 1 m) and acacia shrub savanna; normally carbonate-free soils with no or very low salinization; morphological position above the grass terrace
d: longitudinal pan margin dunes (lunette dunes) of early holocene to recent age with heights less than 5 meters; in northern Namibia normally accumulated at the western and north-western pan margins

Landscape Type IV and V: (denudation landscapes)

g: mountains or hilly terrain with smooth topography and a low degree of dissection
e: single mountains or hills, inselbergs, bornhards
ge: more strongly dissected mountain areas with dense drainage pattern; mostly deeply incised river valleys
z: granitic landscapes with rough surface topography; castle koppies and Granite boulders at the surface created by strong spheroidal weathering
r: structural hill or mountain ridges created by selective weathering of the strongly folded Sedimentites of the Khoabendus Group and partly of the Damara Sequence in northern Namibia; The ridges are formed by highly resistant Quarzites and Dolomites
er: like 'r', but appearing as single mountains (inselbergs)
p: footslope areas of single mountains/hills, inselbergs or mountain areas (pediment, glacis) with low degree of fluvial dissection
pe: fluvially dissected footslope areas with undulating topography
x: escarpment in a morphological sense, e.g. at the transition from the highveld plateau to the strongly dissected "Great Escarpment"
Landscape Type VI: (accumulation landscape)
s: dunes formed by aeolian sands
w: beach ridges ditto sands or gravel

all Landscape Types:
t: termite hills occurring regularly
v: high tree vegetation (high tree savanna or riparian forest)

3. GEOLOGY/LITHOLOGY

The geology/lithology is an important factor for the differentiation of relief and surface substrate. Lithology and geological structures regulate weathering rates, thus govern soil formation and the distribution of water and vegetation. The nomenclature is adapted from SACS (1980) and BUCH (1993). If a more detailed classification of the near-surface layers is necessary, the symbols are connected by a slash (e.g. 1a/2 = sands above Etosha Limestone). If a more detailed stratigraphic or lithologic differentiation of a geological formation is not possible, it is symbolized by the main letter listed below (in brackets).

Caenozoic Sediments and Calcrete (> 1 m deep) (H)
1a: sands, loose sediments
1b: calcrete

Kalahari Group (K)
2: Etosha Limestone
3: Andoni Sand-(3a)/Siltstone (3b)
4: Omatako Sandstone

Damara Sequence (D)
5: M ultrden Group: Quartzite, Phyllite, Conglomerate
6: Otavi Group: Dolomite, Tillite
7: Nosib Group: Sandstone Quartzite, Conglomerate

Khoabendus Group (K)
8: Kamdeshia Granite (G)
9: Kaross Granite (G)
O: Otjoovasandu Formation
10: Intermediate to basic Lava (Andesite)
11: Dolomite, Limestone, Marble
12: Slhist, Phyllite
13: white Quartzite
B: Blyerus Rhyolite Formation
14: Rhyolite, partly transformed to Granite
S: Smalruggens Andesite Formation
15: green andesitic Tuff, Andesite
W: West End Formation
16: Granodiorite, Granite, Pyroklastika
**Huab Formation (H)**

17: Basement Granite, Gneiss

**Etendeka Formation**

18: Basalt & Tuffite

**Examples for the coding of Terrain Mapping Units:**

II-h(v)-1a/3b  ◊ undulating plains with deep sands (>1m) above Andoni Siltstone, partly covered with high tree vegetation

IV-z-9  ◊ granitic hilly terrain (Kaross Granite) with strongly developed micro-topography (castle koppies, granite boulders)
Appendix B: Northern Grootberg Farms

1. List of DBASE files

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2. List of EXCEL files

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3. List of CorelDRAW files (also available as *.map in IDRISI)

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## Appendix C: Uvudhiya Constituency

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<td>bitmap</td>
<td>soil risk</td>
</tr>
<tr>
<td>uvusrwa.cdr</td>
<td>bitmap</td>
<td>combined soil, water and relief risk</td>
</tr>
<tr>
<td>uvusrwra.cdr</td>
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</tr>
<tr>
<td>uvuvege.cdr</td>
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<td>uvuwater.cdr</td>
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4. List of IDRISI files

Vector Files:

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<tr>
<th>name</th>
<th>type</th>
<th>description</th>
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<tbody>
<tr>
<td>roads_u.vec</td>
<td>lines</td>
<td>roads and tracks</td>
</tr>
<tr>
<td>sardep_u.vec</td>
<td>points</td>
<td>SARDEP Field Station</td>
</tr>
<tr>
<td>uvuhicou.vec</td>
<td>polygons</td>
<td>TMU polygons</td>
</tr>
<tr>
<td>uvuspl_u.vec</td>
<td>points</td>
<td>soil samples 1996</td>
</tr>
<tr>
<td>uvusr01_u.vec</td>
<td>lines</td>
<td>road survey 1996</td>
</tr>
<tr>
<td>veglocu.vec</td>
<td>points</td>
<td>veld condition assessment sites</td>
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<tr>
<td>water96.dxf</td>
<td>points</td>
<td>waterholes 1996</td>
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<td>water96u.vec</td>
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Image Files:

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<tr>
<th>real data (risk factors)</th>
<th>classified data</th>
<th>description</th>
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<tr>
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<td>TMUs raster file</td>
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<td>soil map</td>
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<td>soilmap.img</td>
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<td>water risk (lower and upper aquifer)</td>
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<td>wdist96r.img</td>
<td>water (quality, availability) risk values 1996</td>
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<td>flood risk</td>
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<td>vegetation risk, dry season '96</td>
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<td>rainfall risk, rainy season 93/96</td>
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<td>leris4.img</td>
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<td>leris5.img</td>
<td>combined soil, water, relief, rainfall and vegetation risk</td>
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<td>combined soil, water, relief and rainfall risk</td>
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