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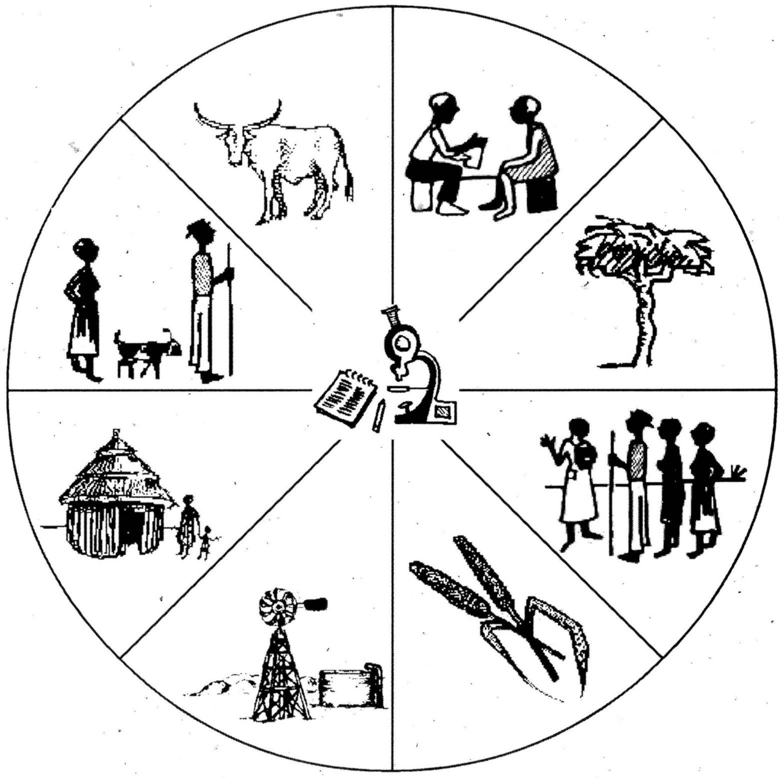
A PRELIMINARY ASSESSMENT OF THE LAND COVER AND BIOMASS VARIATIONS IN THE HUAB CATCHMENT

November 2000

By: D Mouton, T Mufeti and H Kisting



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A Preliminary Assessment of the Land Cover and Biomass Variations in the Huab Catchment

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Desert Research Foundation of Namibia, September 1997

TABLE OF CONTENTS

LIST OF MAPS, TABLES AND FIGURES

Maps

Tables

Figures

A. INTRODUCTION

1. BACKGROUND TO THE STUDY

Concern over the degradation of the Namibian environment has intensified with the event of Namibia's independence. This concern gained governmental support and was formalized in Namibia's Green Plan, an environmental policy framework prepared for the 1992 RIO, UN Conference on Environment and Development.

A world wide program to combat desertification was initiated as a result of the RIO Conference. Namibia localized the world wide initiative and NAPCOD, a joint initiative between the DRFN, MET and MAWRD with GTZ funding, was born (Walters, 1994;).

The objectives of NAPCOD in short are: (Walters, 1994)
- to raise national awareness of desertification
- to conduct a preliminary assessment on desertification, and
- to prepare a proposal for a long-term program to combat desertification.

To meet its objectives NAPCOD required information on the extent, rate, causes and costs of land degradation. Presently, this information is insufficient or non-existent. However, general agreement exists that land degradation has and is continuing to take place. It is also agreed that something needs to be done to halt and if possible reverse the process of land degradation.

A successful strategy to combat desertification in Namibia is crucial since about 75% of Namibia's population is based in the rural areas and is therefore directly dependent on the land for survival (Marsh et al, 1991; Quan et al, 1994; Wolters, 1994). With about 80% of Namibia's surface land classified as arid and semi-arid and with a highly variable rainfall pattern, natural conditions are conducive to land degradation (Marsh, 1991; Wolters, 1994). In addition the Namibian population is growing at 3% per annum which means that the demands on the available territorial resources will grow exponentially (Wolters, 1994). This growth in demand for land should be seen against the background of a loss in the productivity of land i.e. the number of people presently depending on a piece of land will need more and more land to sustain them in the future.

In its attempt to partially understand questions related to the extent, rate, causes and costs of land degradation NAPCOD commissioned the NRSC to conduct a study on land degradation in the communal areas of the Huab catchment.

The study on land degradation in the Huab catchment was justified for the following reasons:
The population consists of subsistence farmers who depend heavily on the land and natural resources for a living (Jacobson et al., 1995, Jobst et al., 1995). Farming is mainly based on livestock farming

and, in most cases, is assumed to have the characteristic of unsustainable land management practices. People are generally unaware of the relationship between land use practices and the perceived state of the natural resources (Jobst et al., 1995).

Although the population is relatively low compared to other areas in the country, it still appears that an increase in pressure has marked negative effects on the available resources (Jacobson et al., 1995).
The farms in the communal areas, with the exception of the Fransfontein Reserve, have had communal status since they were bought by the Odendaal commission to extend the communal areas in the Northwest (Damaraland) in the 1960s.

2. OBJECTIVES

The primary goal of the project was to assess the current land cover and study the possible occurrence of land degradation in a Namibian context.

The original objectives of the project were:
- development of a set of methods and material required for the implementation of land cover monitoring programs in various sites in Namibia,
- development of indicators of man-induced environmental degradation,
- development of contacts, materials and methods to extend the findings to those involved in and responsible for management of land resources on a national and local level.

These objectives were reformulated and adjusted to the following:
1. Develop appropriate methodologies and techniques for quick, but accurate assessment on land cover and land degradation.
2. Investigate signs of land degradation/desertification in the Huab catchment.
3. Create an opportunity for the development of staff at the NRSC as part of national capacity building in the fields of RS, GIS and natural resource assessments.

Although reformulated, the above still aimed at successfully addressing the original objectives of the study.

3. METHODOLOGICAL OVERVIEW

One of the objectives of the project was to propose a quick, but accurate methodology for studies on land cover and land degradation. This section on methodology will be limited to the overall methodology followed. Detailed discussions on methodology will be made under the respective sections where necessary.

The overall methodology of this project was quite simple. Initially the objectives of the study were clarified. This was followed by delineation of the study area . These two procedures were regarded as cardinal to the overall success of the project.

With the objectives clear and the study area identified, production work could start. Firstly, information requirements were clarified, which was followed by a mapping exercise in terms of land cover and land use. With this achieved, a change detection analysis using 1992 as a base year was done. Finally, the project attempted to propose an appropriate methodology for land degradation studies in Namibia.

METHODOLOGY

CLARIFY OBJECTIVES

DELINEATE STUDY AREA BOUNDARIES

IDENTIFY INFORMATION NEEDS

INFORMATION ACQUISITION

LAND COVER MAPPING

LAND USE ANALYSIS

CHANGE DETECTION ANALYSIS

RECOMMENDATIONS

B) ANALYSIS

1. INTRODUCTION

1.1. THE STUDY AREA

Map 1 is a map of the study area.

The study area is broadly defined as the entire catchment of the Huab river. The study was to be done on two levels: the entire Huab catchment for a general understanding of the catchment and selected pilot sites for more insight into land degradation. These are Engelbrecht farm (in the east) and the Twyfelfontein area (in the west). For better understanding and comparisons, attention was also given to the Fransfontein Communal Reserve and the Huab Nature Reserve.

Situated in the north western part of Namibia, the Huab catchment lies within the southern Kunene region. In total, the catchment comprises an area of about 14 800 km². According to Jacobson et al, 1995, approximately 62% (9 176 km²) lies within the communal farming areas.

1.2. CLIMATE

The study area can be regarded as arid to semi-arid with mean rainfall ranging from close to 0 mm in the far west to 300 mm or more in the east during some good rainfall seasons (Jacobson et. al., 1995). The catchment receives summer rainfall during the months of October to April, but most rain can be expected during March and April (Jones, 1993). High evaporation rates, ± 3 000 mm (Jones, 1993; Sullivan, 1994), variable temperatures, coupled with highly variable precipitation (**Figures 1 - 6**) are characteristic of the area. Indications from Sullivan that the average summer day-time maximum for Damaraland is between 22.5 - 27.5 °C and the winter night-time minimum is between 7.5°C and 10°C, also suggest a high diurnal and annual variation in the temperatures of the area.

Since rainfall is the crucial factor in the area, a more detailed discussion was thought necessary.

1.2.1. RAINFALL

Presently only four weather recording stations exist in the area. **Figures 1 - 6** depict rainfall data recorded at various stations in the area (Weather Bureau, 1997). Two of these stations are no longer in operation as can be gathered by the lack of data for recent years. **Map 2** depicts the distribution of these recording stations.

Rainfall recording stations are:

* Khorixas from 1955/56 to 1995/96 - town in the communal farming area.
* Fransfontein from 1942/43 to 1979/80 - communal village (no longer functional)
* Kakatswa Onguati from 1940/41 to 1963/64 - communal village (no longer functional)
* Kamanjab from 1941/42 to 1995/96 - town in the commercial farming area.

* Otjitambi from 1953/54 to 1995/96 - commercial farm.
* Cypress from 1975/76 to 1995/96 - commercial farm

Rainfall in the area is highly variable and highly unpredictable, both seasonally and spatially. Giving averages in terms of rainfall therefore has little meaning.

Rainfall isohyets for Namibia (**Map 3**) indicates that there is an east-west rainfall gradient from the commercial farming areas in the east to the pro-Namib and the Namib in the west. This rainfall gradient was supported during informal interviews with farmers.

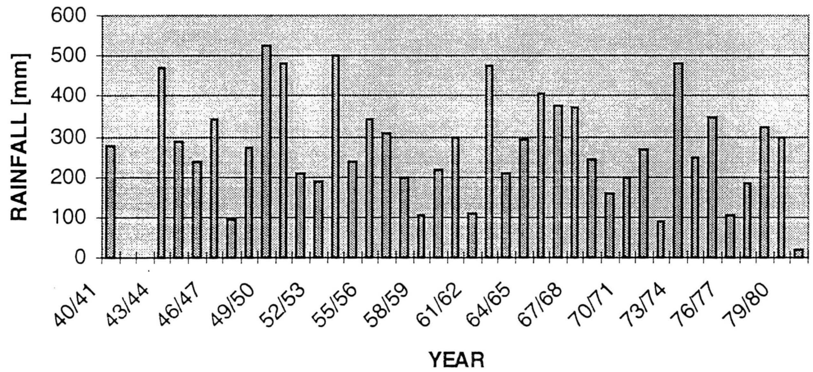


Fig. 2 RAINFALL : CYPRESS

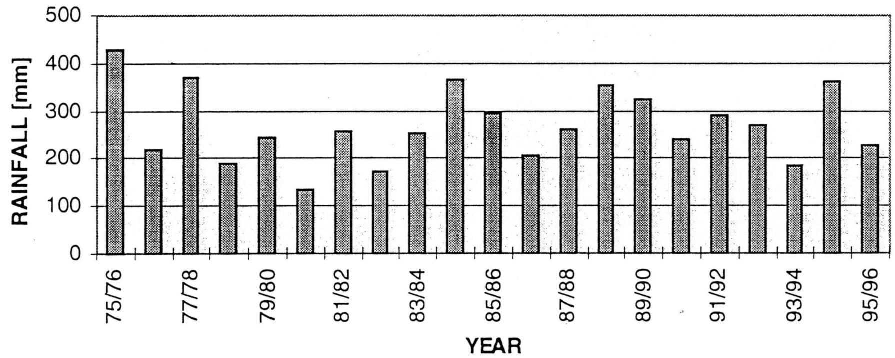


Fig. 3 RAINFALL : KAKATSWA ONGUATI

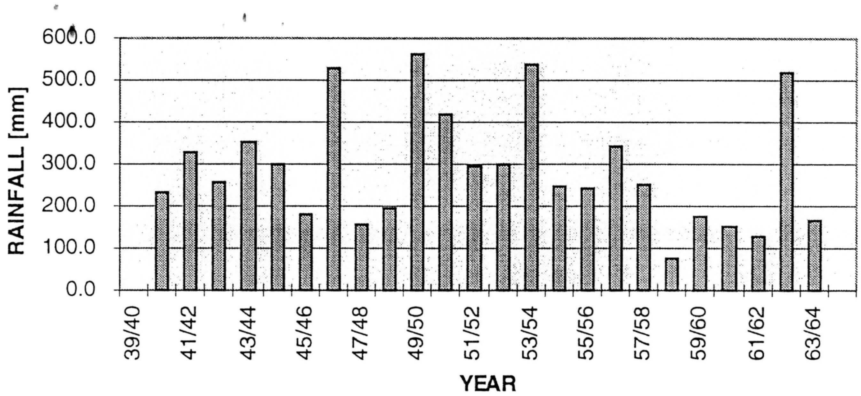


Fig. 4 RAINFALL : KAMANJAB

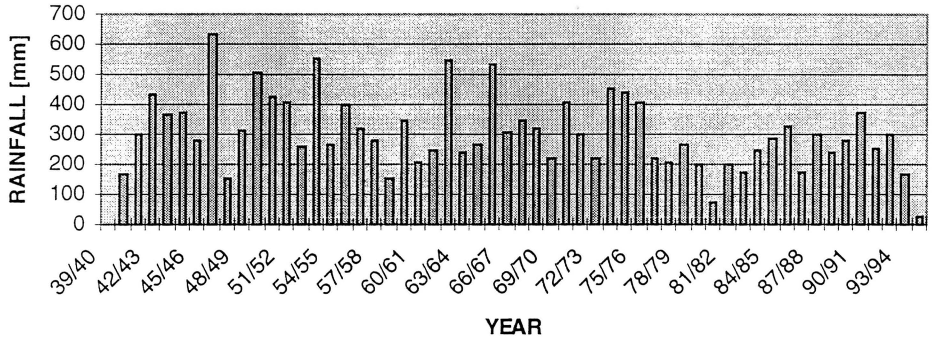


Fig. 5 RAINFALL : KHORIXAS

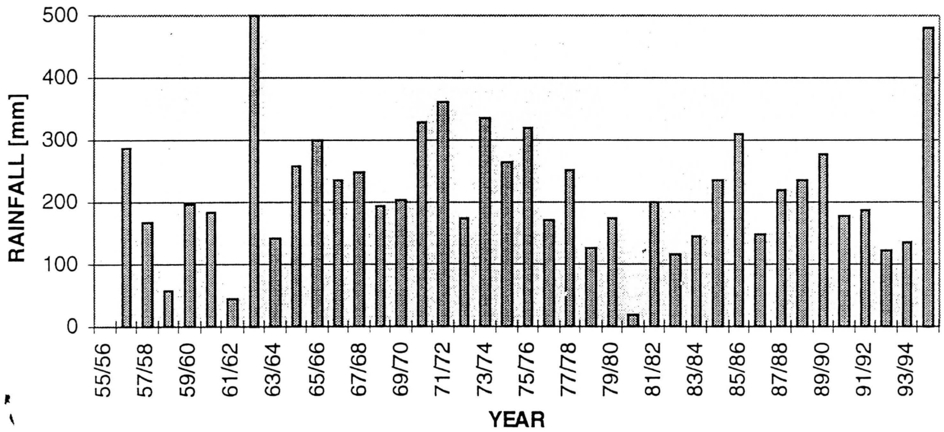
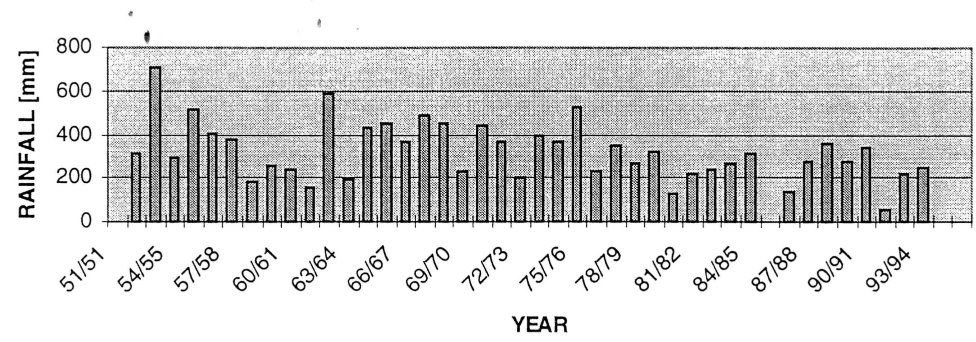


Fig. 6 RAINFALL : OTJITAMBI



1.3. POPULATION AND SOCIO-ECONOMICS

Data on population and socio-economics was derived from the 1991 Census for the Kunene region.

1.3.1. POPULATION

A total population of 64 017 was reflected in the Kunene region with a density of about 0.5 persons/km² during the 1991 Census. According to the Census data, about 12, 107 people stay within the catchment area. About 8 264 people are urbanized of which 7 358 are settled in Khorixas. The total rural population amounts to 3 843 and about 68% lives within the communal area. **Map 5** gives more details on the population in the area according to the 1991 Census.

1.3.2. SOCIO-ECONOMIC CONDITIONS

The region's literacy rate is estimated at about 51% and the study assumes that it is representative for the project area. About 82% of the population forms part of the labor force of which 63% has been reported as employed. Of this, ±48% is involved in subsistence agriculture. Thus, people in this area can be regarded as relatively poor, since not many of the employed population have highly paid jobs. Supporting this is the fact that only 14% of the households in the region has access to electricity. Thus, 84% of the households would have to rely on other energy sources, of which fuel wood appears to be the most dominant.

1.3.3. SETTLEMENTS

The primary settlement in the communal areas of the Huab catchment is Khorixas with a total of 7 358 people. Khorixas functions as a service center for the rural population in and outside the catchment. The second biggest center in the catchment is Kamanjab.

Other settlements that occur are farmsteads and villages which are sparsely distributed. Of these, Fransfontein, to the north of Khorixas and south of Kamanjab, is probably the biggest.

1.3.4. INFRASTRUCTURE

Khorixas and Kamanjab are connected to each other and to other major towns outside the catchment by well maintained tarred and gravel roads. Tertiary roads and tracks leading to individual farms and smaller communities are not so well maintained and sometimes require the use of four wheel drive vehicles. The towns of Khorixas, Kamanjab and the village of Fransfontein are supplied with electricity, but not all residents have access to the supply.

2. THE NATURAL ENVIRONMENT

2.1. LAND COVER MAPPING

2.1.1. METHODOLOGY

The land cover mapping approach followed in this study is a hybrid of the catchment and land unit approaches. Firstly, the Huab catchment was delineated as the area of interest. It was then divided into land systems. Land units within land systems were then mapped, based on vegetation, soil surface properties and terrain. Mapping land units was relatively easy, since the Huab catchment has a strong topography, clearly defining land units.

2.1.1.1. TOPOGRAPHIC INFORMATION

Topographic information, including the Huab catchment, was derived from the 1:1 000 000, 1:5 000 and 1:250 000 Surveyor General topographic maps and the 1:100, 000 Ephemeral Rivers Map. Only topographic features identified as essential for orientation were included. These include: **Main roads, Main centers, Tourist facilities, Land tenure and Farms in the catchment.** In addition, the existing database of the NRSC was used to supplement the information. The catchment boundaries were digitized from the 1:1 000 000 Ephemeral Rivers Catchment Study Map. Tourism sites and tracks driven during the field survey were recorded using a GPS. Digitizing was done using Ilwis. ArcInfo was used to refine and interpret spatial data.

2.1.1.2. LAND COVER MAP - IMAGE PROCESSING TECHNIQUES FOR LAND COVER MAPPING

A land cover map was produced using the 1992 satellite imagery in conjunction with data collected during field surveys in December 1995 and April 1996. Sampling was done on a reconnaissance level for the entire Huab catchment, while detailed sampling was done for selected sites (Engelbrecht farm and Twyfelfontein area).

Image analysis and production were done using Erdas Imagine 8.2. A Landsat TM 5 image of 1992 was used as the land cover mapping source.

The image was re-georeferenced to transverse mercator using 14°00E longitude and 22°00S latitude and bessel spheroid as the datum. For the purpose of land cover interpretation, a standard false color composite of bands 4, 3 and 2 were selected. These bands were displayed in band 4 as red, band 3 as green and band 2 as blue. The bands were visually enhanced to improve contrast and highlight changes in land cover.

Paper copies of the images were printed and used for preliminary interpretation. Interpretation of land unit boundaries were largely subjective and based on visually detected differences in color, texture, pattern, shape and size. Mapping units were preliminarily coded and areas that were thought to be the same received the same preliminary code.

Field research was undertaken to verify boundary delineation and to build descriptors for the mapping units. Preliminary mapping units that needed to be sampled were identified in the office before the fieldtrip.

2.1.1.3. SAMPLE SELECTION METHODOLOGY

Sampling was done at a reconnaissance level and consisted of both point and transect sampling. In this case, point samples were actually quadrate samples with an area of approximately 50 m x 50 m.
Transect samples in this study refer to those observations made either by driving or walking through mapping units in part or fully to obtain an overall assessment of vegetation and terrain characteristics. Point co-ordinates were also taken along these transect routes. Samples provided information on soil surface properties as well as species composition, structure and percentage cover of the dominant vegetation.

Sampling covered all the preliminary mapping units and representativity was influenced by accessibility and biases of the researchers. See **Map 4** for the distribution of samples within the mapping units and **Table 1** for the relation between sample points and the area of mapping units. The units which appear to be under-sampled compared to the percentage of area in relation to the total area of mapping units, were the ones where less variability was expected, where the natural environment was expected to be more uniform, e.g. mountainous and hilly terrain as well as the riverine environments. Other units may seem over-sampled, but those were the ones where a greater variability was anticipated.

An overall assessment of the vegetation and terrain/land forms were established through drive transects.

Mapping Unit	Number of units	Total Area (Ha)	% of Total Area	No. of Samples	% of Total No. of Samples
FmMx-Ri	3	71, 070	4	2	2
G-Pl	2	12, 886	1	3	4

So2Ac-Hi	17	168, 233	10	12	14
So2Cm-Hi	18	441, 031	27	12	14
So2MowG-Pl	31	357, 966	22	17	20
So2Mx-Pl	5	41, 372	3	6	7
Sv1G-Hi	2	46, 433	3	5	6
Sv1G-Mt	3	337, 210	21	2	2
Sv1Mx-Hi	13	65, 158	4	11	13
Sv2wG-Fp	17	56, 911	3	8	10
Sv2wG-Pl	3	39, 528	2	6	7
Total		1, 637, 796	100	84	100

Table 1 Relation between the area of mapping units and sample points.

2.1.1.4. SAMPLING METHODOLOGY

Procedures followed were similar to those suggested by Paul E. Loth, 1990, "The Landscape guided method for vegetation survey and mapping".

As previously mentioned, sampling took place during two reconnaissance field surveys in December 1995 (dry period) and April 1996 (after rainy season/growing period). During these field surveys the following were investigated.

* Soil surface properties such as surface color and surface texture.
  Surface colours were determined using the Munsell color chart.
  Surface textures were determined through the feel method.
* Structure, species composition, and percentage cover especially of the dominant vegetation cover were done. Where it was difficult to identify species, samples were taken in plant presses with field observation sheets for later identification with the help of the late Dr. M. A. N. Müller.
* Informal interviews were conducted to gather information on management practices, types of land uses, opinions of the local people regarding possible land degradation that may have occurred in the area, as well as their opinions on wildlife, especially elephants in the area.

2.1.1.5. CLASSIFICATION PROCEDURES

Terrain and vegetation classifications were done on the following basis:

Terrain

Five categories were mapped out:

Plains - Pl

Floodplains - Fp

Riverine/Riparian environments - Ri

Hilly terrain - Hi

Mountainous terrain - Mt

Vegetation

The proposed classification for the SADC Regional Vegetation Mapping Project was used as a guideline for classification, but was adapted to suit conditions in the study area. Changes were based mainly on the fact that the proposed classification was for studies on national and regional levels and also took into account the relatively low vegetation cover in the study area.

Vegetation Classes

Woodlands - F

Areas with >15m tree canopy cover and a height greater then 4 m.

Four sub-classes can be used:

Very open [v] : 1-4%

Open [o] : 5-19%

Medium dense [m] : 20-50%

Dense [d] : > 50%

Savannah/bushland - S

S1 - Savannah

S2 - Bushland

A vegetation structure with shrubs and bushes and less then 15% of the trees higher then 4 m.

Two main classes have been used:

Shrubland - 1 : < 2 m

Bushland -2 : 2 - 4 m

These are further divided into four sub-classes

Very open [v] : 1-4%

Open [o] : 5-19%

Medium dense [m] : 20-50%

Dense [d] : >50%

Bushland usually also included the less dominant shrub layer which exists in association with the more dominant bush layer.

Grassland

An area with predominantly grass cover and little (<1%) tree, shrub and/or bush cover. Exact cover estimates are not included.

Wooded Grassland

Grassland with sparse tree canopies (a cover of less then 5%), typically, single stemmed trees.

Dominant Species

Where one species dominated the vegetation association in a mapping unit, a code was assigned to it to differentiate it from other units where there was an equal dominance.

Cm – Domination of *Commiphora* species

Mo - Domination of *Colophospermum mopane*

Ac - Dominance of *Acacia* species

Mx - Mixed, more or less equal dominance of more then one species

Information gathered during the field trips was used to derive a fully classified image with 11 classes. **Table 1** gives some statistics on the number of samples per mapping unit. **Map 4** displays the distribution of sample points.

2.1.2. VEGETATION AND TERRAIN

2.1.2.1. VEGETATION

According to the classification done for the whole country by Geiss (1971), most of the catchment falls in the *mopane* savanna. The study has found that indeed there is a high prominence of *mopane* in the study area, but detailed investigation revealed that other associations and species are more prominent in parts of the catchment.

The catchment vegetation structure and distribution is largely determined by the distribution of rainfall and the availability of water. However, soil types and geology also appear to have an effect on this. Woodlands are limited to riverine areas with isolated distributions outside river courses. The upper catchment is characterized by more woody vegetation compared to the lower catchment which is poorly vegetated and characterized by shrubs, mostly annual (seasonal) grasslands, succulent species and barren areas.

Colophospermum mopane (on plains and small river channels) and *Commiphora* savannas (bushlands) on hilly terrains are dominating the woody vegetation of the upper catchment. Densities of these bushlands are much influenced by rainfall distribution and intensity whereas species composition is strongly dictated by soil and rock types. Grasslands in association with bushes dominate most of the plains and undulating hills.

The central part of the catchment (central plateau) is characterized by an increasing occurrence of *Acacia* species in association with *Commiphora* species on the hills. Plains and depressions are again dominated by *mopane*. More succulent species, like the *Euphorbia damarana*, also occur in this region.

A much more open vegetation structure (shrubs and bushes), associated with seasonal grasslands and barren areas dominate the lower parts of the catchment. Species in the lower catchment are adapted to the more arid conditions. Denser vegetation is only prominent along the main river and main tributaries and consists mainly of Mopane. The lower part of the catchment can be regarded as a transition zone from the semi-arid savanna to the desert vegetation of the Namib.

2.1.2.2. TERRAIN

The catchment has a very strong topography in general. In the upper catchment, gently undulating plains are characteristic, with ranges of low granite/schist hills. The central part of the catchment consists of repetitive ranges of low to high hills and forms part of the central plateau of the Huab catchment. Further west, the topography of the catchment becomes more defined, with comparatively higher hills and basalt mountains in the north-west and far west of the catchment. The western catchment also contains ranges of low and sometimes isolated hills with pediplains and poorly defined flood plains.

2.1.2.3. MAPPING UNIT DESCRIPTIONS

As previously mentioned, mapping units are based on vegetation and terrain characteristics. The following section briefly discusses mapping units. **Map 6** contains mapping units and descriptive codes.

So2Cm-Hi - Open *Commiphora* dominated bushland on hilly terrain

Terrain:

Ranges of low granite/schist koppies. Soils are generally shallow, reddish and coarse to loamy sands. Surface stones and boulders are commonly found.

This unit includes the hills of the northern and north-eastern parts of the catchment.

Vegetation:

Undulating and rolling hills are covered mainly by various *Commiphora* spp. with a cover density that ranges from mostly open to medium dense. This unit tends to stay homogeneous in terms of species composition.

Valleys and channels dissecting the hills are characterized by a combination of *mopane* and *Terminalia prunioides*. The grass cover consists of perennial and annual grasses with *Stipagrostis* sp., like *S. uniplumis*, the dominant species.

In general the unit consists of short bushes, 2-4 m high, with an estimated cover of 10-19%.

The list of dominant species and percentage cover found in this unit are:

Colophospermum mopane (10); *Terminalia prunioides* (7); *Combretum apiculatum* (4); *Catophractus alexandri* (4); *Acacia fleckii* (2); *Boscia albitrunca* (2); *Boscia foetida* (1); *Acacia reficiens* (1);

Acacia senegal (1); *Acacia mellifera* (1); *Commiphora multijuga* (1); *Sesamothamnus guerichii* (1); *Dichrostachys cinerea* (1); *Acacia erioloba* (<1); *Parkinsonia africana* (<1).
Grasses include *Stipagrostis uniplumis var uniplumis, Stipagrostis obtusa, Stipagrostis ciliata, Stipagrostis hochostetterana, Aristida meridionalis* and *Aristida adscensionis.*

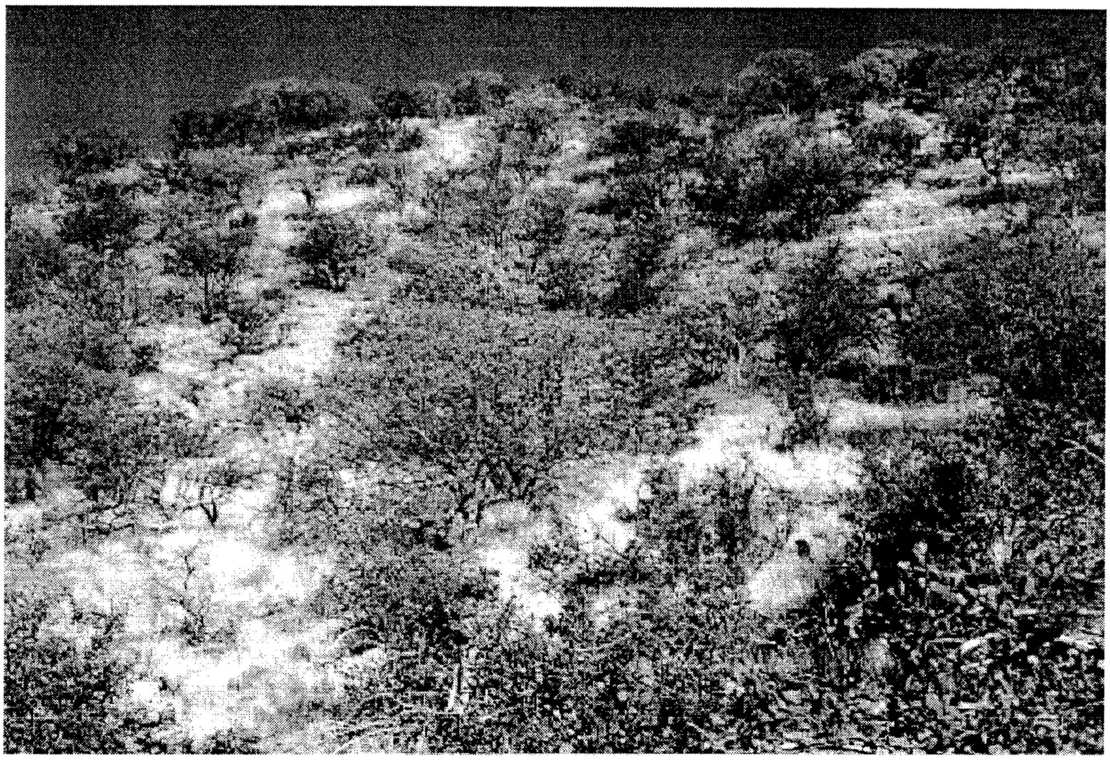


PLATE 1 - *So2Cm-Hi*

So2MowG-Pl - Open *mopane* dominated bushland with wooded grasslands on undulating plains

Terrain:

On these gently undulating and moderately dissected granite plains, soils are moderately deep to shallow, red to reddish brown loamy coarse sands to sandy loams. Poorly defined calcrete outcrops are found especially within channels and erosion scars. This unit is a complex of broad, undulating and sandy colluvial/alluvial plains and footslopes

Vegetation:

In terms of vegetation, it is an almost homogeneous unit, but is sometimes interrupted by small to big riverine woodlands and wooded grassland plains.

The unit is largely dominated by a mixture of bushes of different species with *Colophospermum mopane* most dominant in the unit. Patches of equally prevalent *mopane/Terminalia prunioides* bushlands are found, but are not so prominent. Isolated koppies and outcrops found in this unit are largely covered by *Commiphora* bushlands. Grass cover consists of both annual and perennial grasses with mainly *Stipagrostis* and *Aristida* species. The unit also includes patches of open *mopane* woodland (± 7 m) high mostly close to the rivers.

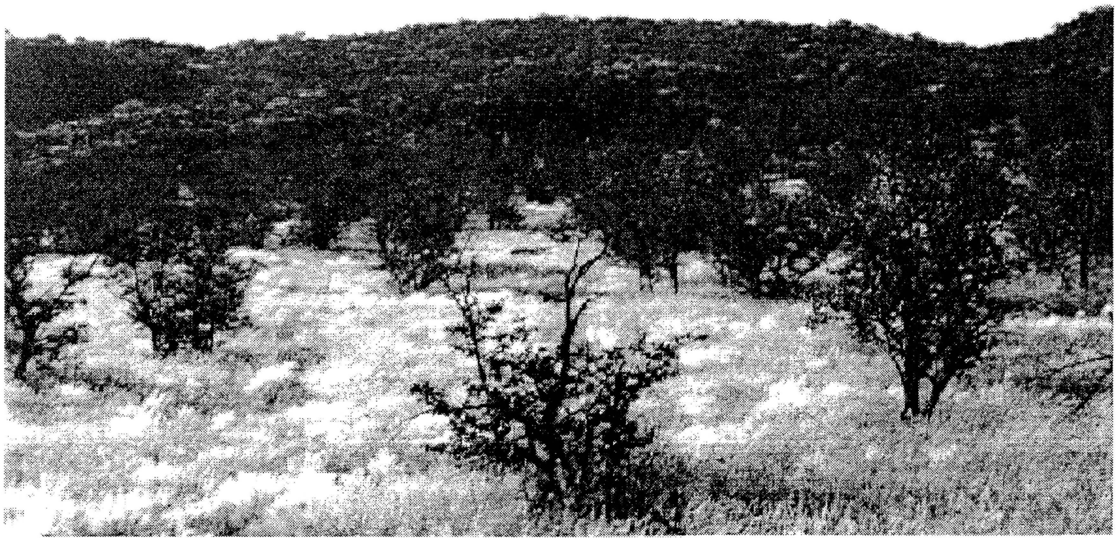


PLATE 2 - *So2MowG-Pl*

Dominant species found in this unit with percentage cover in brackets are:
Commiphora glaucescens (4); *Comm. multijuga* (4); *Comm. tenuipetiolata* (3); *Comm. anacardiifolia* (<1); *Comm. virgata* (<1); *Comm. merkeri* (<1); *Euphorbia guerchiana* (<1); *Terminalia prunioides* (3); *Combretum apiculatum* (2); *Colophospermum mopane* (2); *Boscia albitrunca* (1); *Acacia reficiens* (<1); *Ac. Senegal* (<1); *Grewia bicolor* (<1).

FmMx-Ri - Medium dense mixed riparian woodland

This is probably the most homogeneous unit throughout the catchment.

Terrain:

Occurs along the main river, main tributaries and larger channels. Well defined channels pass through the hills and plains of the catchment.

Vegetation:

River courses are lined with medium dense, tall trees making up the riparian woodland, which is the only distinct woodland found in the catchment. Density varies from medium dense to dense at some places with a percentage cover that ranges from 20% - 70% and an average height of above 7m. The species composition generally stays the same in the main river throughout the catchment.

PLATE 3 - *FmMx-Ri*

Species and percentage cover (in brackets) for this mapping unit are as follows:
Acacia erioloba (10); *Faidherbia albida* (10); *Colophospermum mopane* (7); *Combretum imberbe* (5); *Euclea pseudebenes* (8); *Salvadora persica* (8); *Adenolobus garipensis* (1) and *Maerua schinzii* (<1).

Sv1G-Mt - Very open shrubland with grassland on pediplains on mountainous areas

Terrain:

This unit is characterized by prominent high basalt mountains, steep slopes with moderately incised valleys and gently undulating pediplains. Soils are stony and gravelly, brown to yellowish brown. They are very shallow. The lighter, very gravelly materials occur at the lower slopes. Soils are generally found on rocks and calcrete. On pediplains, sandy clays and loamy coarse sands can be found.

Vegetation:

This unit forms part of a transition zone from the *mopane*, *Commiphora* and *Acacia* savannas in the upper catchment to the desert vegetation of the Namib. The vegetation is very open to bare in terms of woody species on the hills.

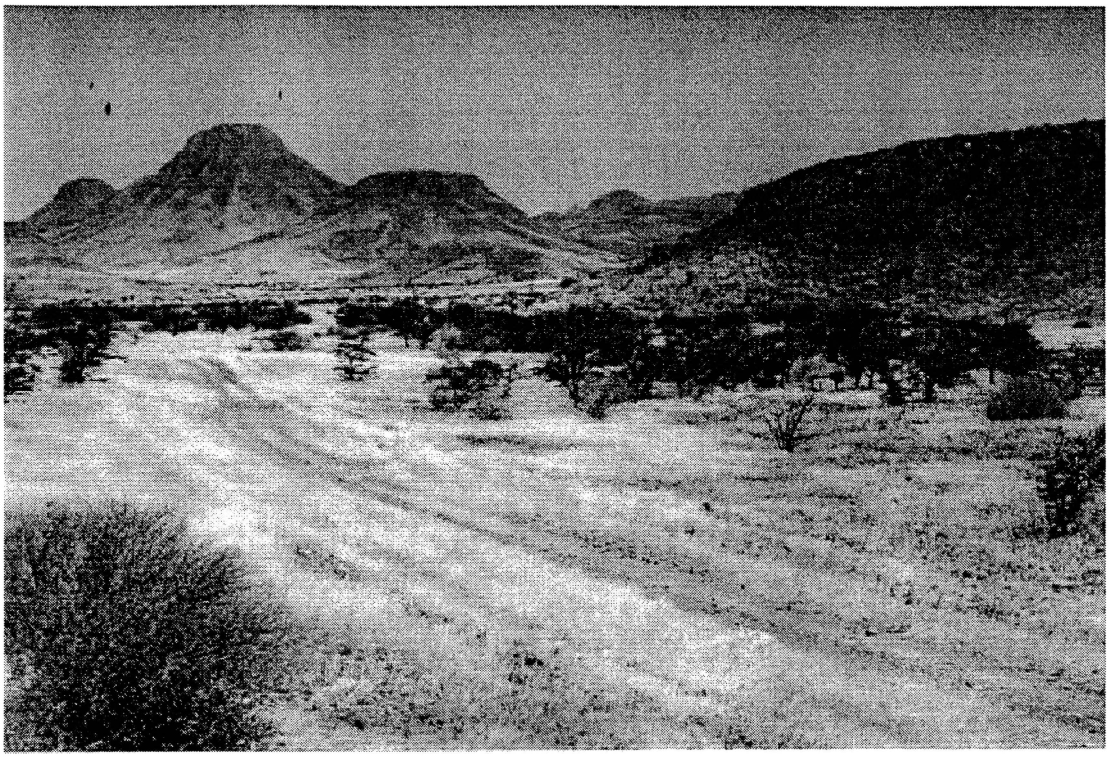


PLATE 4 - ***SvlG-Mt***

Pediplains and footslopes are dominated by seasonal grasslands and very open bushes and shrubs with an average percentage cover of <1%. Plains are dominated by *Euphorbia* spp., *Petalidium variabile* and a few *Acacia* sp. which are well adapted to the prevailing arid conditions.

Mopane and *Commiphora* species only occur sparsely along river channels whereas the central channels are mostly lined with *Blepharis gigantea*. The upper parts of the mountains are almost bare with very few *Euphorbia damarana* and *Petalidium variabile*. Several *Moringa ovalifolia* occur on these mountains.

Dominant species observed are as follows:

Euphorbia damarana (1); *Euph. mauritanica* (1); *Euph. virosa* (<1); *Euph. guerchiana* (<1); *Acacia reficiens* (<1); *Commiphora saxicola* (<1); *Comm. glaucescens* (<1); *Petalidium variabile* (<1); *Calikiorema capitata* (<1); *Blepharis gigantea* (<1); *Maerua schinzii* (<1) and *Moringa ovalifolia* (<1).

Grasses include, *Stipagrostis uniplumis, Stipagrostis obtusa, Stipagrostis ciliata* and *Stipagrostis hochsteteriana*.

So2Ac-Hi - Open *Acacia* dominated bushland on hilly terrain

Terrain:

A repetitive pattern of hills with slightly steep rocky slopes. The unit is in general, characterized by a clear broken topography. A prominent, dense, weakly incised drainage pattern prevails. Gently sloping alluvial/colluvial valleys and pediplains are found within this mapping unit. However, it is not possible to map out these at a reasonable scale and the unit should rather be seen overall as a complex, but homogeneous terrain.

Vegetation:

A mixed bushy vegetation, with the dominance of *Acacia* species which is variable across the unit. The height of the dominating bush layer varies between 2 and 4 meters with an average density of between 5%-20%. *Acacia* species and other species like *Euphorbia damarana, E. mauritanica* and *Petalidium variabile* which dominate these savannas, are generally well adapted to the dry climatic conditions. Whereas valleys and pediplains are equally dominated by *Acacia* spp. and *mopane*, the hills are dominated by *Acacia* and *Commiphora* species. A number of annual and perennial grasses are found on lower slopes and plains, mostly *Aristida* and *Stipagrostis* species.

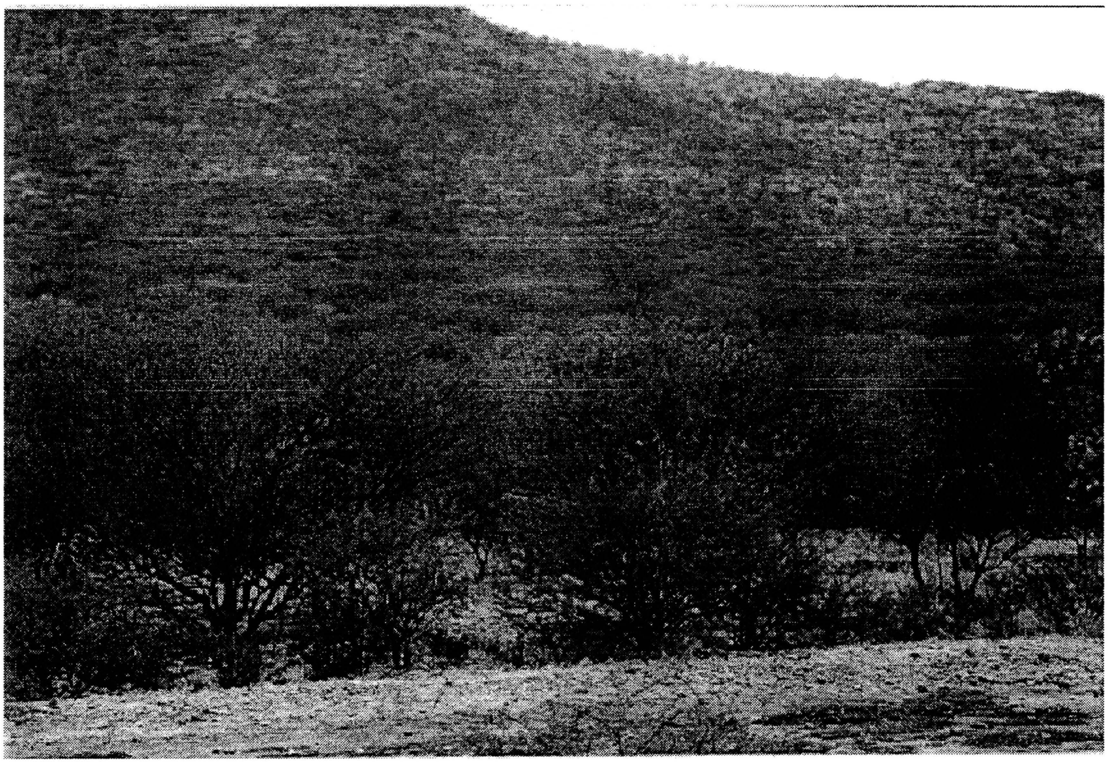


PLATE 5 - ***So2Ac-Hi***

Dominant species found in this mapping unit with percentage cover in brackets are:

Acacia reficiens (10 - 20); *Ac. senegal* (5); *Ac. mellifera* (3); *Ac. tortilis* (3); *Colophospermum mopane* (10); *Commiphora glaucescens* (4); *Comm. tenuipetiolata* (2); *Combretum apiculatum* (1); *Combr. imberbe* (<1); *Terminalia prunioides* (1); *Catophractes alexandri* (1).

Grasses include *Aristida* and *Stipagrostis* species.

Sv1G-Hi - Open shrubland, but predominantly a grassland on hilly terrain

Terrain:

This mapping unit is similar to unit Sv1G-Mt, but the hills are less mountainous. Soils are generally very shallow.

Vegetation:

In terms of species composition, a similar pattern as in unit Sv1G-Mt is also observed for this unit especially in the west. However, the vegetation in this unit is denser than in Sv1G-Mt. Since a large part of this unit lies in what could be termed a transition zone between areas of higher and lower rainfall, the boundaries for are not always distinct. To the east, a slightly higher density of *Acacia*, *Commiphora* and *mopane* species can be found, whereas it is more difficult to establish a clear association towards the west.

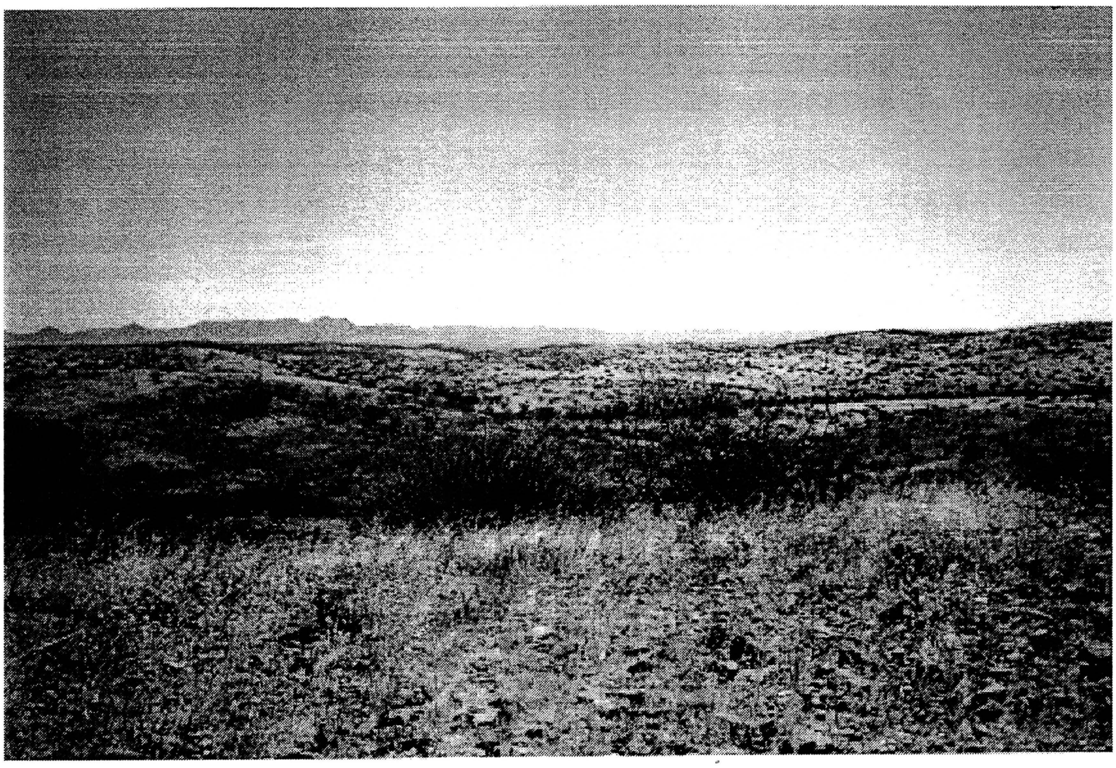


PLATE 6 - ***Sv1G-Hi***

Species and percentage composition for this unit are as follows:

Euphorbia damarana (1); *Euph. mauritanica* (1); *Colophospermum mopane* (1); *Acacia reficiens* (1); *Commiphora glaucescens* (<1); *Comm. saxicola* (<1); *Euphorbia guerichiana* (<1); *Euph. virosa* (<1); *Maerua schinzii* (<1); *Moringa ovalifolia* (<1); *Petalidium variabile* (<1); *Calicorema capitata* (<1) and *Blepharis gigantea* (<1).

Grasses include, *Stipagrostis uniplumis, S. obtusa, S. ciliata, S. hochotetterana* and *Aristida* species.

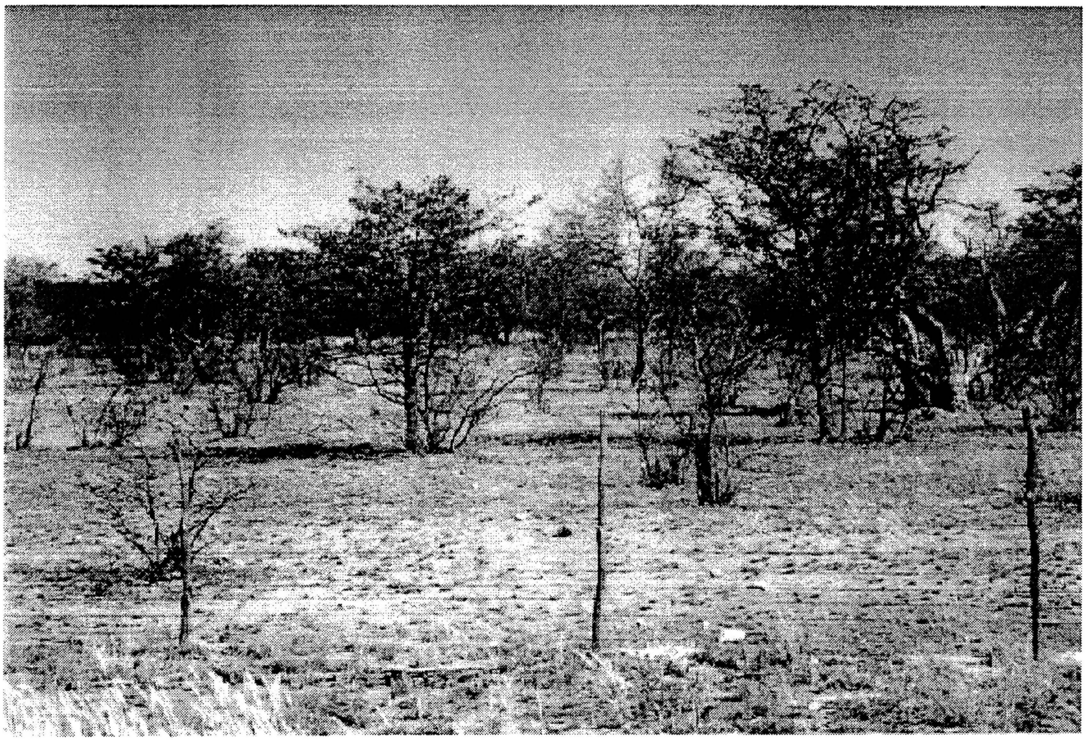
So2Mx-Pl - Open mixed bushland on plains

Terrain:

Well expressed alluvial deposits are provided mainly by the Kalk plateau. Soils are generally greyish brown and moderately deep, but sometimes shallow. Dark clays occur and can be associated with standing water like pans, dams, etc. Frequent calcrete outcrops and, to a lesser extent, low ranges of hills can be found in this mapping unit.

Vegetation:

Although the dominance of *mopane* bushes and trees have been observed in this unit, the *mopane/Acacia* and *Acacia/Commiphora* associations dominate several areas here.



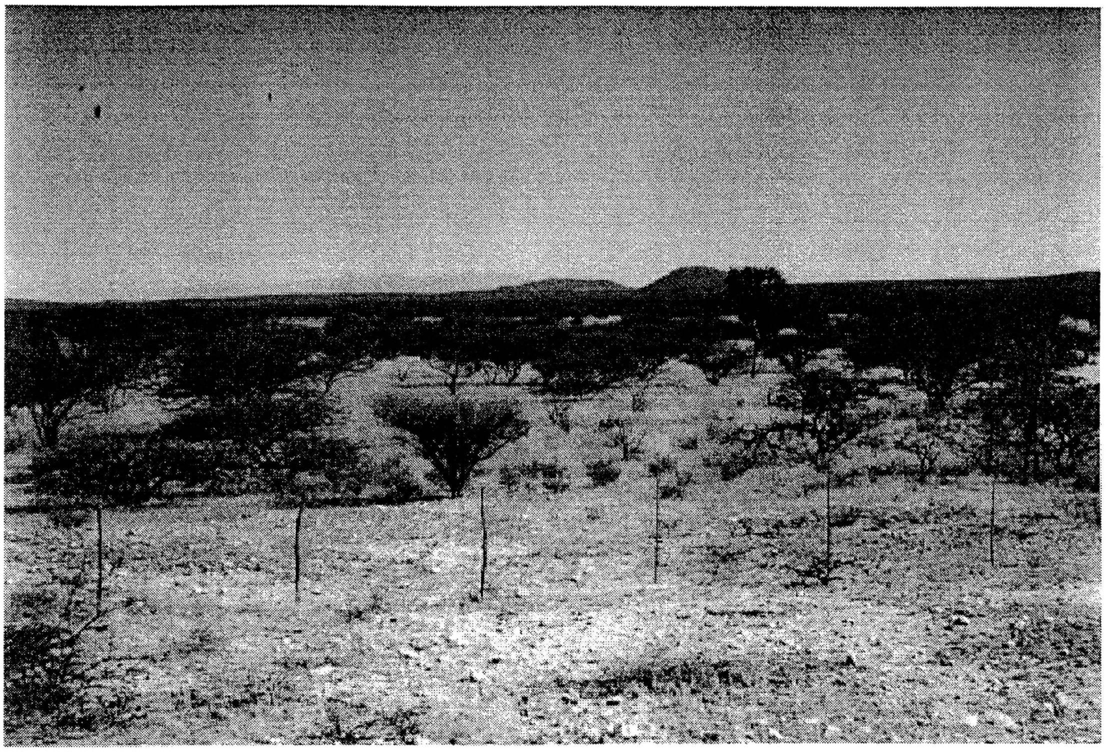


PLATE 7a & b - *So2Mx-Pl*

A diverse species composition can be found in this mapping unit with a combination of a few woody hills and open bushy plains. This diversity can probably be attributed to relatively higher rainfall compared to other areas in the lower catchment (more to the west). Although a number of calcrete outcrops occur, soils are generally less stony and the occurrence of darker, heavier soils in some areas could also contribute to the specific vegetation structure found in this unit. Although a total cover of about 15%-20% can be expected for this mapping unit, the vegetation could be denser further east. Species and percentage composition for this unit are as follows:
Colophospermum mopane (6); *Acacia reficiens* (5); *Ac. tortilis* (5); *Ac. Senegal* (1); *Catophractes alexandri* (3) and *Boscia albitrunca*(1).

Sv1Mx-Hi - Very open, mixed shrubland on hilly terrain

Terrain:
This unit has a very broken topography with steep rocky hills which are deeply dissected. Soils are shallow, stony, gravelly and greyish and there are areas of exposed rock.

Vegetation:
Vegetation is largely influenced by the low rainfall the area receives throughout the year.
Hills are open to bare, with very low, dwarf shrubs the predominant types of vegetation. The height of these shrubs varies between <0.5 m and 2 m and the percentage cover ranges from <1% to 4%.

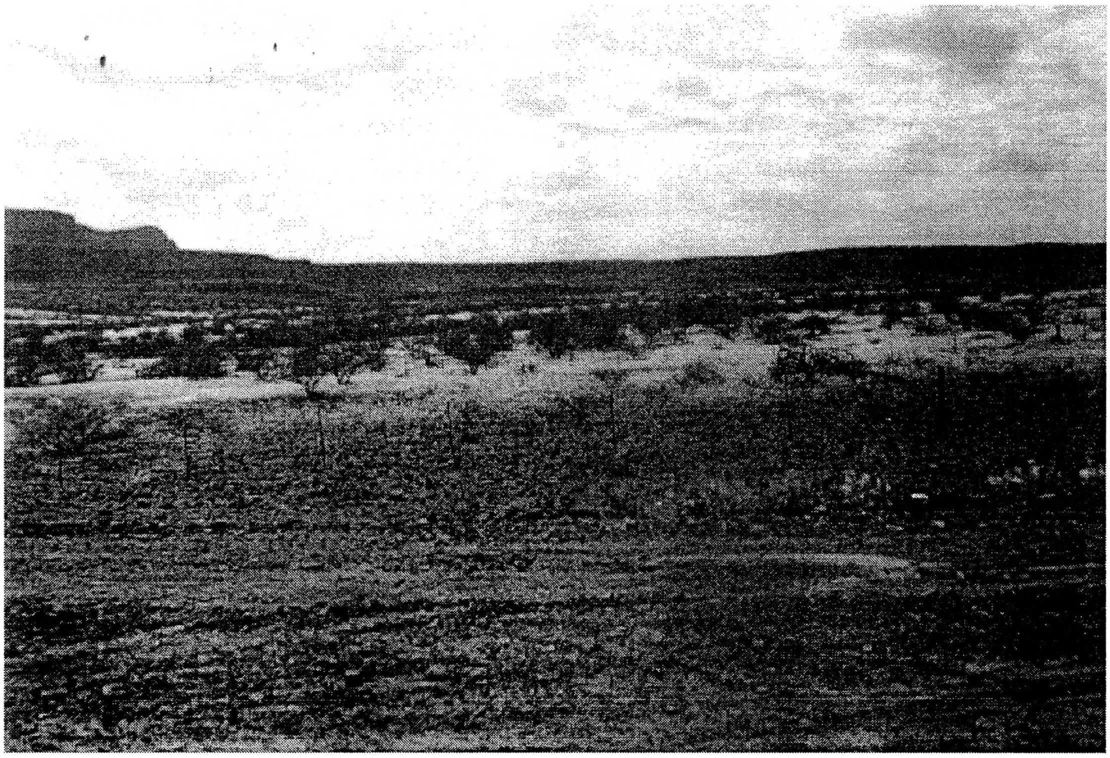


PLATE 8 - ***SvlMx-Hi***

While a few *Commiphoras* (*Comm. krauseliana, Comm. saxicola* and *Comm. virgata*) can be found on the hills, the smaller inter-hill plains are dominated by seasonal grasslands, *Euphorbia damarana* and *Petalidium variabile.* A few *mopane* shrubs occur infrequently, concentrated along channels and depressions. Species and percentage composition for this unit are as follows:
Commiphora kraeuseliana (1); *Comm. virgata* (1); *Comm. saxicola* (1); *Colophospermum mopane* (<1); *Petalidium variabile* (1); *Adenolobus pechuelii* (1); *Euphorbia damarana* (<1); *Euph. mauritanica* (<1) and *Zygophylum stapfii* (<0.5).

Sv2wG-Fp - Very open bushland to wooded grasslands on floodplains

Terrain:
Alluvial valleys and plains. Soils are moderately deep to shallow and consist of greyish to brownish sandy loams. Plains are moderately dissected by various channels, sometimes big and extensive. Ephemeral flooding might occur on these floodplains during heavy rainfall.

Vegetation:
Woody vegetation is centered along channels and is open to medium dense.

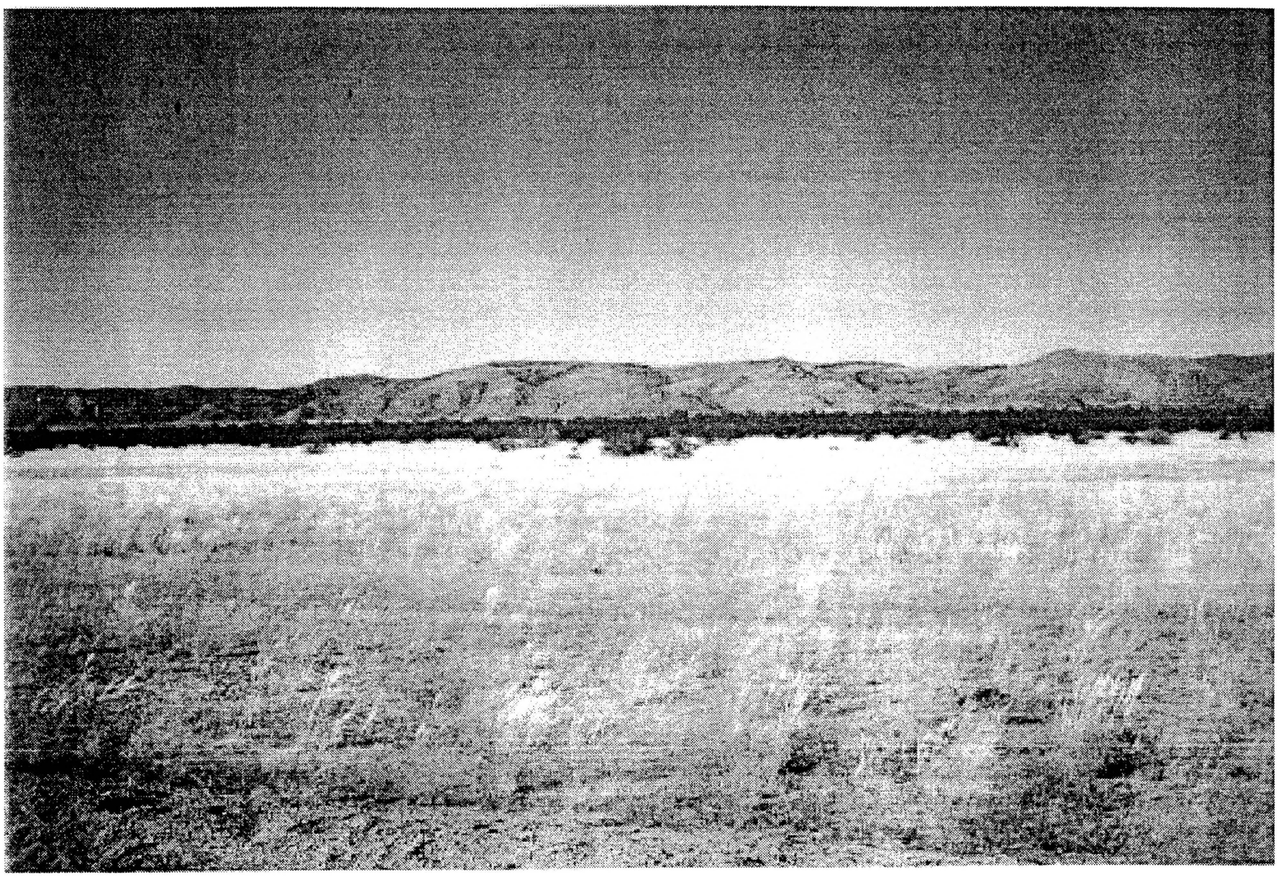


PLATE 9 - *Sv2wG-Fp*

Open *mopane* bushland with a percentage cover of <5% is found, with extensive seasonal grasslands, making up wooded grasslands. Grasslands consist of perennial and annual grasses and again the *Stipagrostis* species dominate. Species include: *Colophospermum mopane* (5-10); *Maerua schinzii* (<1); *Boscia foetida* (<1); *Bos. albitrunca* (<1); *Adenolobus garipensis* (<1); *Euphorbia damarana* (<1); *Euph. mauritanica* (<1); *Blepharis gigantea* (<1); *Calicorema capitata* (<1) and *Petalidium variabile* (<1). Grasses include *Aristida* and *Stipagrostis* species.

G-Pl - Grassland on plains and pediplains

Terrain:

These are broad plains of the western and south-western basalt mountains and the unit consists of gently undulating plains and pediplains as a result of alluvial and colluvial deposits. Soils are light brown to yellowish, coarse loamy sands and are moderately deep.

Vegetation:

Annual (seasonal) grasslands dominate the vegetation on these extensive plains with *Stipagrostis* species like *S. obtula* and *S. ciliala* dominating the grass cover. A few *Euphorbias* and dwarf shrubs occur sparingly. Open woody vegetation and low, dwarf shrubs occur only on or along river channels that dissect these plains. Species include *Euphorbia damarana, E. mauritanica, mopane* and *Acacia* species. Similar patches of these grasslands have been observed elsewhere in the lower catchment, but are too small to be handled as seperate mapping units.

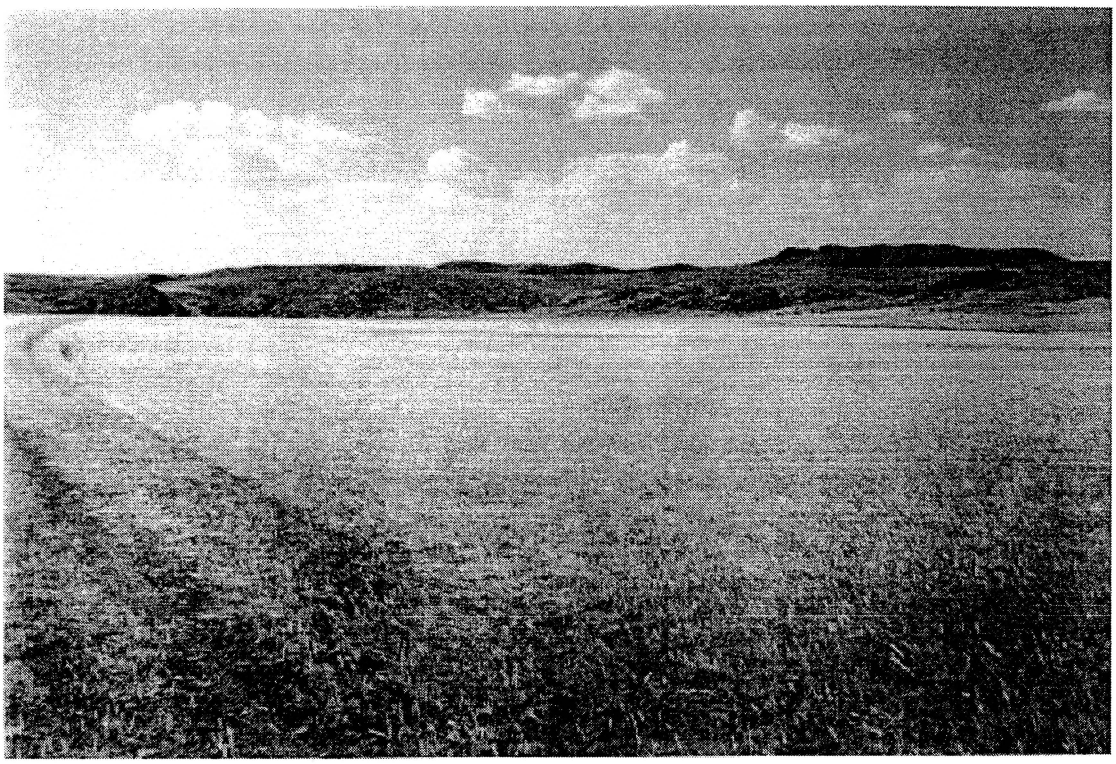


PLATE 10 - *G-Pl*

Grass species include, *Stipagrostis uniplumis, S. ciliata, S. obtusa, S. hochostetiana* and *Aristida* species.

Sv2wG-Pl - Very open bushland to wooded grassland on plains

Terrain:

Flat to gently undulating, granite plains with rock koppies and inselbergs. The plains slope gently towards river channels and rocky outcrops are common. Soils are coarse, reddish brown sands to loamy sands. They are moderately deep, but sometimes shallow. This unit is similar to unit Sv2wG-Fp, but far less dissected.

Vegetation:

This is mainly a grassland which also includes uniformly distributed *mopane* trees. These trees have an average cover of between 5% and less then 10% and can be regarded as very open. An average height of between 4 m to 6 m prevails. Trees are mostly single-stemmed.

This unit could also be classified as a very open *mopane* woodland in terms of structure, but due to the very low cover density, the grass cover remains dominant. The most dominant species is *Colophospermum mopane* (5% cover).

Grass cover is dominated by *Stipagrostis* species.

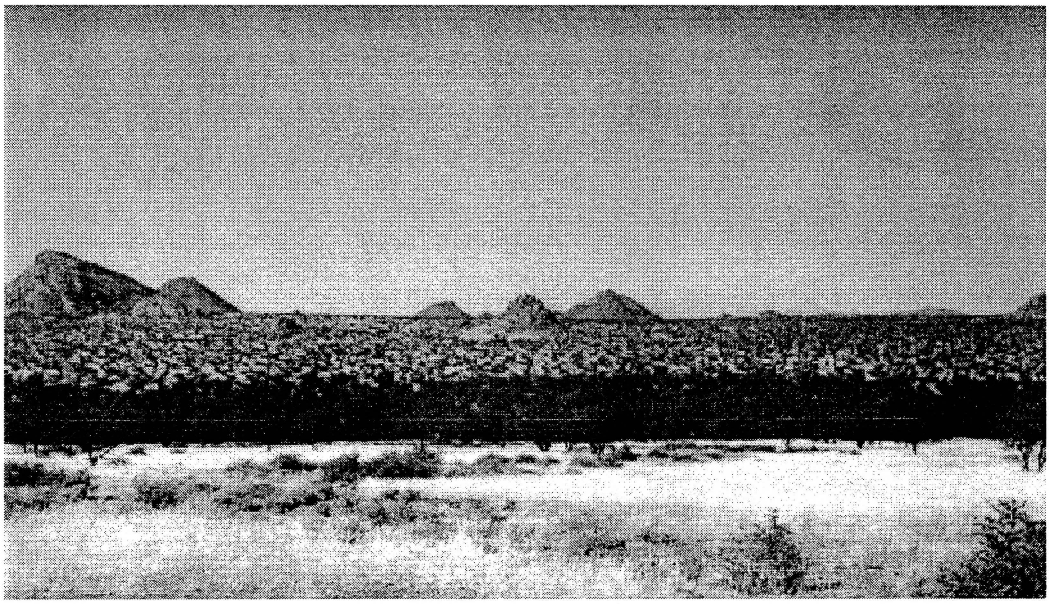


PLATE 11 - *Sv2wG-Pl*

2.2. LAND USE AND MANAGEMENT ISSUES

Two types of land uses can be found; (1) the uses with little/no direct economic benefits (no cash income), and (2) the uses with possible direct economic benefits (cash income).

1) Under the uses with little/no direct economic benefits are:

- Settlement areas
- Wood cutting/collection - as a source of fuel and energy
  - as a source of construction material for houses and possibly kraals
- Gardening
- Harvesting of animal products for household consumption, such as milk, meat, manure, etc.

Although no direct cash income is accrued from these, one should not underestimate their economic value.

2) The uses with more direct economic benefits include livestock farming and tourism related activities. Benefits accrued from livestock farming are the sale of animal products such as skins and the periodic sale of livestock to supplement income. Another source of income is the periodic sale of firewood in towns.

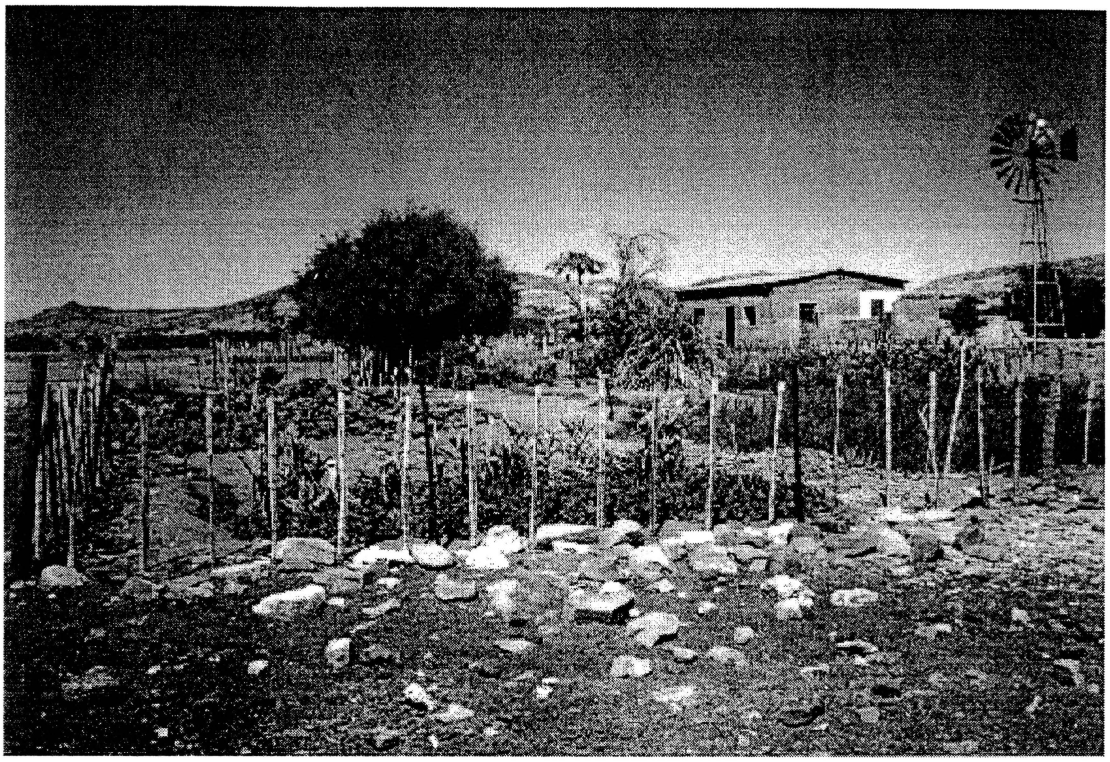


PLATE 12 -

A Typical household garden plot.

2.2.1. SETTLEMENTS

Villages are commonly found in the vicinity of rivers and on plains. It is around these settlements that most of the resource utilization occurs. Woody resources are used as an energy source and as construction material to build houses and sometimes kraals. Given that 84% of the population of the Kunene Region does not have electricity as a source of energy (Census, 1991), a high rate of wood consumption can be expected..

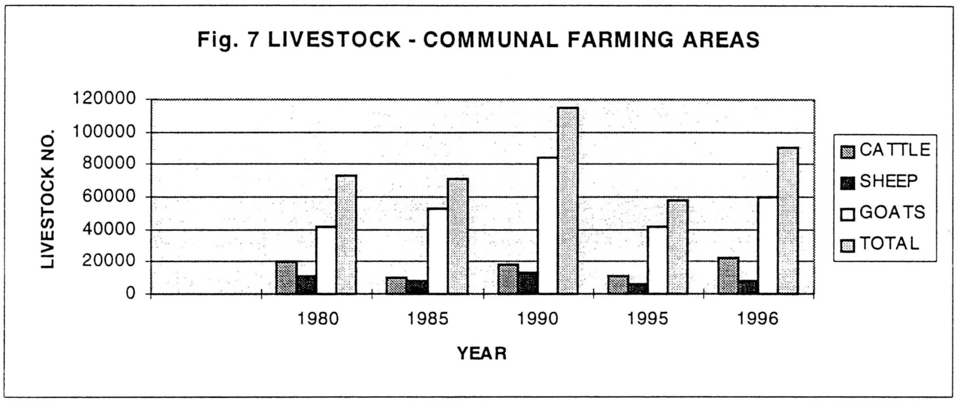
Closer to villages, woodlands are therefore heavily utilized. In addition, most of the grazing and browsing by animals occur in the vicinity of the villages within a radius of about 500 m to 700 m. This is clearly observed from the grazing tracks and clear browselines. Signs of intensive resource utilization near villages include felled trees, the absence of many young trees, absence of grasses and signs of soil degradation resulting from trampling and excessive stock movements. Garden plots are normally found next to the houses.

2.2.2. LIVESTOCK FARMING

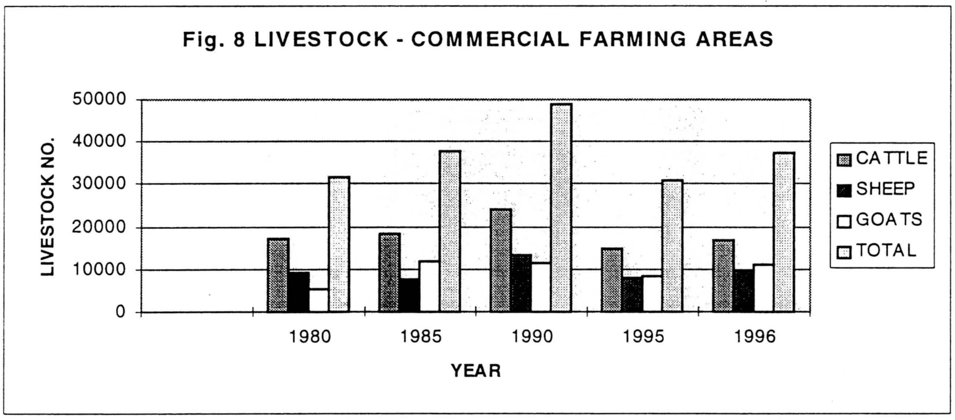
Most of the communal section of the catchment is subjected to extensive livestock farming, which is restricted to cattle, sheep and goats. In the west, livestock farming and tourism activities co-exist. Farming is practised mainly on a subsistence level. However, farmers are becoming increasingly commercial. This is especially true for farmers in the eastern part of the catchment where a strong influence is experienced from bordering commercial farmers.

All over the communal section of the catchment, goats appear to be the most dominant type of livestock kept by most farmers (**Fig. 7**). Cattle are more common in the moister, flatter areas, and especially in the upper catchment.

Livestock numbers in Damaraland have fluctuated over the years, but the last seven years have seen the highest numbers since 1972 (**Fig. 9**). There was a substantial increase in livestock number between 1995 and 1996 in the catchment as a result of higher rainfall (**Fig. 7**).

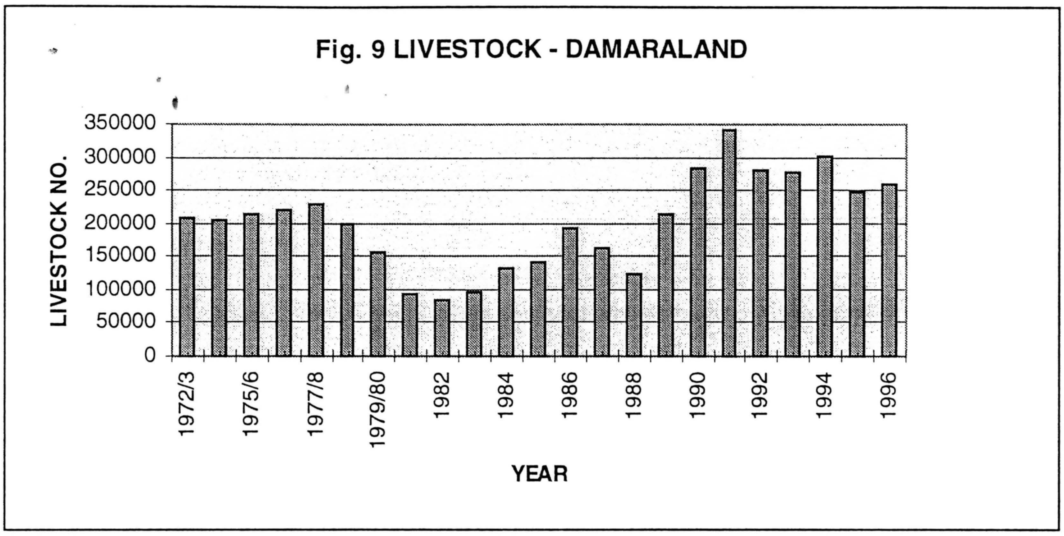


Source : District Veterinary Office, Outjo



Source: District Veterinary Office, Outjo

It appears that livestock trends follow a similar pattern to the rainfall in the area. **Figures 1-6** and **7-9** suggest that, with an increase in rainfall in a particular year, there is usually a corresponding rise in livestock numbers.



Source: Min. of Agriculture, State Veterinary Services, Windhoek

2.2.3. GRAZING MANAGEMENT

Grazing intensities are closely related to grazing potential, which varies across the catchment. In general, grazing intensity increases from west to east.

Common opinion has it that there are little or no management practices regarding livestock farming in communal areas. However, a limited amount of management is practiced here. This is not always ecologically sustainable as it is based on poor information and is limited in its potential for reasonable economic benefits.

Grazing management in the study area varies from community to community and it is difficult to find a general pattern across the catchment. However, farmers, especially in the upper catchment bordering commercial farming areas, have been influenced by neighbouring commercial farmers and are farming increasingly on a more commercial basis. As a result, they are using more assertive management practices.

From informal interviews and observations in the field, the following could be compiled on certain management practices found in the catchment:
At least one kraal exists in most communities. These kraals are of especially high importance to the farmers during the lambing seasons and when extreme climatic conditions prevail. In general, animals return to the villages frequently and in some cases every day. This is the case especially where the only drinking place is at the village or grazing is available close to the village.

In many cases dogs herd the animals, although herders are also used. Otherwise, the animals wander freely in the nearby surroundings. Farmers to the east (granite plains and hill ranges) have indicated that during good rainy seasons, animals usually graze on the plains and close to villages. As grazing depletes and it gets drier, animals move to the fringe areas of the plains for grazing and also browse on trees in channels and near the villages. During very dry periods, animals are either taken to browse and graze in the rivers or on the hills in the area. Sometimes a combination of both occurs. Browselines are commonly seen throughout the catchment, but occur mostly around villages. Some farmers indicated that they monitor the grazing condition in dry years and if necessary, reduce stock numbers accordingly. This is not a common practice however and mainly occurs among the larger-scale farmers. Restocking usually follows after good rains. Farmers also look for grazing elsewhere to relieve the grazing pressure during droughts.

Fewer people farm in the lower catchment. Here, animals graze and browse mainly on riparian or hilly vegetation. However, during the rainy season, grazing is concentrated preferably on plains and pediplains. Although a few people farm permanently in the lower catchment, it is common for other farmers to move into the area to search for periodic grazing. This is not an unusual practice in communal areas. Grazing is concentrated mostly in river beds. Farmers indicated that herds of various sizes are driven into the river where they graze and browse on riparian vegetation until the farmers are convinced that their own grazing has improved or when they migrate again. This could take from a week to several months (indication from local farmers).

At the moment a large part of the lower catchment which was inhabitated by quite a number of people in the past, has been deserted and is grazed periodically. At the time of the field survey, April 1996, the original farmhouse and the farm post at the farm Kröne as well as the farm post at Die Riet, were uninhabited. Only three people were staying at the original village of Die Riet, although this had once been a relatively large community center with a number of basic services provided.
Movement in and out of the area is not monitored, but such monitoring could provide valuable information regarding resource usage as well as for planning economic activities in the area.

No definite guidelines exist regarding the control of livestock numbers in the area. The Agricultural Extension Officer at Khorixas indicated that lower stocking rates had been suggested to farmers, but it was difficult to check whether these suggestions were followed. He also indicated that basic vaccination was done on most farms, but was not always consistent, especially when farmers had to make a contribution.

2.2.4. WILDLIFE AND TOURISM POTENTIAL

Efforts to promote tourism activities as an attempt to diversify the economic activities in the area have been initiated in the western/lower catchment. Here, at least two tourist sites have been established through community involvement.

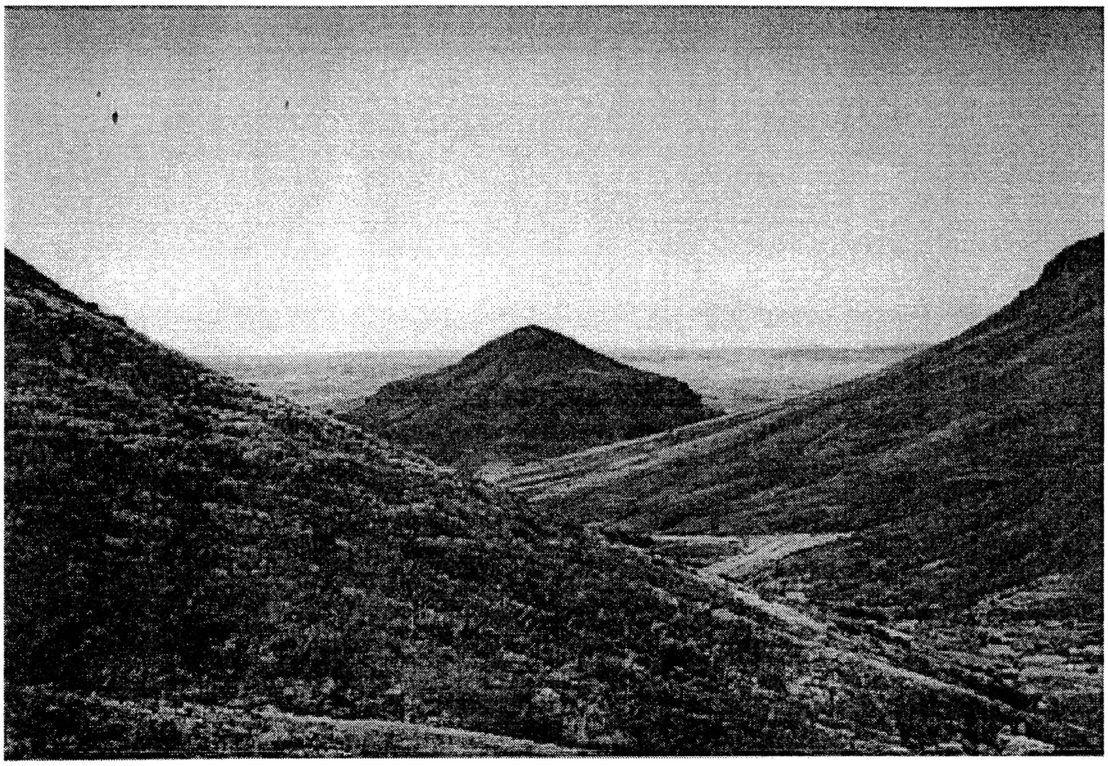


PLATE 13

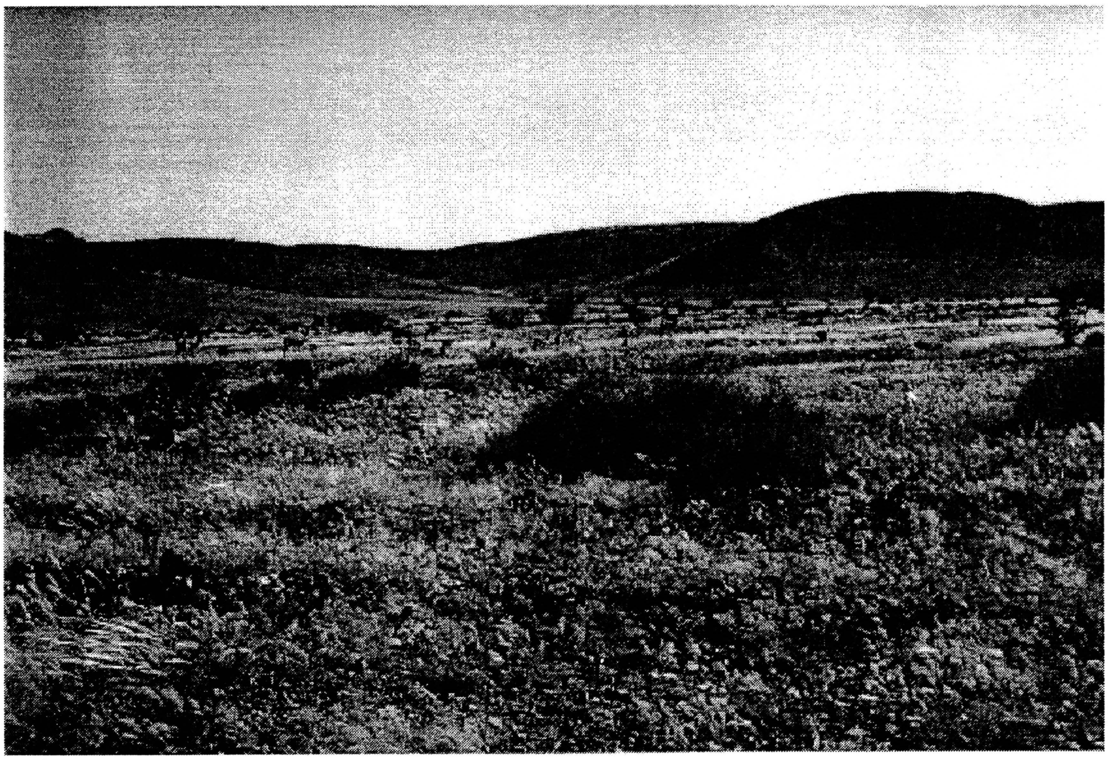


PLATE 14

PLATES 13 AND 14

Wildlife and Scenery - Two major tourist attractions in northwestern Namibia

The Aba Huab campsite is situated near the Twyfelfontein rock engravings and Verbrandeberg. It offers camping facilities to tourists passing through the area.

The Damaraland Camp is a joint venture between the Wilderness Safari Group and the Bergsig-Fonteine Community Development Trust. Overnight facilities and game drives are some of the services provided especially for the wealthier traveller.

During a survey done by the Huab Conservation Project, 1991, the following was found:
Farmers are generally willing to have wildlife in the area, but about 90% of the farmers interviewed did not want elephants on their farms. This is mainly due to the potential danger as well as the fact that elephants cause extensive damage to water holes, garden plots and other infrastructure. However, ± 89% of the interviewed farmers are interested in finding ways to benefit from the presence of wildlife in the area. Wildlife is commonly found throughout the catchment and include:
African elephant, black rhinoceros, Hartmann mountain zebra, warthog, giraffe, duiker, springbok, gemsbok, kudu and other smaller game. Wild cats include: cheetah, leopard, lion, caracal, and the African wildcat.

Wildlife, including elephants, roam and browse in the rivers, on hills and even sometimes on plains where fewer people stay. In the west (lower catchment), movement is generally freer, especially in the rivers. From informal interviews during this study (April 1996), it was gathered that people in the lower catchment are becoming increasingly aware of the potential tourism value of wildlife and especially elephants.

2.3. RESOURCE CHANGE ANALYSIS

2.3.1. CHANGE DETECTION ANALYSIS

In the original project proposal, a change detection analysis was to be done using aerial photography and low and high resolution satellite imagery.

Land cover mapping from large scale aerial photography would have been very useful, but it proved to be too time-consuming. One of the objectives of this study was to find easy and quick methodologies for land cover mapping and assessing land cover changes.

Due to the low vegetation cover and the coarse scale (1:75,000), only changes in the riparian vegetation would have been mapped out with a relatively high degree of accuracy and confidence if aerial photography was to be used. Consequently it would have been even more difficult to quantify changes in land cover from these photographs.

In terms of high resolution satellite imagery, data from the NOAA satellite was to be used. I attempted to do an overall assessment of biomass variations in the study area, using NOAA NDVI data. Due to the very coarse spatial resolution of NOAA (7.5 km x7.5 km and 1.1 km x 1.1 km) and the low vegetation cover in the Huab catchment, biomass assessment at the scale of the Huab catchment using NOAA NDVI data proved to be fruitless.

In the end, only data from the Landsat TM satellite was used for change detection analysis. Imagery from the Landsat TM satellite was identified as the most appropriate data source available for a number of reasons. Firstly the NRSC had a March 1992 image available. The timing of the data was good since March is the peak growing season for the region. In addition, the spatial resolution (30m x 30m) of TM was found to be suitable for change detection analysis at the scale of the Huab catchment. A March 1984 LandSat TM image was obtained to enable a change detection analysis.

2.3.2. IMAGE PROCESSING TECHNIQUES

In this section the primary objective was to produce a difference image using the 1992 and the 1984 images as inputs. The difference image was to give an indication on the areas of change.

It was decided to use band ratio images as inputs to the difference image to reduce some of the image illumination effects. A number of the standard vegetation indices (VI, NDVI, SAVI, MNDVI) were considered for this study. Previous studies have found that vegetation indices using the red and near infrared wavelengths in the calculation for above ground biomass in semi-arid and arid environments is of little use since these ratios only account for green vegetation and fail to account for the high reflectance of soil backgrounds. Vegetation in the study area has a percentage cover below 30% , which means that soil backgrounds need to be considered in above ground biomass assessment. A tasseled cap calculation confirmed the high reflectance of soils in the area.

The SAVI and MNDVI were developed and tested in semi arid and arid conditions and it was proved that they give a better representation of above ground biomass in these conditions since they account to some extent for soil reflectance backgrounds.

More suitable indices for semi-arid and arid conditions are the Perpendicular Vegetation Index and the PD54 index. Both these indices are based on the calculation of a soil line and as a result give better estimations on above ground biomass in these conditions. To successfully implement these indices, more ground work is needed and it was decided not to us these because the calculations are more complex and time consuming. In addition, staff at the NRSC had little experience in the application of these indices and there was a possibility of misinterpretation of results.

Having considered the shortcomings of indices based on the red and near-infrared wavelengths the SAVI was accepted as suitable for the purposes of this study since the project was not required to quantify above ground biomass as such. It was assumed that should there be significant changes in land cover, these changes would be recorded in the difference image using the 1984 and 1992 SAVI indices as inputs. However, a few shortcomings have been identified regarding the SAVI analysis in this study.

* With the relatively low vegetation cover in the area and the consequent high amount of exposed soils and rock, it is suspected that, even with its ability to reduce the reflectance of soil and exposed rock, the SAVI would not be able to fully detect biomass and biomass variations in the study area.
* The SAVI does not account for degradation features such as erosion and bush encroachment. Remarks in the report regarding this are therefore based only on observations made during the respective field surveys.

To support the findings of the SAVI analysis, two additional analyses were done to 1) show areas of various magnitude of change and 2) show areas of various landscape stability.

2.3.3. CHANGE ANALYSIS TECHNIQUES

2.3.3.1. CHANGE VECTOR ANALYSIS - MAGNITUDE OF CHANGE

In principle, change vector analysis should explore both the direction and magnitude of change between two images for different years under study (Michalek et al., 1993; Tyson, 1997). Due to certain limitations, analysis was only done on the magnitude of change in the Huab catchment over the two years of study.

Michalek et al. and Tyson claim that the magnitude of change should show areas of greatest change. This however, does not give an indication of whether the change has been positive or negative.
The procedures involved in finding the magnitude of change were as follows (Bands 3, 4 and 5 are used in this analysis):

- Difference images are produced for each band over the two years of study.
- Each difference image is squared and then all are summed.
- A supervised classification is done on the summed image based on critical classes from pixel histograms.
- Based on these, the images are classified into three classes, denoting areas of low, medium and high change.

In a study in the Kalahari, the idea of change vector analysis proved useful to establish direction and magnitude of change (Tyson, 1997).

2.3.3.2. SOIL ADJUSTED VEGETATION INDEX (SAVI)

Formula: SAVI = (1+L) x (NIR - R) / (NIR + R + L)

Where: NIR	=	Near Infra-red band
R	=	Red band
L	=	Constant introduced to account for the high soil reflectance.

The 1992 image was visually enhanced for maximum contrast in land cover . The enhanced image was filtered through a 5x5 spatial low pass filter to smooth it

For the 1984 image, the same image enhancement procedures done on the 1992 image were followed. The images were then geometrically corrected to each other. SAVI indices were produced for both the 1992 and 1984 images.

A difference image (**Map 9**) was created by subtracting the 1984 SAVI from the 1992 SAVI, i.e. 1992 - 1984 = difference image. In this case, positive values indicate positive change, i.e. there was more vegetation in the 1992 compared to the 1984 image. Negative values indicate areas of negative change, i.e. there was more vegetation in 1984 compared to the 1992 image. Values close to 0 indicate areas of minimal change.

2.3.3.3. MOVING STANDARD DEVIATION INDEX (MSDI)

MSDI is a stability index measuring variations in the landscape (Tyson, 1997). The underlying principle here is that a high standard deviation correlates to a high entropy value for the natural environment, thus indicating a higher degree of instability. Higher instability would normally mean that the area is susceptible to land degradation. The MSDI for the Huab catchment was calculated using LandSat TM **band 4** for 1992. This image was then classed into three classes of low, medium and high stability, based on pixel histograms.

2.3.4. AREAS OF CHANGE

Refer to **Maps 7 - 9** for the **SAVI** analysis done on the respective TM images as well as that for the difference image.

Area 1: Commercial farming area

According to the difference image, there has been a positive change in vegetation in the commercial farming area in general. This could have been brought about by encroaching bushes and does not necessarily mean an improvement in the forage quality of the commercial farming area. The magnitude of change analysis (**Map**) revealed that this is also the area where the highest degree of change occurred.

Area 2: Communal farming area

The communal farming area show indications of less biomass for 1992. These negative changes are especially apparent on the plains. However, the mountainous areas are showing less change. This pattern was partly expected since animals are concentrated on these plains for the greater part of the year. Large areas of the communal section show little change.

According to **Map** , the magnitude of change within the communal areas varies mostly between low and medium. Thus the impact of changes is expected to be less then that in the commercial farming areas. The mapping units which show the most change appear to include the plains in this section of the catchment.

Area 3: Riverine woodland.

Along the river more distinct negative changes can be detected. The decrease in biomass is especially clear in the communal farming area. This distinctly negative change can be attributed to a number of causes including tree cutting and tree die-off and retarded growth as a result of less water in the Huab river.

No clear pattern can be observed regarding the magnitude of change in the riverine environments. The following section will systematically discuss the primary factors that could have contributed to the changes detected in the Huab catchment.

2.3.5. CHANGE ANALYSIS : RESULTS AND DISCUSSION

Factors that could explain the pattern of biomass change detected in the difference image include:

1. changes in rainfall
2. changes in livestock numbers
3. differences in land use and management practices.

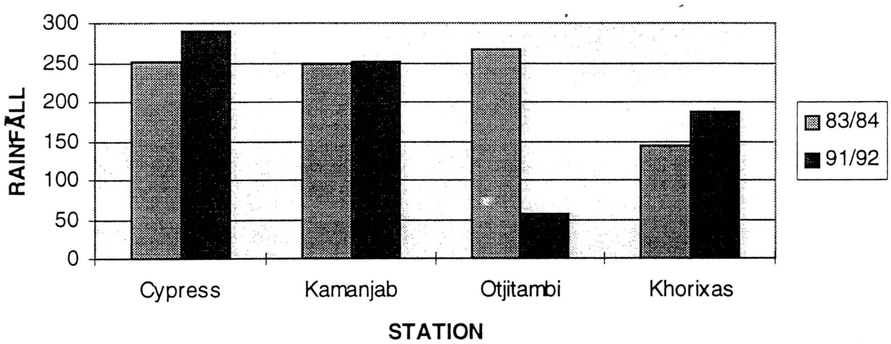
2.3.5.1. RAINFALL

Comparing the rainfall statistics for the years under study (**Fig. 10**), one can conclude that there was little difference in terms of rainfall.

Rainfall figures for Kamanjab and Khorixas showed only relatively slight increases in precipitation for the 1991/1992 rainfall season, while the station at Otjitambi (commercial area) recorded a rainfall figure less than the average. In addition, no dramatic variations in precipitation occurred between 1984 and 1992.

From the limited rainfall data available, it therefore appears that changes in biomass cannot be attributed to rainfall variations between the two years of the study.

Fig. 10 RAINFALL : 1983/4 AND 1991/2



Source: Weather Bureau, Windhoek

2.3.5.2. LIVESTOCK NUMBERS

Figures 7 and 8 indicate the variations in livestock numbers for both communal and commercial (Outjo veterinary district) areas. Also, see **Fig. 9** for the variations in livestock numbers in Damaraland.

According to these figures, there has been an increase in the three major livestock types - sheep, cattle and goats, for both the communal and commercial farming areas. The increase in livestock numbers in the communal area is much more dramatic than in the commercial area. In the communal areas, although there has been an increase in sheep and cattle, it has not been as distinct as that of goats.

The dramatic increase in livestock numbers and the subsequent increase in grazing and browsing pressure in the communal area can partly explain the negative changes in biomass recorded for the communal area. Browsing and grazing pressure is focussed on the riverine environment during the dry seasons and in drought years. As a result, biomass along the Huab river has little time to regenerate and the negative change in biomass is therefore more distinct.

2.3.5.3. DIFFERENCES IN LAND USE AND MANAGEMENT PRACTICES

Most inhabitants of the communal area rely on wood as a source of energy and construction material. The uncontrolled cutting of trees to fulfill these demands has lead to a reduction in woody biomass. Uncontrolled cutting of trees occurs particularly along the Huab river. This further explains the distinct negative change of biomass along the Huab river.

Another factor that could have contributed to the overall negative biomass change in the communal area is the communal tenure system which makes it difficult for farmers to implement sustainable management practices.

The uncontrolled construction of farm dams (**Map 10**) in the upper Huab catchment also contributes to a distinct change in biomass in the lower Huab catchment, since less water is available for trees along the river. The large number of boreholes in the area (**Map 11**) exacerbates this.

2.4. PILOT SITES

More detailed studies at pilot sites had the main objectives of verifying the existence of land degradation and the observed manifestations thereof.

2.4.1. ENGELBRECHT

This is one of the farms bought by the Odendal Commission to expand the communal areas in the 1960's. Eleven households with approximately three persons per household (school going children excluded) reside at the main farmstead. Another community lives at the farm post situated to the north-east of the main village. These two communities live and farm separately and should not be regarded as one, even though they both occupy land on the farm Engelbrecht.

2.4.1.1. LAND USE AND MANAGEMENT

Apart from the vegetative cover, the general land cover types are: houses, kraals and boreholes.
Residents rely mainly on natural resources for their livelihood of which both intensive (around the village) and extensive (in and around the hills) livestock farming form the main contributor. Other uses of natural resources include fuel wood collection, the use of tree trunks and branches as construction materials for houses and kraals, the use of animal products such as milk, meat, skins and manure for household consumption and household gardens. It is mainly the *mopane* tree that appears to be used for construction purposes. Farming is practised largely on a subsistence level.

2.4.1.2. FARMING

Stock includes cattle, goats, sheep, donkeys, horses and poultry. He following are some results from informal interviews conducted during the study:
All farming activities are managed from the villages and no posts are in use. Kraals do exist around the villages which indicates that some management is practiced. These kraals are of special importance during the lambing season and during extreme climatic conditions. Most fences still existing, originate from the commercial farming era, but are not used by the farmers to enforce a specific management strategy.

Farmers at both villages practice some grazing control. Stock usually grazes near the settlement in good years. However, as grazing becomes depleted, stock shift to the edges of the plains and the lower slopes of surrounding hills. Animals are forced to move up the hills for grazing only in very dry periods. In general, goats appear to have little problems because of their good browsing ability. Villagers claim that, in general, they do not experience many grazing problems (re: interview).
One farmer at the main village(who appears to be more influential) indicated that he moved his livestock to the Hereroland communal areas in the 1980s when they were hit by a severe drought. Livestock is also sometimes moved to nearby "farms" where better grazing is available at that specific time.

During the study, through observations and informal interviews, it was found that animals also graze and browse in the river channels. Pressure on this riparian vegetation usually increases during drought periods and together with the harvesting of trees may cause problems in the future regarding the regeneration patterns of this vegetation.

Mopane trees are generally heavily browsed especially by goats. *Mopane* and *Commiphora* trees and bushes as well as *Faidherbia albida* are browsed by elephants. The pods from the *Faidherbia albida* are also of great nutritional value for livestock. Grasses on the plains are grazed heavily, especially near the villages. Areas that experience the highest grazing pressure can be found in a radius of 500 - 700 m from the villages.

Only one borehole is available at each village. However, an elephant drinking place has been established near the main village because of the damage done to the infrastructure by elephants when they visit community water points.

2.4.1.3. LAND DEGRADATION OBSERVED

Signs of land degradation, although significant at some points, are not easily quantifiable. As previously mentioned, permanent land degradation is more conspicuous within a radius of 500-700 m around the settlements. Further away, it becomes temporal and difficult to observe. Temporal signs of land degradation on the plains and hills disappear after good rains. After the rains, land degradation can be assessed to some extent by the response of the vegetation.

Land degradation is a result of several factors relating to uses such as settlements, stocking, harvesting of veld products such as firewood, etc. Degradation around the water points is obvious and expected. Signs of land degradation include the following:

A) Obvious **browselines** in the channels and river and near the villages, indicating the occurrence of selective browsing. This is also an indication that the grazing resources, mainly grasses, are depleted often and have to be replaced by a browsing source.

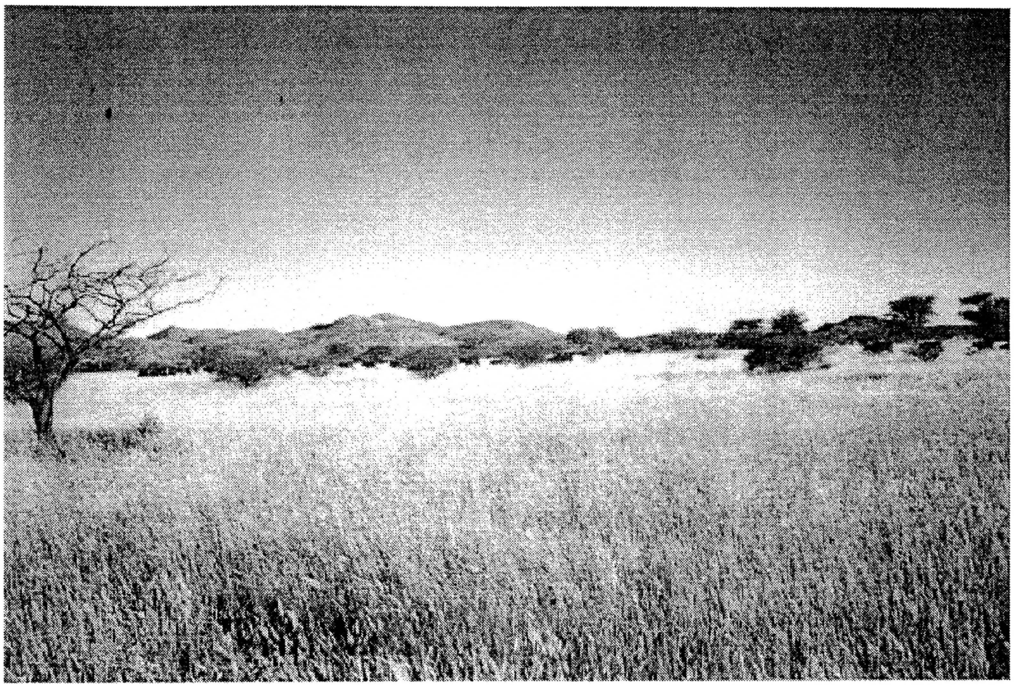
B) Signs of both rill/gully **erosion** and aeolian erosion are evident at this site and again are concentrated near the villages and on the plains. Given the arid climate and the ephemeral occurrence of rainfall, one should not forget that erosion is part of the natural processes in such an environment.

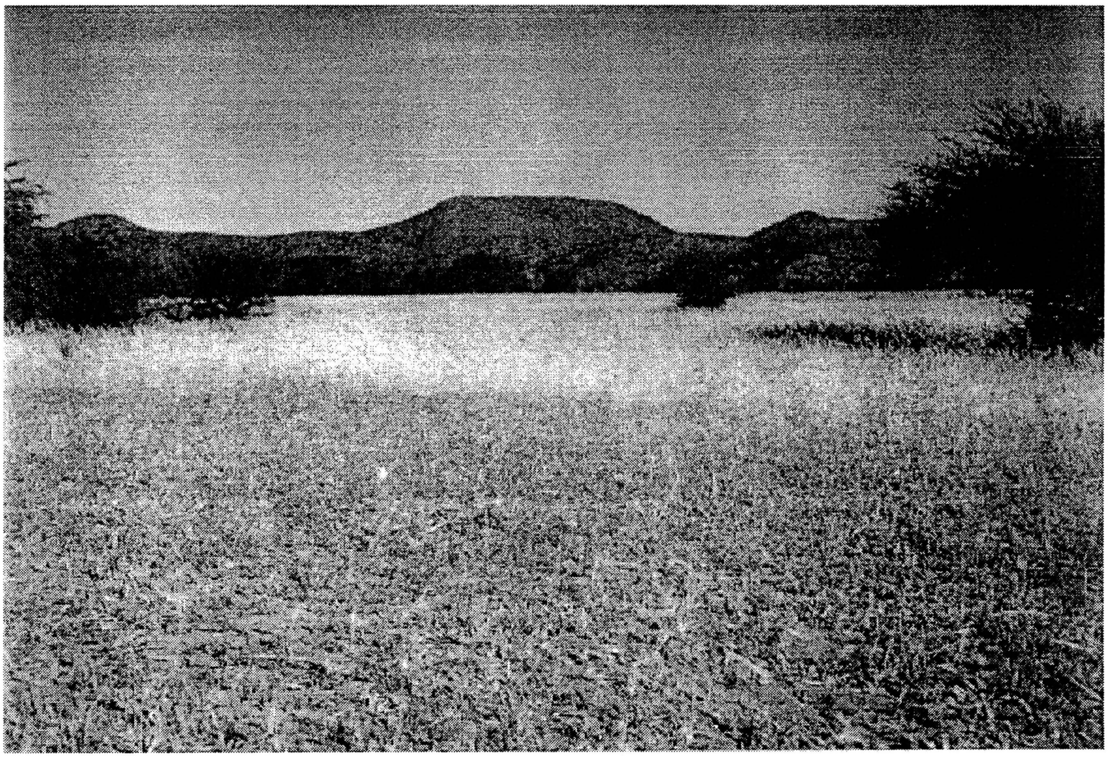
C) **Wood cutting** is obvious from the many trees felled around the village and in the river channels.

D) In the degraded plain near the main village, a high occurrence of invasive species such as the *Acacia mellifera* and the locally known blue bush is an indication of the high pressure on this area. It was observed during the study that these species only occur where clear signs of overgrazing can be observed and that this vegetation differs from vegetation in the surrounding areas. These trees are still relatively young and this study proposes that their development be monitored in the future. The exact area should be determined on image and on the ground. Grasses disappear soon after the rain due to trampling and grazing by animals.

E) What could not be established firmly during the study was whether there has been **a change in dominance from perennial to annual grasses**. A high occurrence of annual grasses has been observed, but the study was unable to establish through interviews whether this has occurred over the years or whether it is in fact a natural phenomenon.

F) Although a reasonably acceptable rate of **regeneration** of young trees was observed in the river, a number of the older *Faidherbia albida* trees near the village are dying off. Regeneration of *mopane* around the village however appears to be hampered by browsing animals.





PLATES 15 AND 16

Seemingly "degraded" and dusty plain after the summer rains. Note the livestock in the background (15), progressive grazing (16) and a number of young Acacia mellifira (15 and 16).

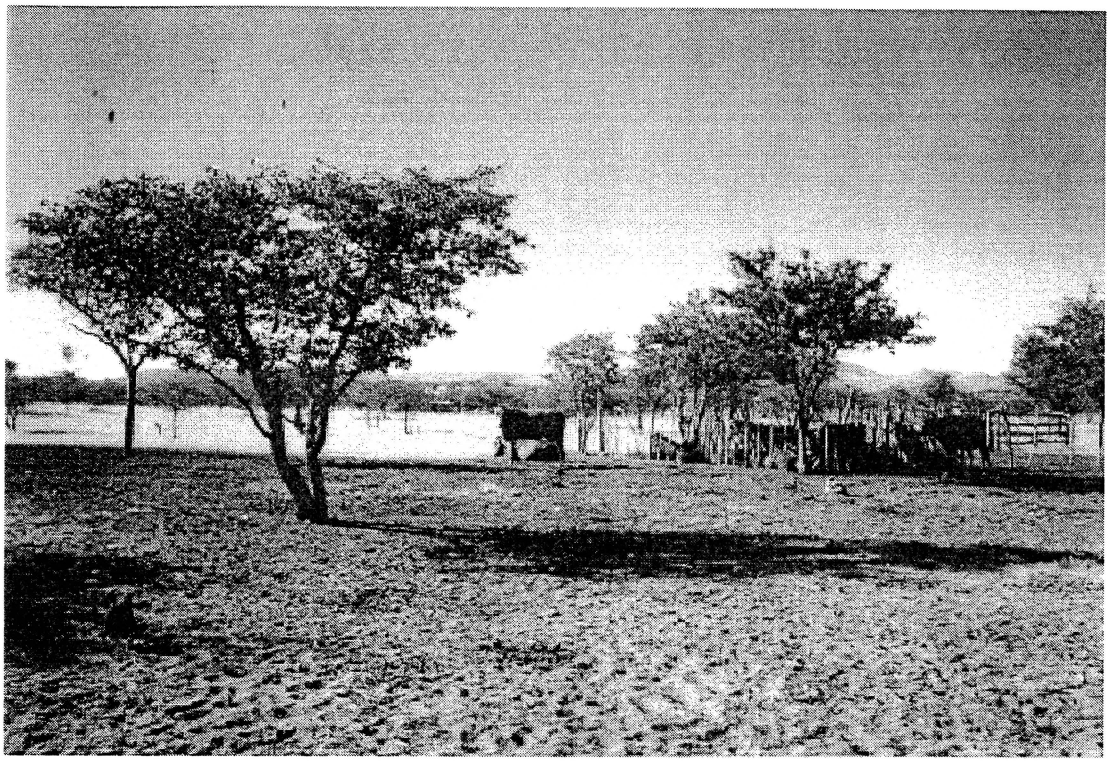


PLATE 17 AND 18

The browseline and absence of young mopane trees gives a good indication of the high pressure exerted around villages.

It is interesting to note that most people in these communities indicated that over the years there have been variations in the available grazing for the area, but in general it is perceived to be enough for their needs. Only during very severe droughts, do they need to look for alternative grazing. They are also of the opinion that, if there have been any changes in the natural vegetation, they were caused by a reduction in precipitation over the years. Especially older inhabitants are of the opinion that the rainfall has reduced since they moved into the area. They do however recognize the fact that when they moved to the farm, it had been abandoned for some years and that the grazing then was in an excellent condition, and that over the years more people and animals moved in and out of the area, causing reduced grazing.

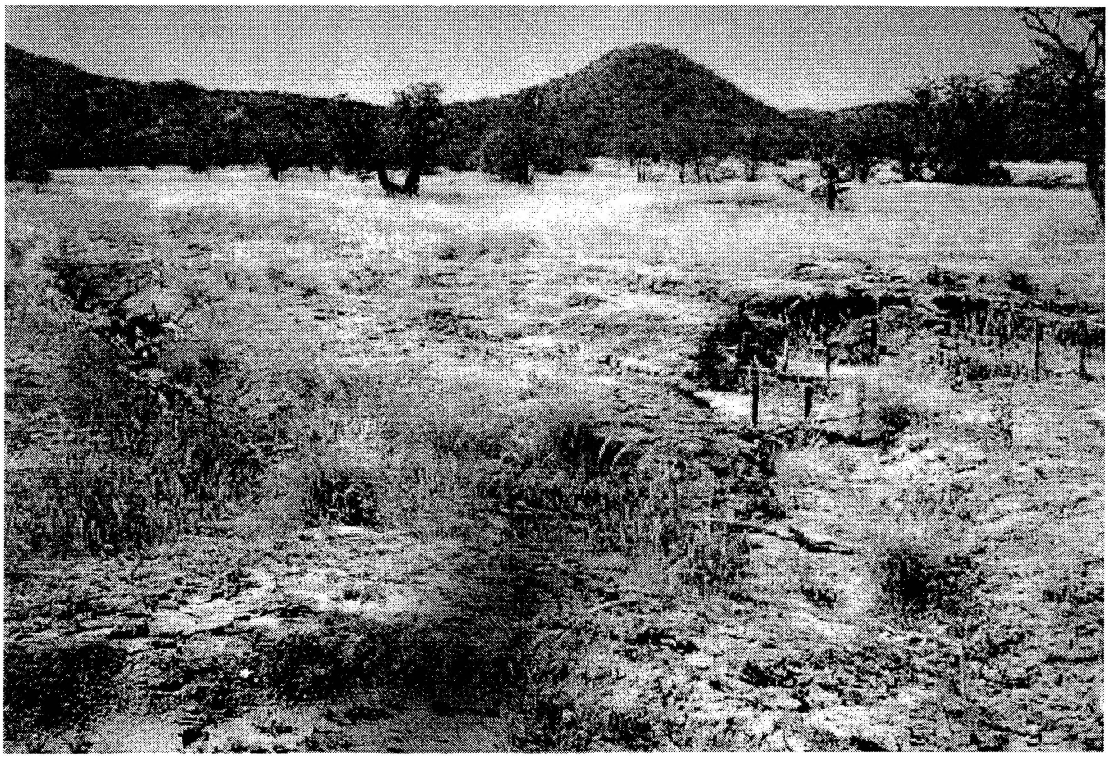


PLATE 19

Gully erosion is common throughout the catchment. This picture shows efforts at the Huab Private Nature Reserve to slow down the effects of soil erosion.

2.4.2. TWYFELFONTEIN

2.4.2.1. GENERAL

There is a community restcamp at Twyfelfontein, managed by Elias Xoagub. Informal interviews were held with residents and workers and resulted in the following.

Until 1992/3, farming was still the dominant economic activity in the area. But with the drought and the resulting livestock losses, the community, with the help of the Save the Rhino Trust, started the restcamp. It became fully operational in 1993. Since then livestock numbers were kept as low as possible and emphasis was placed on tourism. There are still a number of livestock, but the numbers vary since animals from neighbouring communities sometimes also graze in the vicinity of the camp. Livestock is kept mainly for household consumption. Workers at the campsite and the nearby rock engravings receive a salary each month.

The area falls in the low rainfall regimes as suggested by the rainfall isohyets (**Map 3**). Consequently, the area is poorly vegetated compared to the Engelbrecht farm in the upper catchment (for remarks on vegetation and species composition, see the mapping units within which the area falls). Although good rains were received in 1994/95 and the vegetation recovered well, livestock numbers are still kept low and according to the interviewees, this will be the case while the rest camp is still operational. Grasses recovered well after these rains. There is an apparent regeneration of Ana trees (*Faidherbia albida*). Game visiting the site include, oryx, elephant, giraffe, kudu, springbok and ostrich.

2.4.2.2. LAND DEGRADATION

With the low rainfall and consequent low natural vegetative cover, it is very difficult to assess the degree of over utilization and land degradation in the area. However, land degradation has been observed near and around the settlement i.e. browselines and bare soils. This is probably a combination of the effects of the livestock in the area and the movement of tourists within a very vulnerable environment.

Most of the grasslands here become very bare from August to December. It is hard to establish whether this is caused by overgrazing and the study would rather suggest that it is due to other factors like wind and the natural death of the annual grasses. Cutting of trees in the river (Aba Huab tributary) is evident. This is mainly used for household energy needs as well as to supply hot water and fire wood to tourists. With the continuous harvesting of trees for an expanding tourist business, the riverine vegetation is set to decrease over the years. It is suggested that another source of energy for hot water be found.

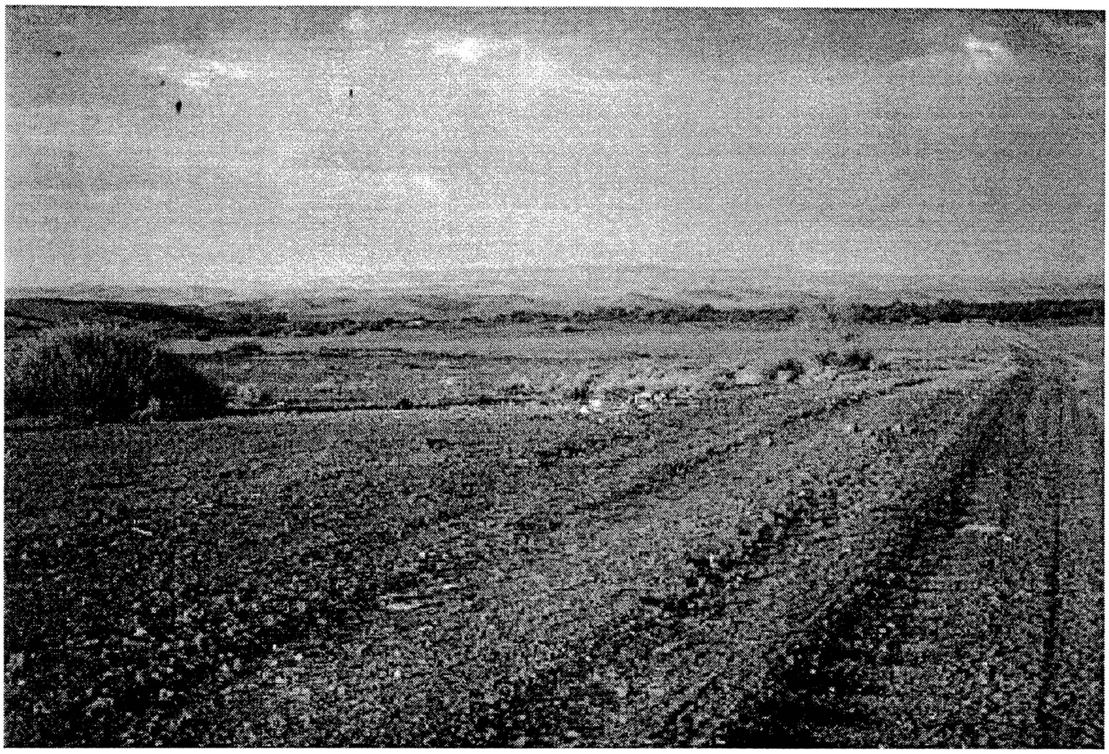


PLATE 20

The harsh natural conditions and the already low vegetative cover make it difficult to qualify land degradation in most of the western part of the catchment

3. CONCLUSIONS AND RECOMMENDATIONS

3.1. CONSTRAINTS

- The staff directly responsible for this study was relatively inexperience in the fields of remote sensing and geographic information. Training was time consuming, but fitted the objective of capacity building initially agreed upon.
- There was a lack of clear guidelines and information requirements from NAPCOD.
- The absence of real-time images complicated the assessment of the current vegetation status. However, this problem could be addressed through proper field research.
- Not many studies of this kind, using remote sensing, have been done in Namibia and a considerable amount of time went into the clarification of appropriate methods.

3.2. GENERAL CONCLUSIONS

The conclusions to this study should be viewed with an understanding of the objectives set out earlier in this report.

1. The study has set a basis for remote sensing to be used in the future for the assessment of land cover and the changes thereof. It has shown that remote sensing, in particular the analysis of LandSat TM images can be used effectively to asses variations in above ground biomass. Note should however be taken of the limitations experienced in this study. The experience of these limitations will be an advantage for future studies, since investigation could be done at the initial stages of any such project to minimize these limitations.

2. The study has come up with a possible classification system for the land cover in the study area. On the basis of this, a land cover map, taking into account both terrain and natural vegetation, was compiled. There are observed variations in vegetation in terms of structure, cover and species composition from east to west. Vegetation becomes more open, shorter and more succulent to the west. In addition, vegetation towards the western part of the catchment appears to be more resistant to climatic variability and prolonged dry periods. The study also found that vegetation is not only influenced by rainfall distribution, but also by prevailing soil conditions and the predominant geology. As is the case with rainfall, vegetation characteristics are variable and caution should always be taken not to generalise a structure for the whole of the catchment.

3. It was possible to highlight areas of biomass variations in the larger study area using remote sensing and field research. However, positive changes in biomass need more intensive research since it could be an indication of bush encroachment. The extent of negative changes in riparian biomass could not be established and would also need further study.

4. There seems to be a gradient in livestock numbers from east to west and the general observation is that numbers decrease along this gradient. However, vegetation data also suggests that the grazing potential follows a similar trend. It is thus difficult to say that the grazing pressure, in terms of its proportion to grazing potential, is really decreasing. It is also difficult to establish that widespread land degradation has occurred in the catchment due to specific grazing intensities. Despite low and variable rainfall, livestock figures from the State Veterinary services show an increase in livestock numbers over the years. This, with the presence of a number of degraded grass plains especially in the upper catchment, indicates that over-utilization, overgrazing, and general land degradation occurs.

5. With the identification of degradation signs in pilot areas, possible parameters for future research have been established.

The study has been successful to a large extent in assessing whether there has been a change in biomass, taking into consideration the limitations mentioned in this report. However, the specific dynamics and parameters need more detailed study over longer periods and it is advised that the discussion in this report regarding biomass changes be consulted as an aid to identifying possible parameters and methods of monitoring.

3.3. RECOMMENDATIONS REGARDING METHODS AND TECHNIQUES

Proposing a monitoring approach was one of the objectives of the project. The following is a general guideline. It is hoped that future studies will build on the proposed methodology.

Initial stages

1 Clarify objectives of the project.

2 Identify areas of interest, including pilot areas if requested, as well as the scale of the study.

3 Set a proposed time frame for the study. If monitoring is to be done stipulate the periods.

4 Visualization of expected outputs.

5 Identification of information requirements.

6 Preliminary guidelines for data acquisition, capture and formats. Consistency should be kept in database.

7 Methodologies to be used should be clarified, including your study parameters. (Consult relevant reading materials.)

8 prepare image selection criteria

8.1.1.1.1 : date(s)

8.1.1.1.2 : spatial resolution

8.1.1.1.3 : temporal resolution

Prior to Field Research

1 Collect available information on the study area (in digital and paper formats).

2 Identify information deficiencies regarding the study area and the study topic(s).

3 Land cover mapping:

3.1 Enhance imagery for land cover and/or change analysis.

3.2 Select an appropriate mapping approach and classify image(s).

3.3 Do preliminary mapping

4 Change detection:

4.1 register images to be used to each other,

4.2 do difference analysis (this will indicates sites where drastic biomass variations have occurred).

5 Interpret land cover mapping and change detection results.

6 Print preliminary maps to aid in field research.

7 On the basis of preliminary mapping, set sampling requirements and procedures.

8 Design field observation sheets and/or questionnaires to cover the objects/parameters being studied.

Field survey

1 Field research can be based on the recommendations by Paul E. Loth, 1990, "A Landscape guided method for vegetation survey and mapping". The objectives of the study should however be kept in mind and other references should also be used.

2 All sample points, survey tracks and other geographic information of importance should be recorded using the Global Positioning System (GPS).

3 Take photos of sample sites and number them systematically.

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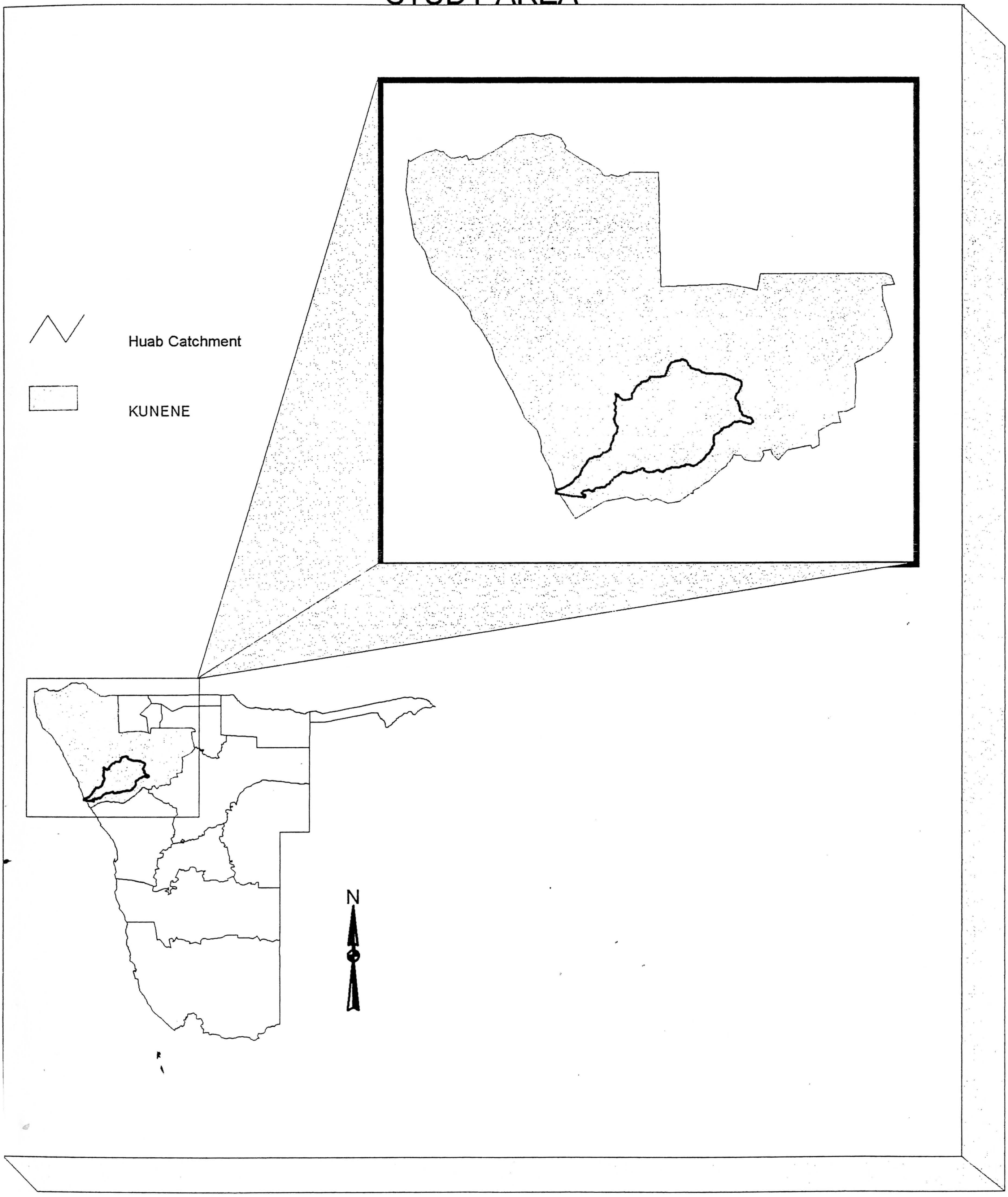
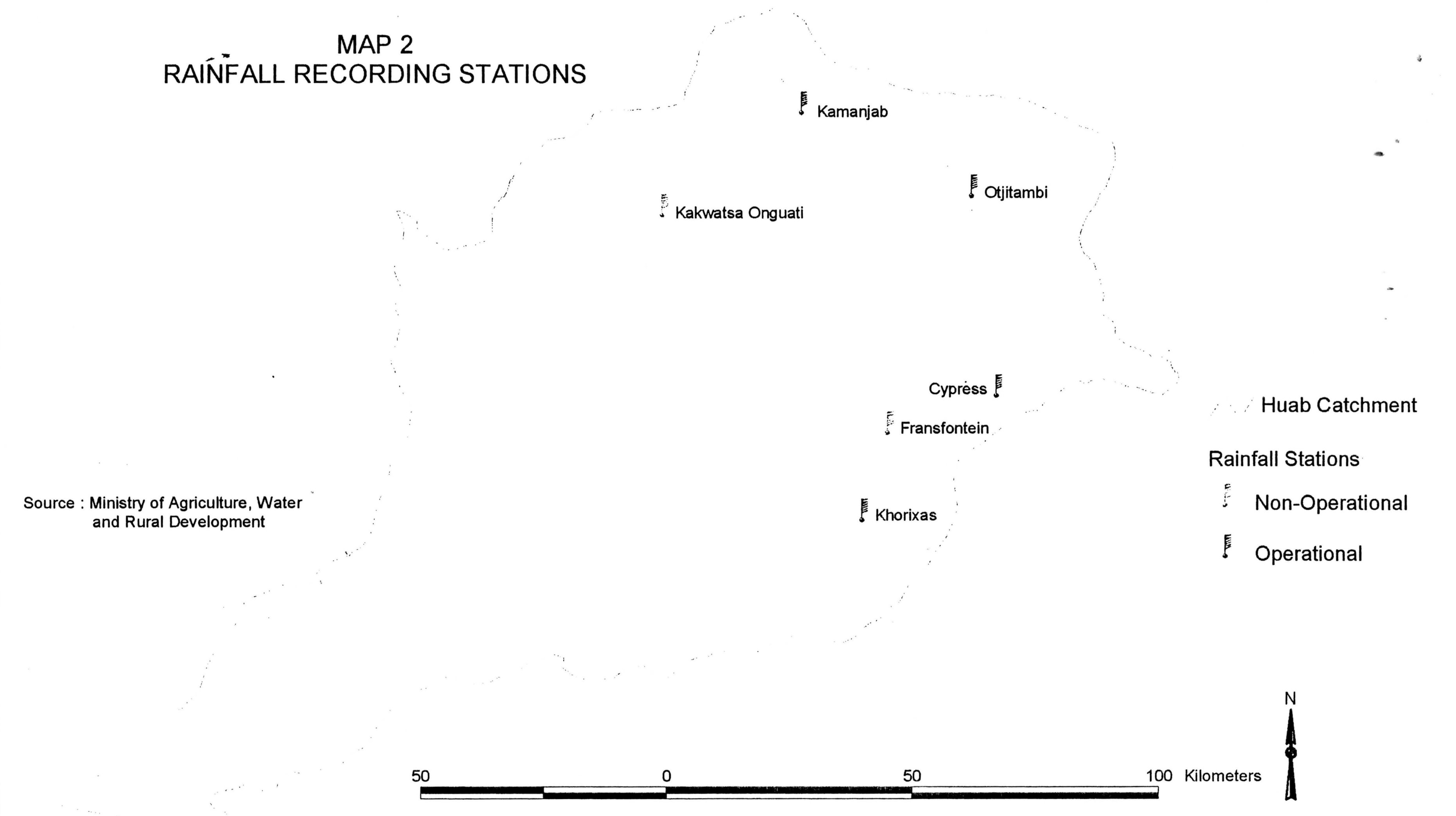
MAP 1
STUDY AREA



Sources : Jacobson et al., 1995, and
National Remote Sensing Center

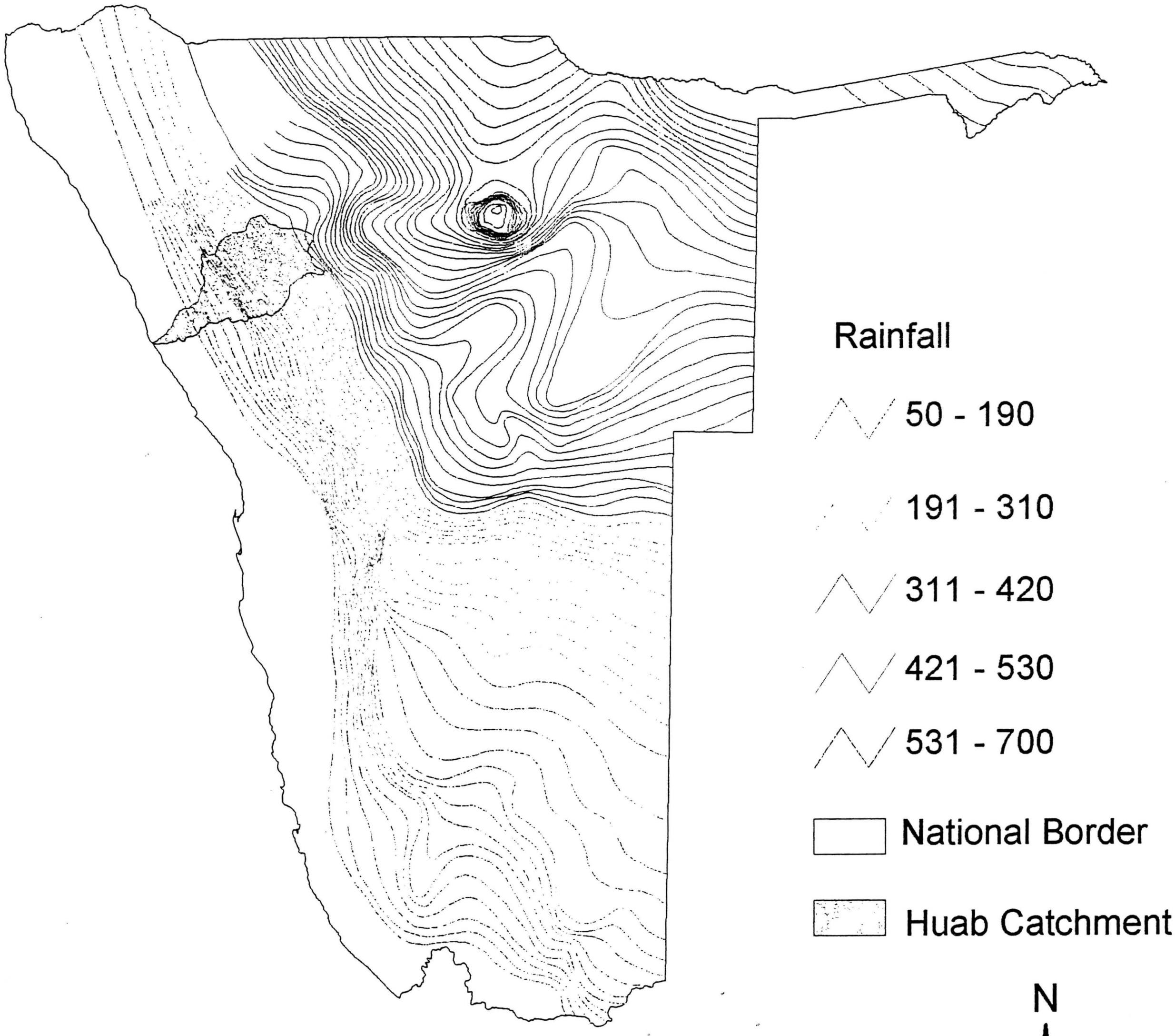
MAP 2
RAINFALL RECORDING STATIONS



Scale 1 : 1,200,000

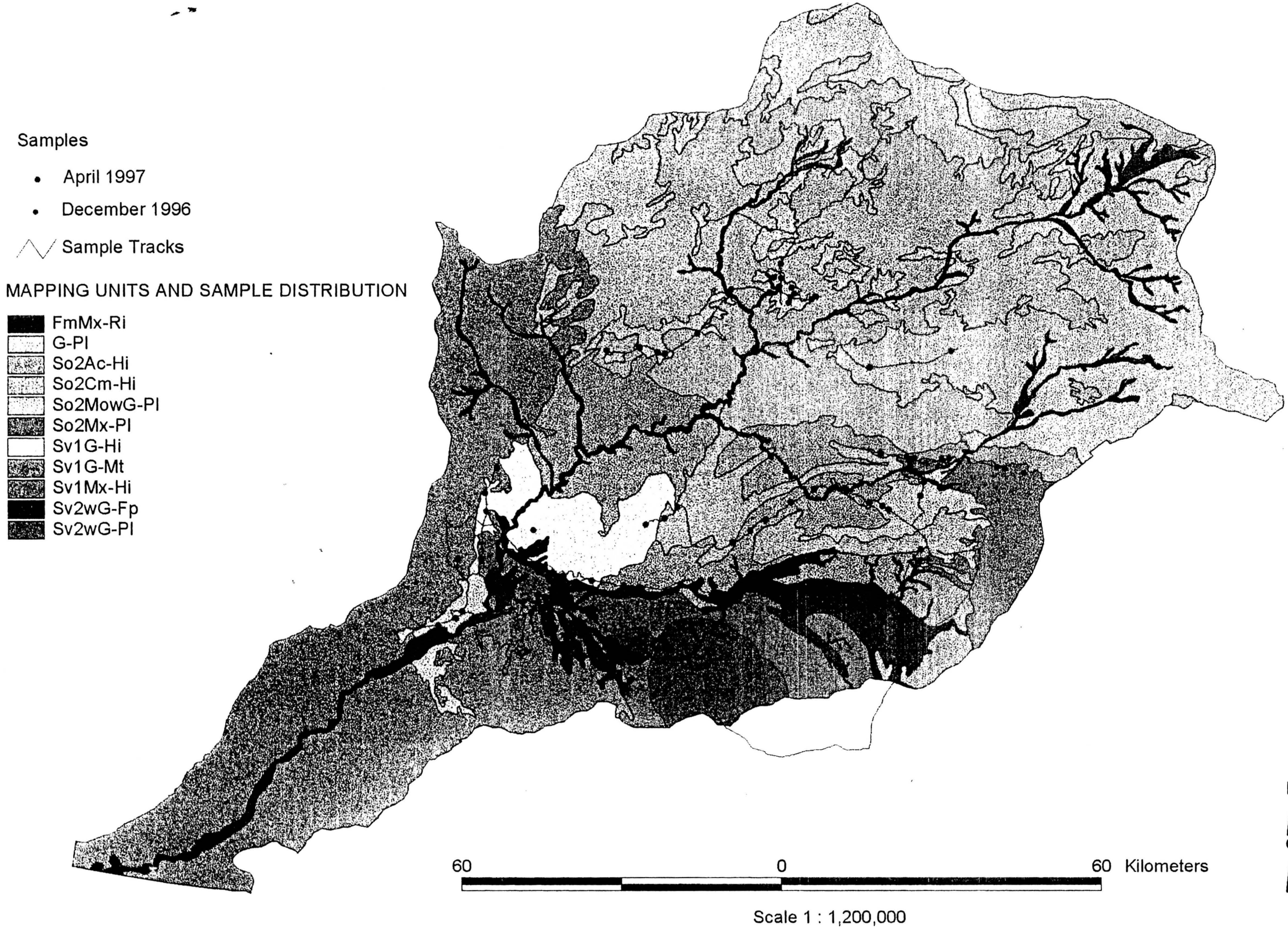
Source : Ministry of Agriculture, Water and Rural Development

MAP 3
RAINFALL ISOHYETS - NAMIBIA

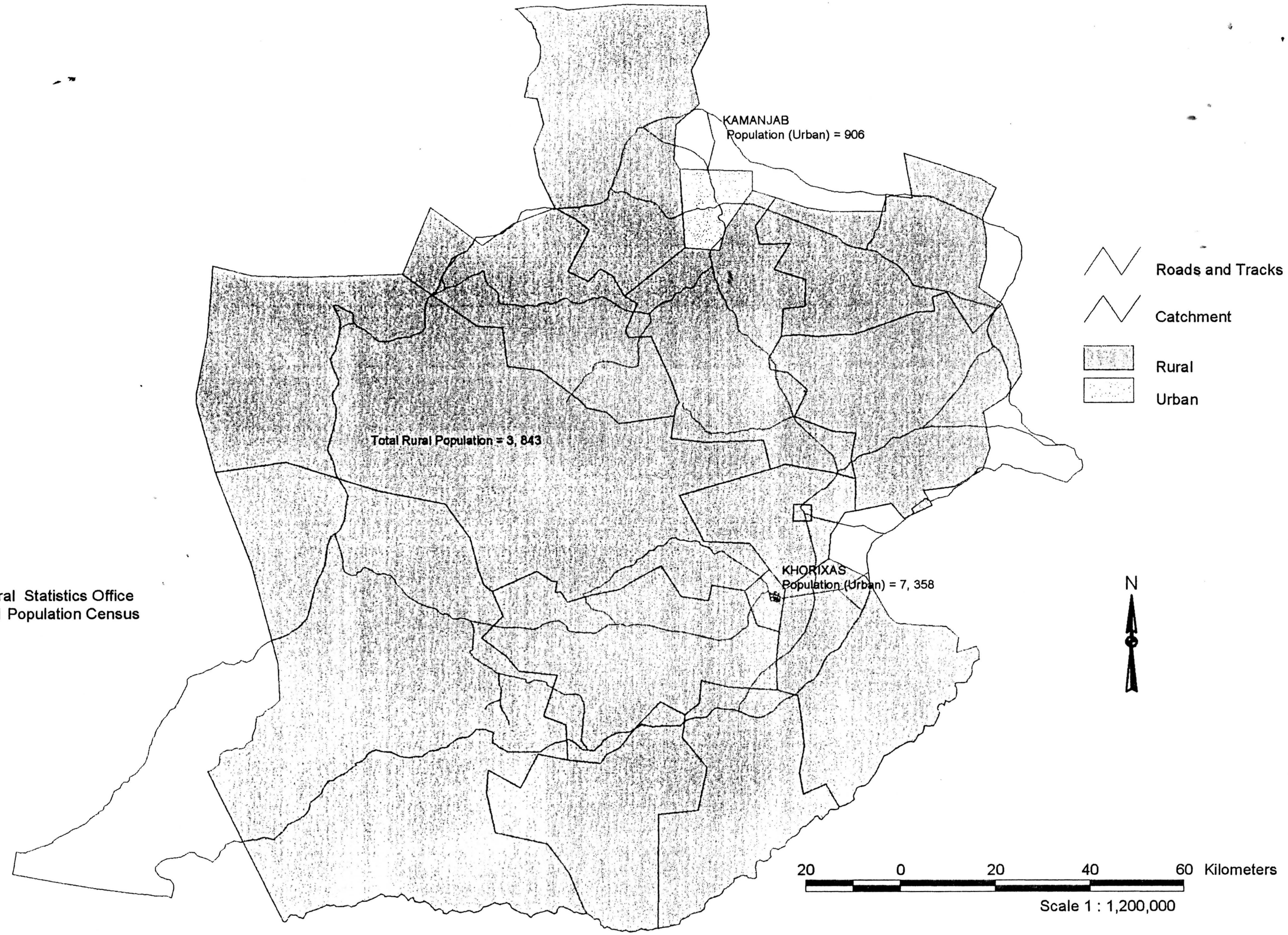


Source : Ministry of Agriculture, Water
and Rural Development -
Department of Water Affairs

MAP 4
SAMPLE DISTRIBUTION PER MAPPING UNIT

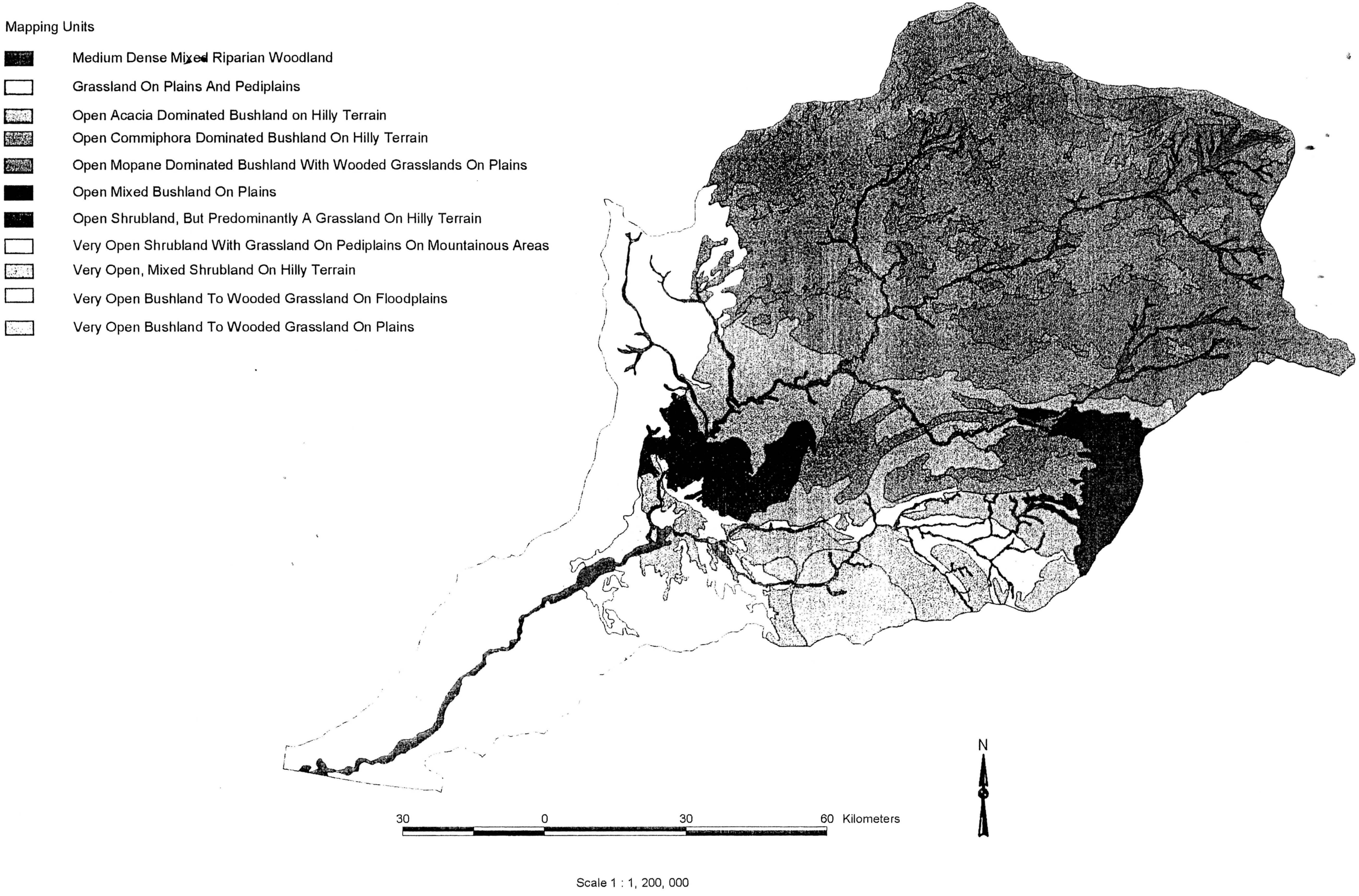


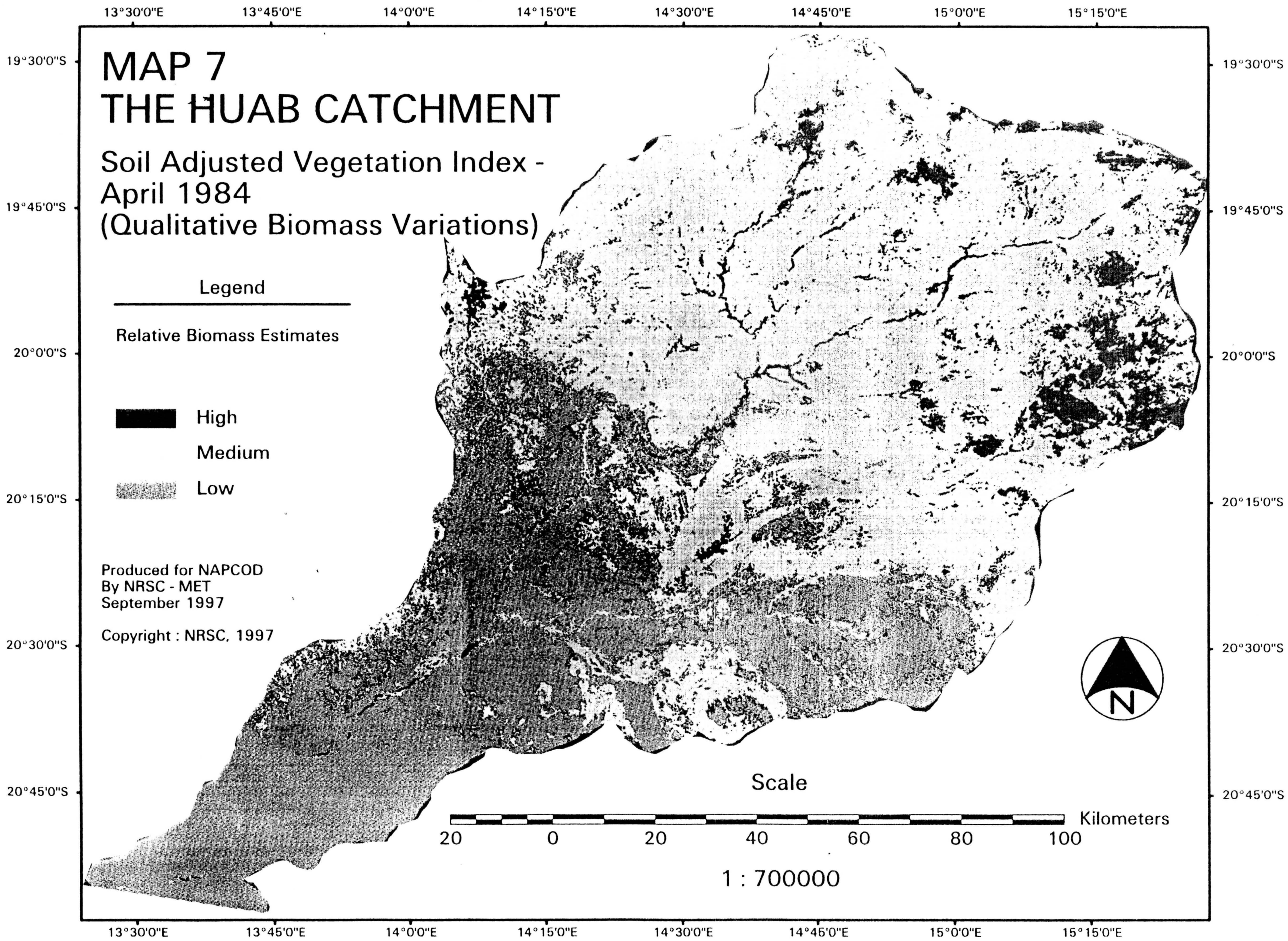
MAP 5
POPULATION OF THE HUAB CATCHMENT



Source : Central Statistics Office
1991 Population Census

MAP 6
LAND COVER IN THE HUAB CATCHMENT




MAP 7
THE HUAB CATCHMENT
Soil Adjusted Vegetation Index -
April 1984
(Qualitative Biomass Variations)
Legend
Relative Biomass Estimates
High
Medium
Low
Produced for NAPCOD
By NRSC - MET
September 1997
Copyright : NRSC, 1997
Scale
Kilometers
20
0
20
40
60
80
100
1 : 700000
N
13°30'0"E
13°45'0"E
14°0'0"E
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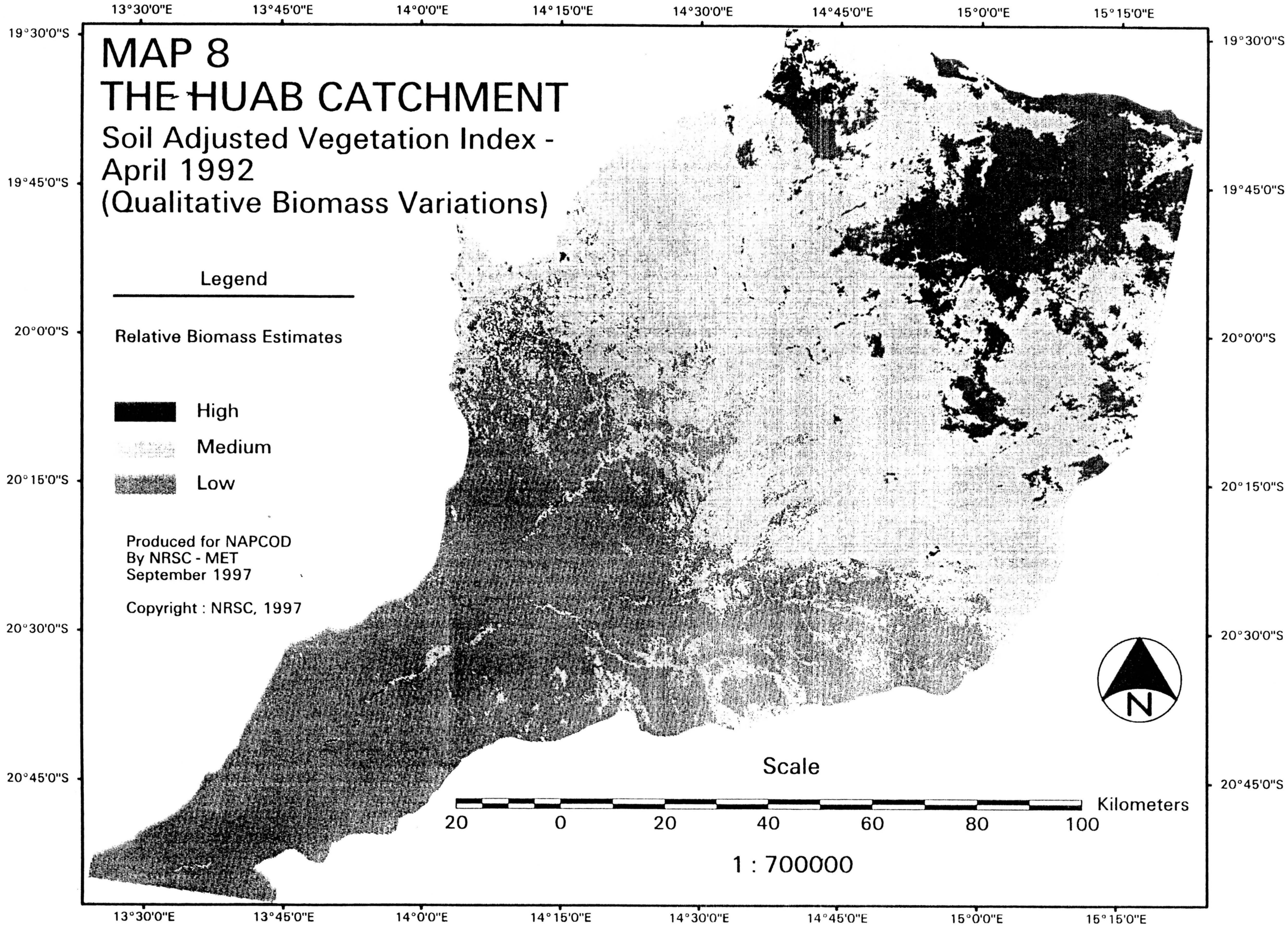
MAP 8
THE HUAB CATCHMENT
Soil Adjusted Vegetation Index - April 1992
(Qualitative Biomass Variations)
Legend
Relative Biomass Estimates
High
Medium
Low
Produced for NAPCOD
By NRSC - MET
September 1997
Copyright : NRSC, 1997
Scale
20 0 20 40 60 80 100 Kilometers
1 : 700000
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13°30'0"E
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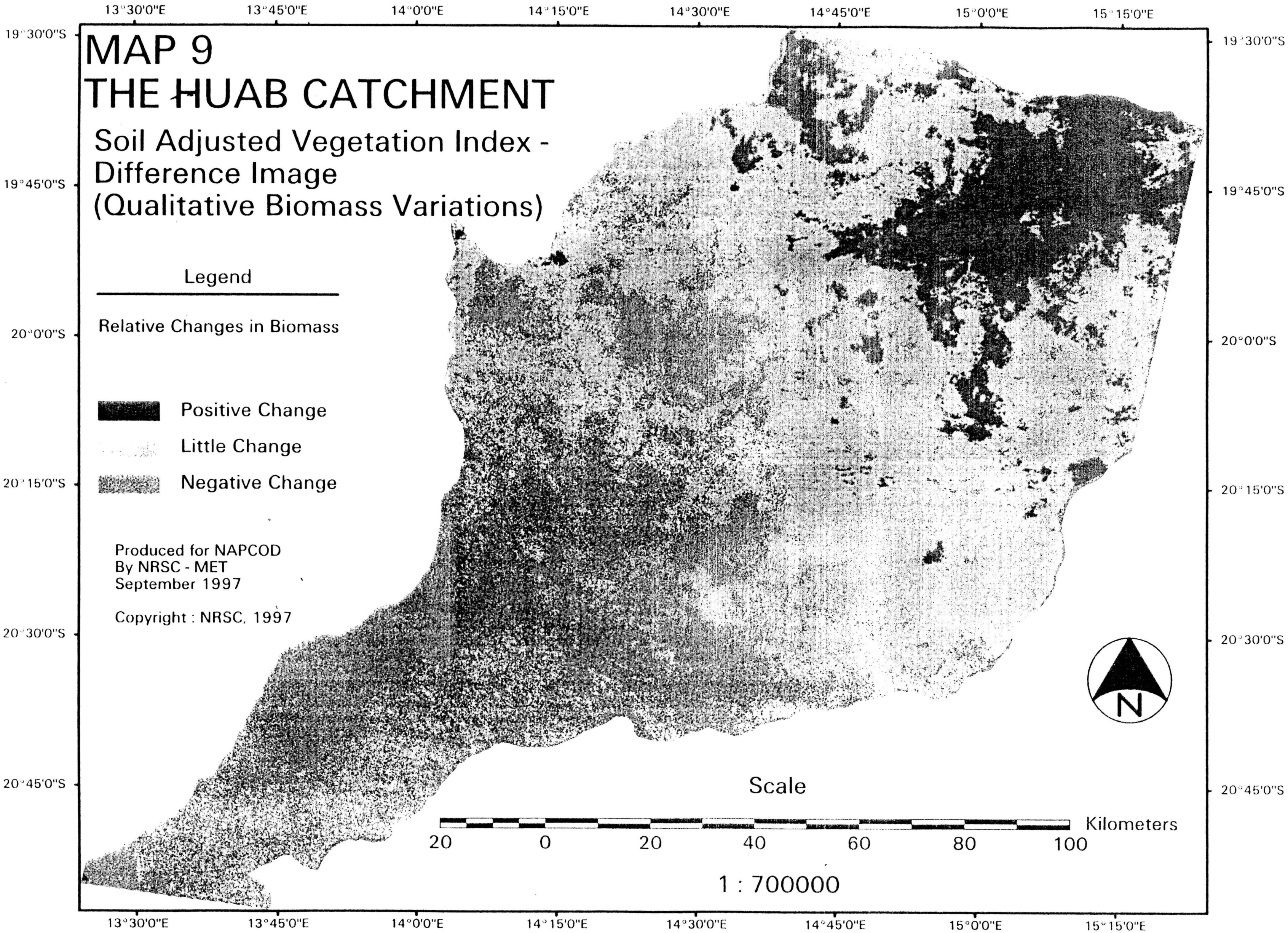
MAP 9
THE HUAB CATCHMENT
Soil Adjusted Vegetation Index -
Difference Image
(Qualitative Biomass Variations)
Legend
Relative Changes in Biomass
Positive Change
Little Change
Negative Change
Produced for NAPCOD
By NRSC - MET
September 1997
Copyright : NRSC, 1997
13°30'0"E
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15°15'0"E
19°30'0"S
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20°30'0"S
20°45'0"S
N
Scale
Kilometers
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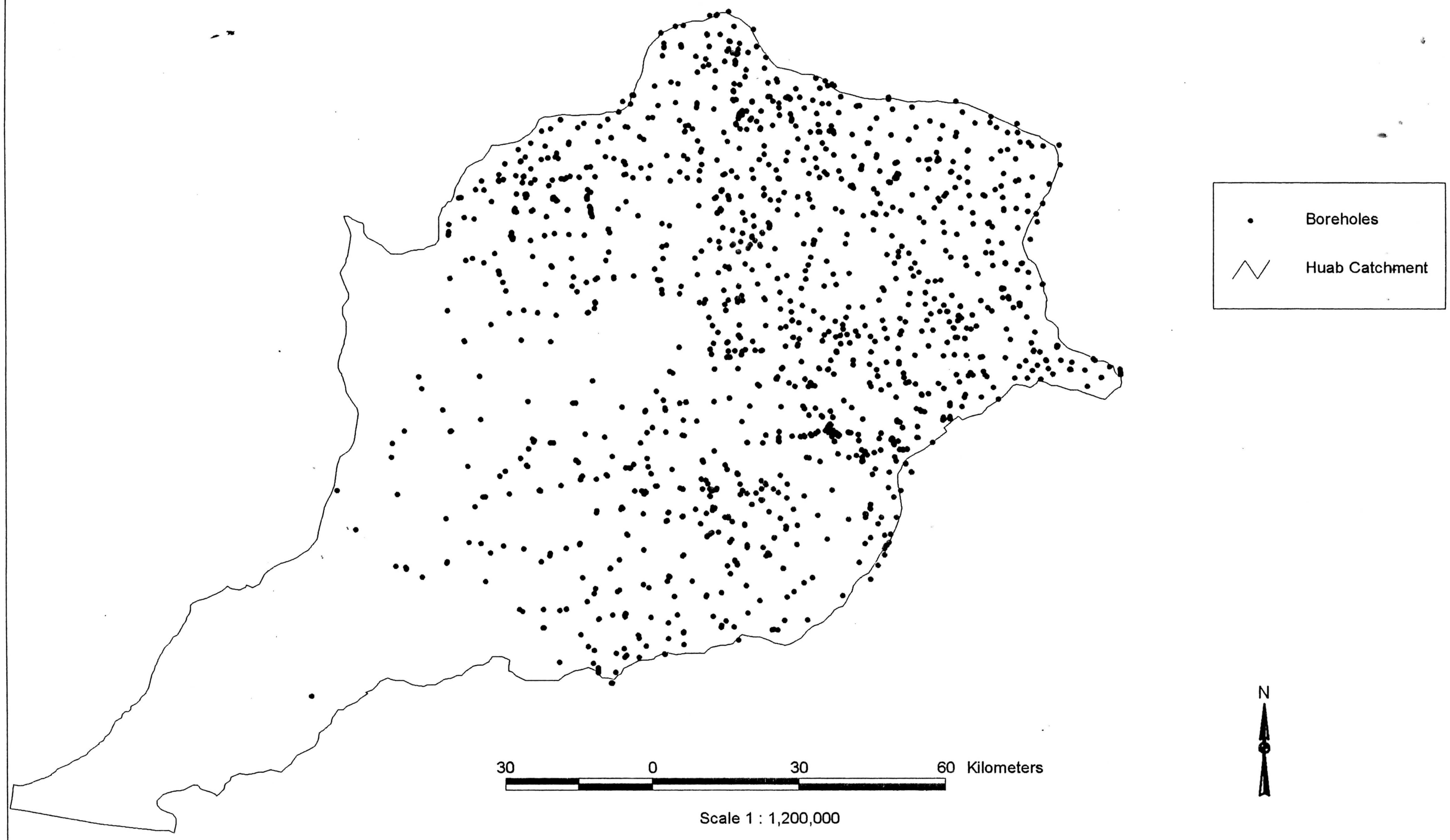
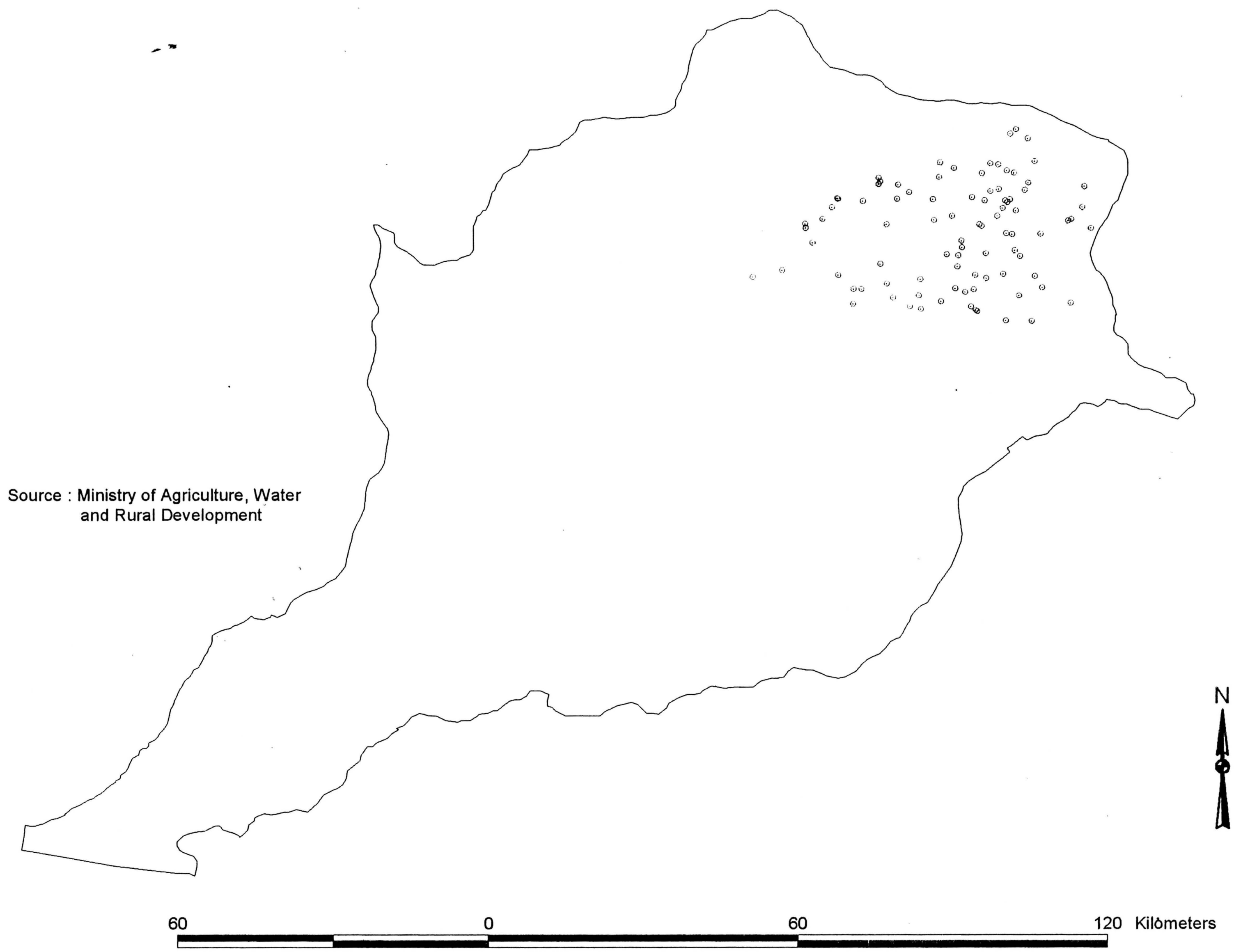
MAP 10
BOREHOLES IN THE HUAB CATCHMENT



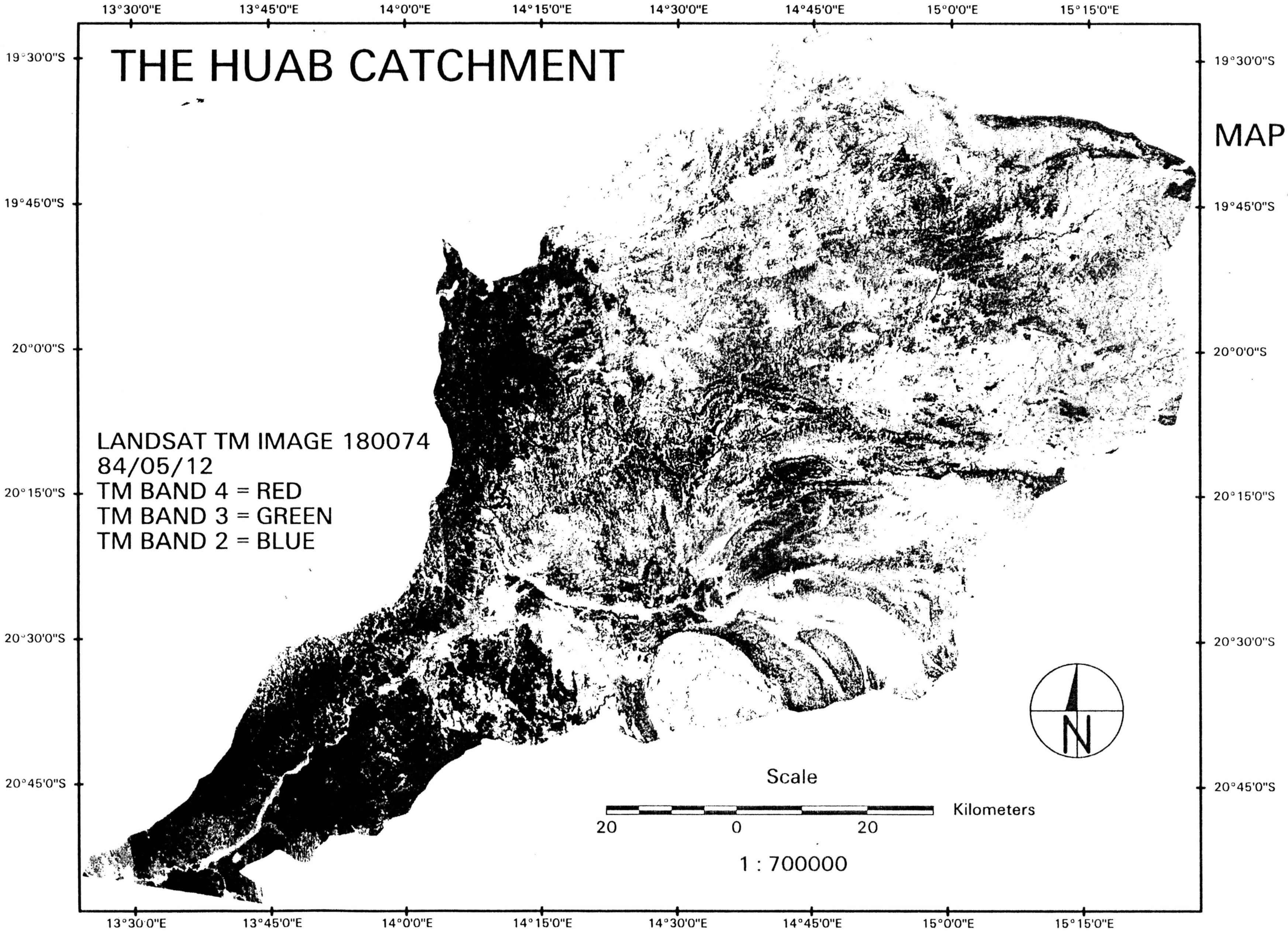
Source : Ministry of Agriculture, Water and Rural Development

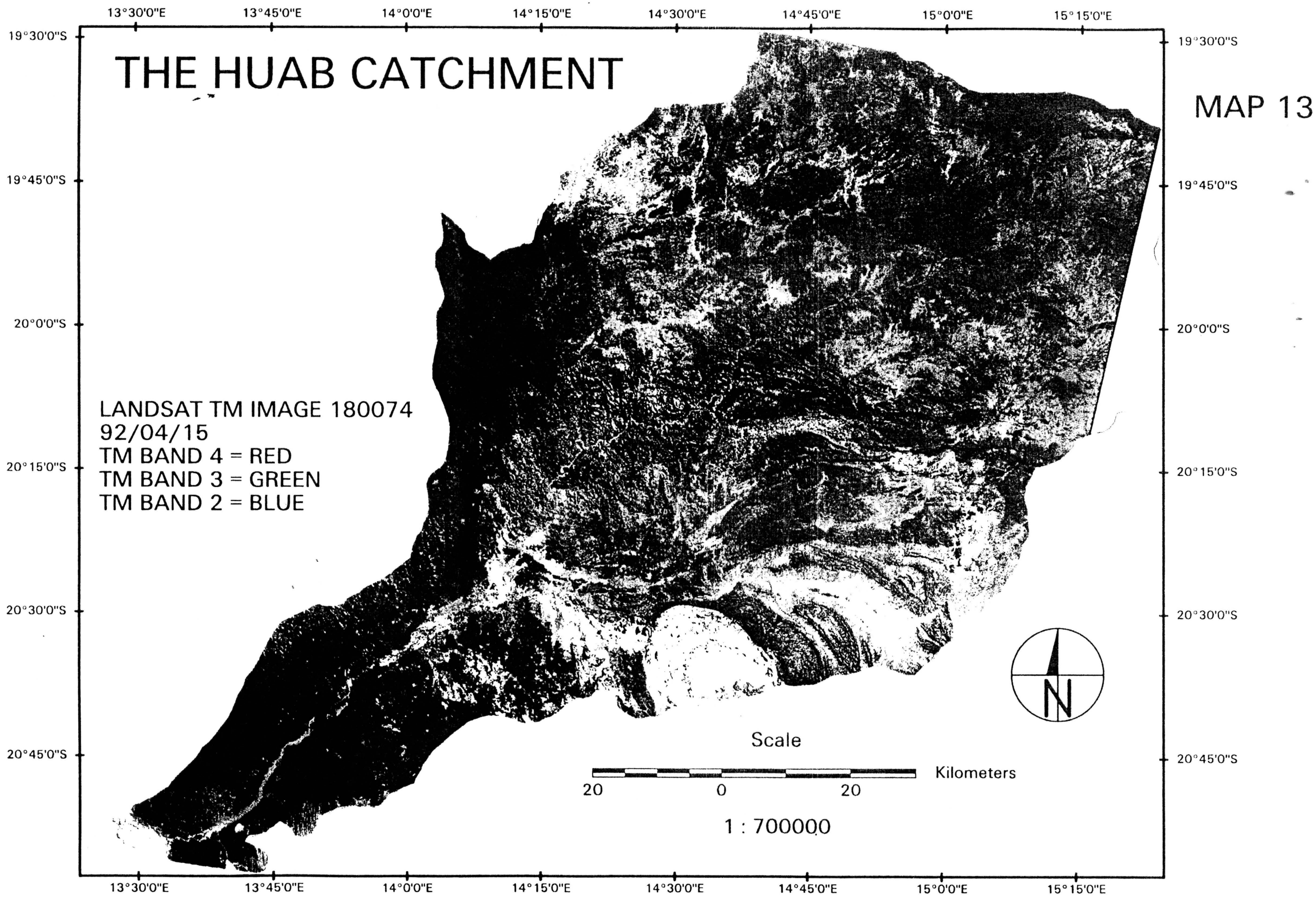
MAP 11

FARM DAMS IN THE COMMERCIAL FARMING AREAS OF THE HUABCATCHMENT

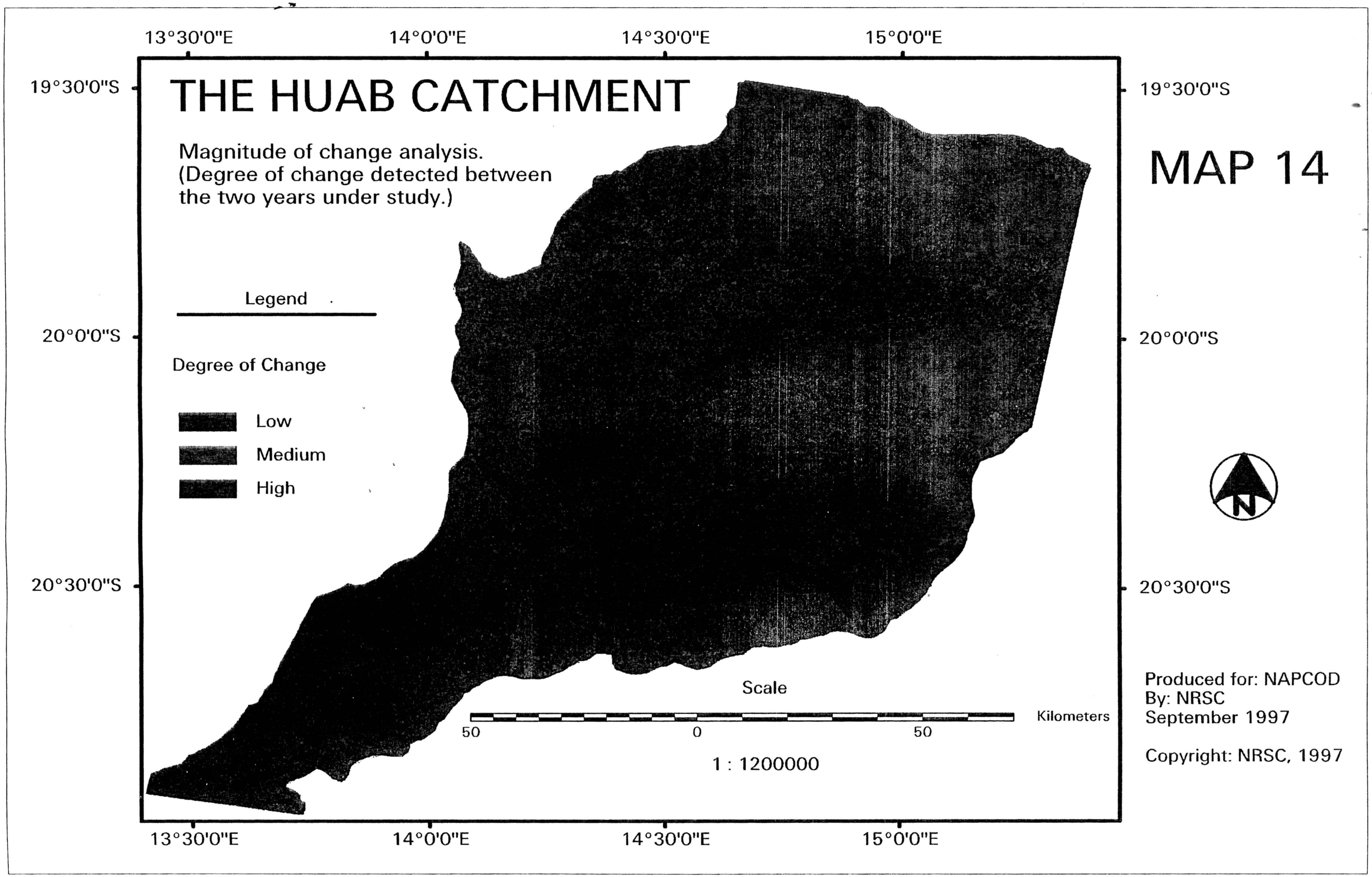


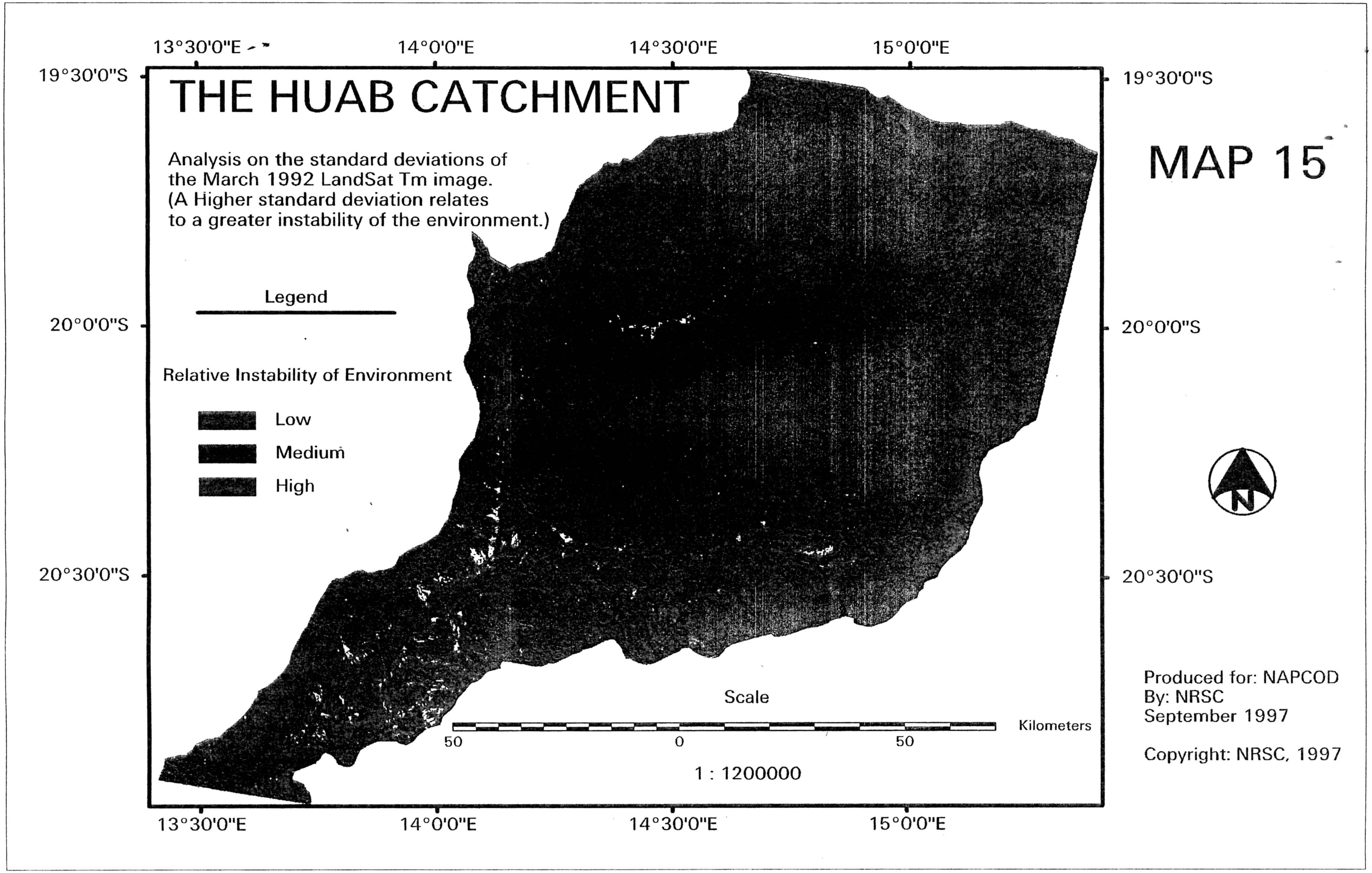
MAP 12


THE HUAB CATCHMENT
LANDSAT TM IMAGE 180074
84/05/12
TM BAND 4 = RED
TM BAND 3 = GREEN
TM BAND 2 = BLUE
Scale
20 0 20
Kilometers
1 : 700000
N
13°30'0"E
13°45'0"E
14°0'0"E
14°15'0"E
14°30'0"E
14°45'0"E
15°0'0"E
15°15'0"E
19°30'0"S
19°45'0"S
20°0'0"S
20°15'0"S
20°30'0"S
20°45'0"S



THE HUAB CATCHMENT
MAP 13
LANDSAT TM IMAGE 180074
92/04/15
TM BAND 4 = RED
TM BAND 3 = GREEN
TM BAND 2 = BLUE
Scale
Kilometers
20
0
20
1 : 700000
N
13°30'0"E
13°45'0"E
14°0'0"E
14°15'0"E
14°30'0"E
14°45'0"E
15°0'0"E
15°15'0"E
19°30'0"S
19°45'0"S
20°0'0"S
20°15'0"S
20°30'0"S
20°45'0"S


THE HUAB CATCHMENT
Magnitude of change analysis.
(Degree of change detected between the two years under study.)
Legend
Degree of Change
Low
Medium
High
Scale
50
0
50
Kilometers
1 : 1200000
MAP 14
N
Produced for: NAPCOD
By: NRSC
September 1997
Copyright: NRSC, 1997
13°30'0"E
14°0'0"E
14°30'0"E
15°0'0"E
19°30'0"S
20°0'0"S
20°30'0"S


THE HUAB CATCHMENT
Analysis on the standard deviations of the March 1992 LandSat Tm image. (A Higher standard deviation relates to a greater instability of the environment.)
Legend
Relative Instability of Environment
Low
Medium
High
MAP 15
Scale
50
0
50
Kilometers
1 : 1200000
13°30'0"E
14°0'0"E
14°30'0"E
15°0'0"E
19°30'0"S
20°0'0"S
20°30'0"S
N
Produced for: NAPCOD
By: NRSC
September 1997
Copyright: NRSC, 1997

MAP 16
FARMS IN THE HUAB CATCHMENT

Source : Jacobson et al., 1995.