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# Review: Vegetation Studies in Namibia

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## Abstract

*Published and unpublished reports and a questionnaire were used to compile an overview of completed, ongoing and planned vegetation survey related projects in Namibia. The main objective of this activity was to determine gaps and identify priorities for future research accordingly.*

## Introduction

Primary producers are the most essential component in almost all ecosystems. Thus knowing which plant species grow in a particular area and why is elemental knowledge required for any decisions related to resource management and conservation. In the developed world national inventories of plant species are almost complete, while many developing countries are struggling to complete even basic inventories of high priority areas. Preoccupied with day to day issues of survival, policy makers usually pay very little attention to supporting basic research. Yet, basic research provides the much-needed information to solve environmental problems such as desertification and restoration of disturbed land. Biogeographical studies concerned with distribution of particular taxa help in interpreting the vegetation history in a specific area, while interrelations between vegetation and the environment explain the small-scale patterns encountered as well as contribute to the understanding of the functioning of a particular ecosystem. A combination of both can, for example, elucidate the desertification problem. Understanding the vegetation history may give clues to climatic and land-use changes in the past, while the current vegetation patterns indicate the environmental pressures imposed on a specific piece of land. In view of this, the present paper aims (1) to summarise completed, ongoing and planned vegetation surveys and related projects in Namibia and (2) to identify priorities for future research.

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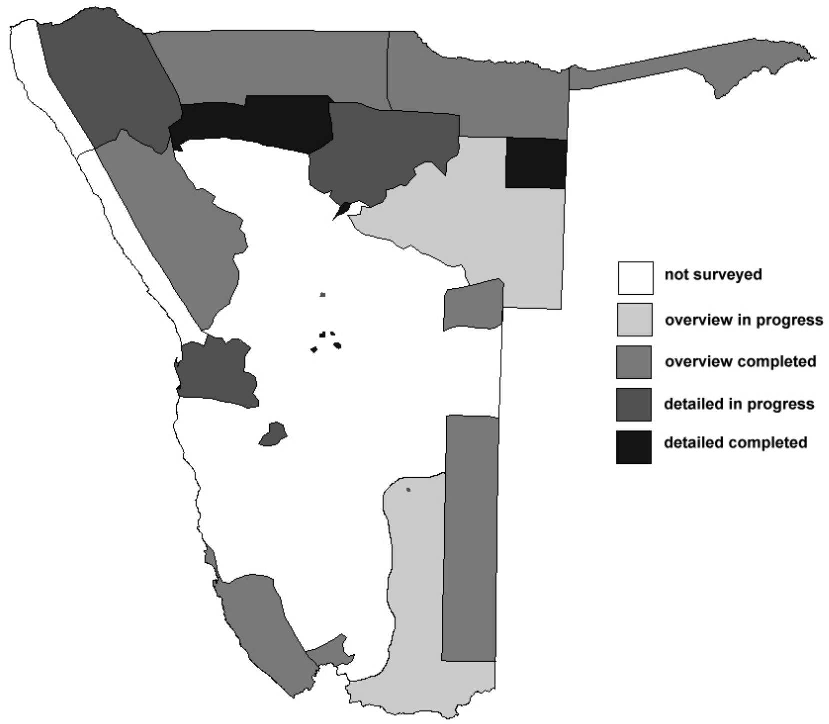


Figure 1: Vegetation surveys done in Namibia.

**Vegetation studies in Namibia**

The major part of Namibia is arid to semi-arid. Hence livestock farming is the most prevalent land use activity, while dryland and irrigated crop agriculture are minor sectors in the Namibian economy. However, the most arid parts of the country cannot support even extensive farming and most of these areas are privately owned or state wildlife/nature reserves (e.g. the majority of the Namib Desert), attracting large numbers of tourists every year. The natural vegetation forms the base of these land-use practices.

In many parts of Namibia the vegetation has been studied extensively (e.g. the Etosha National Park) while the majority of the farmland has been neglected entirely (e.g. Hardap, Karas, Omaheke and Otjozondjupa regions) (Figure 1).

In this review we will summarise vegetation-survey related activities in the past and critically assess their value in the light of land use planning and new developments in vegetation science. Although we have included unpublished reports and theses, where available, we are aware that this paper may not be complete. There are unpublished and half completed projects which are filed by ministries, non-governmental organisations and internal as well as overseas researchers. Not being mentioned should thus be taken as encouragement for researchers to complete and publish their projects in the near future.

## Procedure and Definitions

It would be beyond the scope of this paper to discuss every study in great detail, thus a summary table is provided, naming the author(s), the area of study, the general method used and the type and extent of study (Table 1). General vegetation survey (GVS) refers to studies which are mainly based on collecting trips, although sometimes including quantitative data, for areas or vegetation types defined according to field observations without quantitative environmental data. Phytosociological studies (PHY) are restricted to plant community studies according to the Braun-Blanquet approach (Mueller-Dombois & Ellenberg 1974). Vegetation-environmental studies or vegetation dynamic studies (VENV) are investigations based on quantitative data for both vegetation and at least one environmental parameter. The category value combines the type of data handling (descriptive, quantitative or analytical), extent of the study which refers to the size of the area (local, regional or country-wide) and the duration of the field survey. A questionnaire was distributed to vegetation scientists within Namibia as well as to overseas researchers to enquire about area, scope and duration of ongoing and future projects.

## Results

### 1. General vegetation studies and overviews

This section deals with vegetation studies ranging from distribution records from collecting trips to studies which monitor vegetation dynamics.

### 1.1. Completed vegetation studies

The first attempt to define phytogeographical regions in Namibia was undertaken by Volk (1966) who used key species to delimit the Nama-Karoo from the Sundano-Zambezi floral region. Based on country-wide field observations during many years of extensive plant collections throughout Namibia, as well as a concerted effort over a 2-year period, Giess compiled in 1971 a preliminary map of vegetation types in Namibia. Although today there are some disagreements with Giess' classification, his work is the only complete treatment of this kind. Meant to be preliminary and needing more detail in several parts, Giess' work has tremendous value and should serve as a baseline study and hypothesis to be tested and developed further. In his classification he categorised the main vegetation types as desert, savanna and woodland, which were subdivided in 14 smaller vegetation units. Recently Irish (1994) has published a general overview of biomes in Namibia, based on the concept of Rutherford & Westfall for southern Africa (1994), which uses dominating plant life forms and climate as parameters to define the different biomes. Besides summarising available vegetation studies, Irish used field observations and photographs of vegetation types to define the biome boundaries in Namibia. His biome categorisation needs to be substantiated with more quantitative field data. Jürgens (1991) used plant distribution records for a new phytogeographical classification of the Namib, contradicting earlier classifications of the southern Namib.

Many regional and local plant surveys did not attempt to explain the vegetation in relation to their environment and merely resulted in plant checklists. The Etosha Park (Nordenstam 1970; Giess 1970), Brandberg (Nordenstam 1974, 1982), Naukluft Mountains (Joubert 1979), Central Namib (Giess 1981), Gamsberg (Giess 1983) and Hauchab (Burke *et al.* 1998) were covered in this way. Thus plant inventories cover at least all the major park areas and some botanically interesting sites. Additional minor studies, often with a different aim also produced plant checklists locally (Loutit *et al.* 1987; Tarr & Tarr 1989; Viljoen 1989; Viljoen & Bothma 1990; Bethune 1991). Also local ethnobotanical studies are often combined with general vegetation surveys (Malan & Owen-Smith 1974; Sullivan 1993; Sullivan & Konstant 1997).

Other descriptive or quantitative surveys on regional and local scales resulted in maps with *vegetation zones* (Leistner 1967 and Leistner & Werger 1973 for the Kalahari Desert; Leser 1972 for the Nossob area; Eloff *et al.* 1977 for Damaraland; Seely *et al.* 1980/81 and Theron *et al.* 1980 which both addressed the Lower Kuiseb River; Williamson 1995 and 1997 for Diamond Area No. 1), *veld types* (Viljoen 1980 for Kaokoland; Nel 1983, Nel & Opperman 1985 for the central Namib) and *vegetation* and/or *land-use units* (De Sousa Correia 1976 for the northern regions; Claasen & Page 1978 for Ovamboland; Page 1979/80 and De Sousa Correia & Bredenkamp 1986 for the Okavango; Hines 1997 for Caprivi). Some of these studies were carried out during intensive field observations and produced descriptive accounts of the vegetation plus useful recommendations for management (Viljoen 1980; Nel 1983).

Concerned with the function of savanna ecosystems, Rutherford chose the Omuverume Plateau near Waterberg for his study on structure and dynamics of savanna woodland, which as a secondary result produced a species list for the area (Rutherford 1972, 1975). Other vegetation-related studies such as long-term observations of the central Namib dunes (Seely 1991) and short-term responses of serotinous plants on the plains (Günster 1994) produce data which should ideally be incorporated in growth models (see below).

With the emphasis to develop a method for rapid rangeland resource assessments in the northern regions a pilot study in the Kabbe (Caprivi) and Okatjali area (Oshana) produced vegetation maps for these areas (Hines & Burke 1997).

The Environmental Profiles Programme recently completed an atlas including a detailed vegetation map of the Caprivi Region (Mendelsohn & Roberts 1997).

### 1.2. Vegetation studies in progress

For several years Jürgens (1994) has been carrying out a mapping programme of the Namib Desert. Initially based in the southern Namib, he has recently extended his survey into the central and northern Namib. With main emphasis on phytogeographical affinities, the inselberg floras of the Namib are currently under investigation by Burke. Although mainly concentrating on plant species with agricultural potential, collecting trips carried out by the Plant Genetic Resources Centre contribute distribution data with brief habitat descriptions of selected species (H. Kolberg, pers. comm.). The Ministry of Environment and Tourism carries out monitoring programmes in several conservation areas dealing with alien and threatened plant species (M. Lindeque, pers. comm.), while the SARDEP programme and the NOLIDEP programme at the Ministry of Agriculture, Water and Rural Development carries out vegetation surveys with the main emphasis on determining livestock carrying capacities (A.S. Kruger, pers. comm.; J. Sweet, pers. comm.).

## 2. Phytosociological studies

This category summarises completed studies which followed the Braun-Blanquet approach (Mueller-Dombois & Ellenberg 1974), but did not incorporate environmental data in the analysis.

Since the 1970s several surveys were carried out in Namibia using a phytosociological approach, based on classification of plant communities. These were conducted either in new areas, e.g. the Khomas Hochland (Volk & Leippert 1971), or revisited areas in a more thorough fashion, e.g. the central Namib (Robinson 1976) and Waterberg (Jankowitz 1983; Jankowitz & Venter 1987). The study in the Waterberg Plateau Park included a vegetation map and recommendations for management of bush encroachment, measures to prevent veld fires, potential new waterholes and estimates of carrying capacity of different communities (Jankowitz & van Rensburg 1985). A localised, short-term study used a phytosociological approach to classify vegetation on the Welwitschia Plains near Swakopmund (Moisel & Moll 1981).

Several small-scale vegetation studies have been carried out in the commercial and communal farmland near Grootfontein, Rehoboth and around Gibeon, as well as state land in the Swakompund and Lüderitz districts (Fanroth 1990; Hachfeld 1996; Lindenbach 1996; Gimborn 1996; Jakobs 1996; Leuchtenberg 1997; Schedel 1997; Strohbach 1997; Strohbach 2000).

Nowadays phytosociological studies are used as a tool to explain vegetation-environmental relationships, thus they are usually correlated with environmental data and analysed with computer programmes. Ongoing and planned studies will thus be dealt with below.

## 3. Vegetation in relation to environmental parameters

The development of sturdy field data loggers for environmental data enables researchers today to link vegetation studies directly with collection of environmental data (e.g. climate as well as soil acidity and conductivity). The large amount of data produced in this way requires computer analysis. Several computer packages exist which carry out classifications (e.g. TWINSPAN, Hill 1979a; PHYTOTAB, Westfall 1992 & Westfall *et al*. 1997) and ordinations (DECORANA, Hill 1979b; CANOCO, Ter Braak 1987), thereby organising plant data and correlating these to environmental parameters.

### 3.1. Completed studies

Although not based on computer analysis, a vegetation study in western Etosha described plant communities in relation to soil parameters and resulted in a vegetation map for this area (Joubert 1971). Almost a decade later le Roux (1980) conducted an intensive survey of the entire Etosha National Park in which he related vegetation to soil parameters using classification and ordination (Principal Component Analysis) for data analysis. His thorough, analytical treatment was based on extensive field observations, included recommendations for management, and serves as the baseline for many ecological studies in Etosha National Park today (le Roux *et al.* 1988).

Kellner (1986) carried out a classification and ordination of vegetation in the Daan Viljoen reserve and the farms Claratal and Neudamm. His thesis includes maps with veld types of the different areas. Also based on extensive field observations was

Hines (1992) vegetation study of eastern Otjozondjupa (Bushmanland). He used classification (TWINSPAN) and ordination (DECORANA) to define plant associations, and related those to varying substrate conditions. Unfortunately no map was included in his survey. However, he further classified the different wetland types in his study to provide recommendations for management and conservation (Hines 1993). With the aim of determining possible impacts of large-scale groundwater abstraction from the Karstveld region, a recent study investigated the correlation of woody vegetation with environmental parameters (Chivell 1992). This study resulted in vegetation maps along 10m belt transects and recommended further monitoring using IR aerial and fixed point photography.

Although generally concerned with investigating grazing indicators, recent studies in the Grootfontein area (Strohbach 1992), Daan Viljoen Nature Reserve (Joubert 1997), Etosha (du Plessis *et al*. 1998a; du Plessis *et al.* 1998b) and northern Oshikoto region (Strohbach 1999) give insight to the response of plant communities to overgrazing. Similar rangeland studies are also done in the south eastern Kalahari (Dean *et al.* 1999; Jeltsch *et al.*1996; Jeltsch *et al.*1997; Jeltsch *et al*. 1999) as well as the western Khomas Hochland (Ward *et al*. 1998). A study of the soils of the Etosha National Park resulted in an in-depth description of the habitat criteria for *Colophospermum mopane* (Trippner 1996).

The composition of perennial grass communities in the central Namib dunes was found to be correlated with sand stability and average rainfall (Yeaton 1988). Based on Yeaton's initial observations, a descriptive, short-term study in the central Namib dunes explained the composition of dune plant communities by varying substrate penetrability and differences in dune aspect and slope instability (Boyer 1989).

### 3.2. Studies in progress

To refine Giess' preliminary vegetation map (1971) is a high priority long-term project pursued by several vegetation scientists in Namibia. Presently B. Strohbach carries out a vegetation survey in the northern Kalahari/Grootfontein area, M. Strohbach in the southern Namib and A. Burke (1997; 2000) in the Naukluft Mountains. These studies are expected to give more detailed descriptions of the communities, correlation with environmental parameters and provide guidelines for land use planning and resource management. Vegetation data along a transect from Lüderitz to Aus and along transects in the Sperrgebiet have been collected since 1988 with the aim of contributing to ecosystem studies along a coast-inland gradient (N. Jürgens, pers. comm.; Fanroth 1990; Schedel 1997). A review of the vegetation of the central Namib is currently in process (N. Jürgens, pers. comm.; Hachfeld 1996).

As part of a comparison of vegetation and grazing history in North-, East- and southern Africa, an extensive vegetation survey is being carried out in the Kunene

Province (Kaokoland) (ACACIA 1998). Using remote sensing techniques (LANDSAT) and extensive ground surveys along environmental gradients, backed by climate and soil data, this project is expected to contribute to several programmes within Namibia. Amongst the expected outcomes are a detailed vegetation map of the Kaokoland area and possibly recommendations for conservation and land use planning.

On a national level, Strohbach recently initiated a major project to update the preliminary vegetation map of Giess (1971) (Strohbach & Sheuyange 1999). For stratifying purposes, the preliminary Agro-ecological Zones map of Namibia (de Pauw 1996, de Pauw *et al*. 1998/99) is used. This map reflects typical land forms and thus typical habitats at a 1:1000000 scale.

Sample plots are selected on a stratified random basis, ensuring that each land region as defined by the land type map is covered with a minimum of 4 sample sites. Approximately 1000 such sample sites across Namibia are envisioned for the survey. Following the proposed method by Westfall *et al.* (1996), the actual sample site will be 1000 m in radius. As it is physically impossible to survey a sample site of such magnitude at fine scale, 5 sub-samples of 50 x 20 m are surveyed systematically in each sample site. Each sub-sample is to be on a specific habitat type, while the main sample can be over a variety of habitat types, as long as it is well within a Land Types. A habitat description as well as a complete species list with abundance values is to be taken at each sub-sample site for classification purposes. Each sub-sample will be entered as an individual sample in to the initial data base. This makes the sub-sample available for future detailed surveying for either a larger scale map and (possibly) for vegetation dynamic studies.

Data basing is to be done on TurboVeg (Hennekens 1996). This allows older data to be included (including completed studies mentioned earlier) in order to expand the data base and thus reduce the amount of field work needed. The possibility also exists to compare the Namibian data with data collected in South Africa and Botswana in similar communities in an effort of cross-border matching. Analysis is to be done with PHYTOTAB.

First results from south-eastern Namibia were recently presented (Strohbach 2000b).

### 3.3. Planned studies

The Great Escarpment, one of the most species rich areas in the country, will be investigated for its potential as a conservation island to regenerate degraded farmland in the surrounding areas. Using a multidisciplinary approach a team of botanists (Esler and Burke), entomologists (Gilbert and Samways) and theoretical ecologists (Wissel) will collect data on distribution and reproductive potential of key plant and insect species at various sites. Studies on plant population dynamics, the distribution data of key taxa, etc. are expected to be useful by-products of this project.

The BIOTA project plans to establish a series of 'bio-observatories' on the climatic gradient from the winter rainfall area in the Cape (RSA) via the arid winter-summer rainfall transition zone of the Richtersveld / southern Namibia to the summer rainfall area of the Kavango (BIOTA 2000). The main aim is to do long-term monitoring of the species diversity (including fauna, flora as well as the abiotic environment). However, essentially to map transitional zones along the gradient, a vegetation strip of ca 30 km along the gradient is also to be mapped.

## 4. Surveys based on remote sensing

### 4.1. Completed surveys

As part of the SADC Erosion Hazard Mapping project a Normalised Differentiated Vegetation Index derived from NOAA AHVRR satellite images was used to assess vegetation cover during the dry and wet season as a first approximation of minimum cover in the country (Strohbach *et al.* 1996). This information could be used to evaluate changes in total cover related to climatic conditions and should ideally be part of an annual monitoring programme.

Recently, various phytosociological studies also use remote sensing techniques to map the vegetation (see Hines & Burke 1997 and Strohbach 2000).

### 4.2. Surveys in progress

Based on satellite imagery (LANDSAT and SPOT), the Directorate of Forestry is presently carrying out a reconnaissance of forest types in northern Namibia (M. Chakanga, pers. comm.). The north-eastern regions (Caprivi and Okavango), mapped on a 1:50 000 scale, provide sufficient detail because this is the most wooded area of Namibia. The rest of the project area, former Ovamboland, is mapped on a 1:100 000 scale to economise on expenditure in this less wooded area (M. Chakanga, pers. comm.). However, technical problems with the interpretation of the satellite images on a 1:100 000 scale in low vegetation cover areas (e.g. Kaokoveld) are expected.

In the framework of establishing a GIS programme for environmental monitoring, vegetation is currently being mapped using satellite imagery in the Etosha Park and surrounding area (D. Davies & W. du Plessis, pers. comm.). This includes a "Vegetation Productivity Index" which estimates the quality of the grazing with the aid of NOAA NDVI images (Sannier *et al.* 1998).

A similar project is being undertaken by the Agro-Ecological zones programme of the Ministry of Agriculture, Water and Rural Development. Here the aim is to give an annual quantitative estimate of the grazing produced, also using NOAA NDVI images (du Pisani 1999). The methodology has been developed in Kenya (Ganzin 1997), based on a model by Moneith. This project should replace the outdated "Carrying Capacity Map" of the Department of Agricultural Technical Services (1979).

**Table 1**: Summary of completed vegetation and plant community studies in Namibia. Method: GVS = general vegetation survey, PHY = phytosociological study, VENV = vegetation-environmental study, Value: d = descriptive, q = quantitative, a = analytical; extent: l = local, r = regional, c = countrywide.

| Author | Area/district | Method | Value |
|---|---|---|---|
| Volk 1966 | Namibia | GVS | d,c |
| Leistner 1967 | Southern Kalahari | GVS | d,r |
| Nordenstam 1970 | Etosha | GVS | d,l |
| Giess 1970 | Etosha | GVS | d,l |
| Giess 1971 | Namibia | GVS | d,c |
| Joubert 1971 | Otjivasandu area | GVS | d,l |
| Volk & Leippert 1971 | Farms in the Khomas Hochland south of Windhoek | PHY | q,l |
| Rutherford 1972 | Omuvereme plateau | GVS | d,l |
| Leser 1972 | Nossob area | GVS | d,l |
| Leistner & Werger 1973 | Southern Kalahari | GVS | d,r |
| Nordenstam 1974 | Brandberg | GVS | d,l |
| Rutherford 1975 | Omuvereme plateau | GVS | d,l |
| Robinson 1976 | Central Namib | PHY | q,r |
| De Sousa Correira 1976 | Northern Namibia | GVS | d,r |
| Eloff *et al*. 1977 | Damaraland & Kaokoland | GVS | d,r |
| Claasen & Page 1978 | Ovambo | GVS | d,r |
| Department Agiculture Technical Services 1979 | Commercial farming areas | GVS | d&q,c |
| Joubert 1979 | Naukluft | GVS | d,l |
| Page 1979/80 | Kavango | GVS | d,r |
| Viljoen 1980 | Kaokaland | GVS | q,r |
| Seely *et al*. 1980 | Kuiseb River | GVS | q,l |
| Theron *et al*. 1980 | Kuiseb River | GVS | d,l |

| Author | Area/district | Method | Value |
|---|---|---|---|
| le Roux 1980 | Etosha | VENV | a,l |
| Giess 1981 | Central Namib | GVS | d,r |
| Moisel & Moll 1981 | Welwitschia plain | PHY | q,l |
| Nordenstam 1982 | Brandberg | GVS | d,l |
| Nel 1983 | Central Namib | GVS | q,r |
| Jankowitz 1983 | Waterberg | PHY | q,l |
| Giess 1983 | Gamsberg | GVS | d,l |
| Nel & Opperman 1985 | Central Namib | GVS | q,r |
| Jankowitz & van Rensburg 1985 | Waterberg | GVS | d,l |
| Kellner 1986 | Daan Viljoen, farms Claratal and Neudamm | PHY | d,l |
| De Sousa Correia & Bredenkamp 1986 | Okavango | GVS | d,r |
| Jankowitz & Venter 1987 | Waterberg | PHY | q,l |
| Le Roux *et al*. 1988 | Etosha | VENV | d,l |
| Yeaton 1988 | Central Namib Dunes | VENV | a,l |
| Boyer 1989 | Central Namib Dunes | VENV | d,l |
| Tarr & Tarr 1989 | Ganias Flats | GVS | d,l |
| Bethune 1991 | Kavango wetlands | | d,r |
| Fanroth 1991 | Lüderitz - Aus | PHY | d,r |
| Jürgens 1991 | Namib Desert | GVS | a,r |
| Seely 1991 | Central Namib Dunes | GVS | q,l |
| Chivell 1992 | Karstveld | VENV | a,r |
| Strohbach 1992 | Grootfontein | GVS | a,l |
| Hines 1992 | eastern Bushmanland | VENV | a,l |
| Hines 1993 | Bushmanland | GVS | d,r |
| Günster 1994 | Central Namib | GVS | a,r |
| Irish 1994 | Namibia | Review | d,c |
| Jürgens 1994 | Namib Desert | GVS | d,r |
| Williamson 1995 | Diamond Area No.1 | GVS | d,r |
| Hachfeld 1996 | Central Namib | PHY | d,r |
| Gimborn 1996 | Namaland | PHY | q,l |
| Jakobs 1996 | Namaland | PHY | q,l |
| Jeltsch *et al.* 1996 | Southern Kalahari | VENV | a,r |

| Author | Area/district | Method | Value |
|---|---|---|---|
| Lindenbach 1996 | Namaland | VENV | a,l |
| Strohbach *et al.* 1996 | Nation-wide | Remote sensing | a,c |
| Burke 1997 | Naukluft | VENV | a,l |
| du Plessis 1997 | Etosha | VENV | q,l |
| Schedel 1997 | Namaland | PHY | q,l |
| Strohbach 1997 | Acacia Park, Rehoboth | PHY | d,l |
| Hines & Burke 1997 | Kavango, Oshana regions | GVS | d,l |
| Hines 1997 | Caprivi | GVS | d,r |
| Jeltsch *et al.* 1997 | Southern Kalahari | VENV | a,r |
| Williamson 1997 | Diamond Area No. 1 | GVS | d,r |
| Jürgens *et al*. 1997 | Namib Desert | Review | d & a, r |
| ACACIA 1998 | Opuwo district | PHY, VENV | q, r |
| Joubert 1997 | Daan Viljoen | PHY | a,l |
| Leuchtenberg 1997 | Otukarru | PHY / VENV | d,l |
| Burke *et al*. 1998 | Hauchab | GVS | d,l |
| du Plessis *et al*. 1998 a & b | Etosha | VENV | q,l |
| Sannier *et al*. 1998 | Etosha, Namibia & Zambia | Remote Sensing | q, l & c |
| Ward *et al*. 1998 | Western Khomas | VENV | a,l |
| Dean *et al.* 1999 | Southern Kalahari | VENV | a,r |
| Du Pisani 1999 | Nation-wide | Remote Sensing | q,c |
| Jeltsch *et al.* 1999 | Southern Kalahari | VENV | a,r |
| Burke 2000 | Naukluft | PHY | d,l |
| Strohbach 2000a | Uitkomst Research Station | PHY | d,l |
| Strohbach 2000b | South-eastern Namibia | PHY | d,r |

## Discussion

### 1. Are there any common trends in comparable studies?

Climate and soil, proposed as the most important factors determining the distribution of vegetation in the Namib Desert (Jürgens *et al.* 1997), also appear to be controlling the composition of the vegetation in other parts of Namibia. Le Roux's (1980) vegetation analysis of Etosha concluded that soil moisture and nutrients are the critical factors, while Hines (1992) stressed the importance of exposure of geological strata which resulted in higher diversity of associations in eastern Otjozondjupa (Bushmanland) than in the surrounding Kalahari with a much thicker sand cover. More detailed studies, investigating small-scale vegetation patterns in relation to the environment, should help to elucidate the general picture.

## 2. Anything new to science?

Even the latest techniques and developments in assessing and analysing vegetation (Roberts 1989; van der Maarel 1989) are only a means of describing plant communities so as to generate hypotheses at the species, community and ecosystem levels. In developing countries, such questions are almost invariably needs-driven, directed towards solving environmental and socio-economic problems such as overgrazing leading to loss of arable land. In Namibia, desertification is one of the major environmental problems (Seely & Jacobson 1991). Thus investigations of the underlying causes of land degradation have high priority. Processes leading to desertification are complex and operate on an ecosystem level. Patchiness and redistribution of moisture and nutrients might give clues to what sets off the process of desertification (Schlesinger *et al.* 1990). Yet, this can only be investigated once current plant communities have been identified and their relation to environmental parameters and grazing pressures is understood. In brief: vegetation description and analysis in many areas has to precede every effort to combat desertification.

Diverting from the initial method of simply describing the existing vegetation, vegetation scientists in the developing world are pressed to assess vegetation in such a way that they are able to supply practical suggestions on how to manage the land in a sustainable fashion (Müller 1983). This implies that besides quantitative assessment, vegetation dynamics and responses of vegetation to environmental factors have to be monitored and included. The large number of different parameters and amount of data require computer modelling to develop recommendations for management.

## 3. Where do we go from here? - Future studies

Considering that the vegetation in about 60 % of Namibia has not been surveyed in detail, there is still much to be done. Hitherto entirely uncovered are the Namib Desert between Lüderitz and Kuiseb River, the entire Hardap region, most parts of the Khomas, Otjozondjupa, Omaheke and eastern Kunene regions, and the Skeleton Coast (Fig. 1).

In addition, there are disagreements between several authors about the delimitation of vegetation units in the southern Namib (Giess 1971; Werger 1978; Jürgens 1991; Irish 1994). Since few of these are based on detailed vegetation surveys, Strohbach-Fricke's ongoing study might contribute the much-needed data to resolve the dispute.

### 3.1. Phytosociological studies

As a vegetation classification and vegetation map have been shown to be the basis for further applied studies, such as vegetation changes due to rangeland management, a detailed vegetation map is to be produced for Namibia. Craig (1983) suggested a relatively simple technique to produce such a vegetation classification in Zimbabwe. However, considering that the map and its description will serve as a management tool, it will be imperative to have detailed data available upon which to base the description. Ideally the descriptive data (i.e. the species composition and the cover/abundance of each species) for each mapping unit should be usable as base-line data for further studies of vegetation dynamics, and even monitoring action.

For this purpose it is imperative that if not all, at least 90 % of the species on a sample plot should be listed. Basing a vegetation classification on only limited groups of plants - trees, shrubs and grasses as is generally used - will not reveal a true picture of the vegetation types. Especially in the desert environment dwarf-shrubs and forbs constitute a major part of the vegetation, with woody plants restricted to favourable habitats such as drainage lines. Many dwarf-shrubs and forbs are also of importance as indicators for management practices, or are of economic importance. Poisonous plants like *Geigeria* spp., *Dichapetalum cymosum* and *Urginea* spp. form a constant threat to livestock. However, these plants are often not included in surveys, since they are neither woody nor a grass.

The Braun-Blanquet/Domin scales (Mueller-Dombois & Ellenberg 1974), generally used by phytosociologists, are rough estimates of the cover. From these cover estimates no actual abundance value of the species can be derived. Thus such data are generally of a descriptive nature, and should not be used in further vegetation dynamics analyses, where actual abundance's are required.

Alternatives for the Domin scale would be the Plant Number Scale (Westfall & Panagos 1988; Westfall *et al*. 1996) or the McAuliffe scale (McAuliffe 1990). Both could be used for both phytosociological and vegetation dynamic studies, the former being more suitable for denser vegetation, the latter being specifically developed for desert (i.e. low cover) communities. Both methods are however cumbersome and time-consuming to apply compared to the visual estimate as used with the Domin scale. Other commonly used survey methods are also under fire for not giving the desired results like the wheel-point survey (Tidmarsh & Havenga 1955), as used for grasses. The selection of the survey method to apply is thus dependant on the purpose of the data and the aim of the study. A trade-off between detail (and compatibility) and time and resources available has to be made for each project.

For the classification of vegetation data, various methods are available. The classical Braun-Blanquet approach of manual tabulation, often supported by computerised methods like TWINSPAN (Hill 1979) and others, is widely used. A recent development is PHYTOTAB (Westfall 1992; Westfall *et al*. 1997). Unlike the currently widely used classification programme TWINSPAN, PHYTOTAB does not only cluster species assemblages, but identifies weak, normal and strong competitors using a linear correlation between cover and frequency to elucidate plant associations. In addition, the programme gives numerous descriptive data on life form composition, species richness and competitive abilities of species in specific communities.

### 3.2. Vegetation dynamic studies

For nearly 200 years many parts of Namibia have been under varying, mainly extensive grazing pressure (Walter & Volk 1954). In these areas the type and intensity of grazing largely determine the recent structure and composition of the vegetation. As a contribution to the desertification programme it might be useful to investigate recent vegetation changes in farmland by revisiting areas for which detailed surveys have been carried out in the past (e.g. Volk & Leippert 1971; Kellner 1986). Monitoring of vegetation changes in conservation areas could be done in a similar way.

Comparing Robinson's study of the central Namib (1976), which had been carried out after an unusually wet period, to the much more arid situation today may reveal insights to possible vegetation changes in an extreme arid area in response to short-term climatic change.

In terms of actual management, it is important that an estimate of the production potential of a plant community is obtained, related to the actual rainfall and the condition of the veld. For this purpose, modelling with NOAA AVHRR satellite images, veld condition assessment models and plant growth models will need to be done.

## 4. Research priorities

Two main environmental issues have high priority in Namibia: the conservation of biodiversity and combating desertification. To conserve areas of high biodiversity value might also have positive spin-offs in the attempt to restore degraded lands.

Species which are eliminated by overgrazing might be present in conservation areas or centres of high diversity and could recolonize degraded lands from these refuges. It is therefore imperative that areas which are expected to be species rich and have not been investigated hitherto should have high priority. The southern Namib and especially the eastern boundary of the Namib and the Great Western Escarpment, are some examples. Commercial and communal farmland which has not been investigated until now can serve as study areas to investigate vegetation in response to different grazing pressures. Considering the extent of these uncovered regions, sites which are under investigation at present could serve as case studies to test appropriate methods and develop analytical techniques to be used in other areas. The northern Kalahari serves as one testing site (Strohbach 1995), while the area around Bethanien, currently used as a study site for sustainable livestock development (A. Kruger, pers. comm.), could serve as the southern counterpart. Future studies should be designed in a way to combine the surveying aspect with plant population dynamics and responses to environmental stresses. Multidisciplinary approaches and long-term monitoring are conducive to address these questions appropriately. This should enable researchers to suggest definitive measures for management in a particular region.

## Conclusion

Although a preliminary vegetation map (Giess 1971) reflects the main vegetation types in Namibia sufficiently, a refinement of this map is imperative to provide sufficient data for rangeland and resource management. Using the Agro-ecological zones map as a basis, sites should be selected on a stratified random basis across entire Namibia. This is to be done in combination with older (existing) data, using a compatible databasing system. Care should be taken to collect compatible samples, especially concentrating on proper collecting procedures as used in the Braun-Blanquet methodology. A fairly detailed habitat description and soil analysis should accompany this survey.

Remote sensing is a valuable tool in mapping the vegetation. However, care should be taken not to overemphasise the remote sensing, but to rather concentrate on the collection of ground-truthing data.

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