PROVIDING RELEVANT, USEFUL INFORMATION ON NAMIBIAN VEGETATION TYPES

B.J. STROHBACH

National Botanical Research Institute, Private Bag 13184, Windhoek, Namibia
e-mail: bens@nbri.org.na

ABSTRACT

Vegetation maps are essential to land use planning, by providing information regarding an important resource for especially extensive livestock farming, but also game farming, and with that, the tourism industry. However, many vegetation maps provide only a name of the vegetation unit, in combination with a spatial description – mostly in the form of a polygon on a map.

With the presently ongoing 'Vegetation Survey of Namibia' project, an attempt is made to provide as much useful information per vegetation type as possible. This ranges from basic descriptors like species composition; characteristic species; and diversity statistics; to highlighting species of conservation as well as economic importance, and to rating the sensitivity and utilisation potential of the vegetation type. The method used to derive these descriptors is shortly described. An outlook on future ways to improve on this information, and to make this information widely accessible, is given.

INTRODUCTION

The knowledge of and ability to differentiate between various vegetation types is seen as a measure to aid land use planning and more sustainable utilisation of this finite natural resource (Mueller-Dombois & Ellenberg, 1974; Vorster & Roux, 1983; Küchler & Zonneveld, 1988). In practice, however, only limited information for farming and veld management is provided by many vegetation mapping and description studies in Namibia (compare e.g. Giess, 1971; Volk & Leippert, 1971; Mendelsohn & Roberts, 1997; Giess, 1998; Mendelsohn, El Obeid & Roberts, 2000; Mendelsohn, Jarvis, Roberts & Robertson, 2002; Mendelsohn & El Obeid, 2003). Exceptions are studies done specifically for management purposes in Etosha and Waterberg National Parks (Le Roux, 1979; Jankowitz & Van Rensburg, 1985; Jankowitz & Venter, 1987; Le Roux, Grunow, Morris, Bredenkamp & Scheepers, 1988). These studies, however, needed extensive collection of additional data in order to be able to make such management recommendations possible.

Collecting such additional data is time-consuming, and not feasible for a large-scale project like the Vegetation Survey of Namibia project. The Vegetation Survey of Namibia project was initiated in 1996, with the aim to update the rather basic vegetation map created in the 1970s (Giess, 1971) to a more detailed, more accurate map, which also provides a sound baseline of information on the different vegetation types (Strohbach, 2001). This project is based on extensive vegetation sampling ranging between a reconnaissance to a semi-detailed scale. The formal classification of these sample relevés into associations or higher-order syntaxons, as well as the mapping of these vegetation associations, or landscape groupings of associations, at a reasonable, interpretable scale, follows. In recent years the project has progressed steadily (Strohbach & Jürgens, 2010), with several descriptions and maps being published or in the process of being published (Strohbach, Strohbach, Kutuahuripa & Mouton, 2004; Strohbach & Petersen, 2007; Hüttich, Gessner, Herold, Strohbach, Schmidt, Keil & Dech, 2009; Hüttich, Herold, Strohbach & Dech, 2010; Strohbach & Jankowitz, 2012). In order to make these descriptions a truly useful tool for land use planners, land managers, conservationists and environmentalists, a system of presenting data and information regarding the vegetation was developed, considering all suitable, available data on the vegetation association. This follows a basic concept developed for the description of the Spitzkoppe vegetation (Burke, 2008).

DATA COLLECTED AND GENERATED DURING ANALYSIS

Field data collection

Field data collection is based on the Braun-Blanquet procedure (Braun-Blanquet, 1932; Mueller-Dombois & Ellenberg, 1974), with specific adaptions for the project (Strohbach, 2001). Sample plots are as a rule 1 000 m^2 in size, mostly 20 x 50 m, occasionally (depending on the habitat) changing to either 30 x 30 m (e.g. a rock outcrop) or 10 x 100 m (e.g. a narrow stream). The use of a 1 000 m^2 plot allows the calculation of species densities.

At each plot, the position and altitude is recorded using a Garmin GPS. The habitat is described as part of the larger landscape, using SOTER classes (FAO, 1995). The local topographic description refers to the habitat of the actual plot. In addition, the steepness of the plot (as per SOTER classes), the aspect of the plot – if the steepness is classed as 'rolling' or steeper (> 6° or 10 %), and the stone cover of each plot is recorded. Also following the SOTER classes is the lithology, i.e. the type of substrate from which the soils have been derived. The degree of surface crusting is often difficult to determine accurately, particular if it has rained, thus only a rough grading from none to severe (four classes) is presented. The degree of erosion is subdivided into wind-, sheet-, rill- and gully erosion. At each site at least one photo, often many more, is taken.

The actual Braun-Blanquet survey follows: All species found on the sample site are listed, their typical growth form noted and their crown cover estimated. This abundance estimate differs from the original Braun-Blanquet approach, not using the Braun-Blanquet or even a revised Braun-Blanquet scale (Mueller-Dombois & Ellenberg, 1974), but an estimated percentage cover. This can typically be translated as per Table 1 below.

Table 1. Typical conversion values for the original and the revised Braun-Blanquet scale into percentage crown cover values as used by the Vegetation of Namibia Survey project

Original Braun-Blanquet Scale	Revised Braun-Blanquet Scale	Typical ratings used in the Vegetation Survey of Namibia project	
r	r	< 0,1 % (0,1 % recorded)	
+	+	< 1% (0,5 % recorded)	
1	1	1 %–5 % (recorded as 2 or 5 %)	
2	2A (or A)	5 %–10 %	Recorded as 5, 10, 20 or 25 %
	2B (or B)	10 %–20 %	
	2C (or C)	20 %–25 %	
3	3	25 %–50 % (recorded as 25, 30, 40 or 50 %)	
4	4	50 %–75 % (recorded as 50, 60 or 70 %)	
5	5	> 75 % (recorded as 80, 90 or 100 %)	

This list of species, with their abundancies and related growth form information, constitutes the relevé, or abstraction of the sample plot.

Classifying vegetation types

Once the relevé data has been entered into a suitable database and cleaned, data processing using Juice (Tichý, 2002) can commence. The outcome is a classification of vegetation units, aiming to delimit vegetation associations or higher synatxons. An association is defined as: '… a plant community of definite floristic composition which presents a uniform physiognomy and which grows in uniform habitat conditions' (Weber, Moravec & Theurillat, 2000). Such associations are used as basic descriptive units.

Classification results can be displayed as a phytosociological table or a synoptic table. The main difference between these two are the fact that the phytosociological table displays the individual relevés, grouped into associations, whilst the synoptic table displays only a summary of the associations. The matrix of the synoptic table can take different forms – generally, it is either an average of the abundance of the particular species in the association (the constancy a species occurs in a particular association), or the fidelity a particular species has to the association (i.e. occurring constantly in the association, but not in other associations) (Bruelheide, 2000). For the Vegetation Survey of Namibia project, where various data sets of differening resolution are often combined, fidelity phi-coefficient values are generally used (Chytrý, Tichý, Holt & Botta-Dukat, 2002).

From these two tables, summary statistics can be prepared to describe the vegetation association. For the purpose of formal description following the International Code of Phytosociological Nomenclature (Weber *et al.*, 2000), diagnostic species are determined. Diagnostic species can be subdivided into characteristic species displaying a high fidelity value (i.e. species occurring in most of the relevés of the particular association, but little or not at all in other associations), as well as constant species (i.e. those occurring in most relevés of the association, but also occur in other associations). Together with a (relative) typical relevé, which is assigned as type relevé, the diagnostic species are used to formally describe the association (or other syntaxonomic level).

Various other summarising statistics (like biodiversity statistics) and information (like species lists) can be extracted from the phytosociological table. In addition to the actual number of species observed, an average species density (i.e. number of species per unit area) is calculated, as well as an estimated number of species occurring in the association, using the Jackknife procedure (Heltshe & Forrester, 1983; Palmer, 1990; Strohbach & Strohbach, 2004).

Structure

The vegetation structure is a function of the composition of the vegetation – the cover of trees, shrubs, dwarf shrubs, grasses and herbs in relation to each other. Edwards (1983) proposed a structural classification scheme, which can be easily applied with the context of Namibia savannas. By calculating the mean canopy cover for the different strata (trees, shrubs, dwarf shrubs, grasses and herbs), the structure can be categorised. In order to visually illustrate the structure (including variations), a box-and-whisker plot of the various structural components for each vegetation association has been constructed.

ADDITIONAL CALCULATED DATA AND DATA EXTRAPOLATED FROM GIS

Habitat data

Not all essential habitat data can be collected in the field. A fair amount needs to be extrapolated from GIS applications, e.g. the rainfall, agro-ecological zone and growing period zone (De Pauw, Coetzee, Calitz, Beukes & Vits, 1998; NARIS, 2001). Although the growing period zones have been mapped as an agronomic measure of suitability, this also proved to be highly suitable for describing climatic conditions for natural vegetation, which is often used for extensive grazing. Geological data is generally extrapolated from the Geological Map of Namibia (Geological Survey, 1980) and augmented by information from other sources (South African Committee for Stratgraphy, 1980; Schneider, 2004).

Altitudinal data from Global Positioning Systems (GPSs) were not always accurate. Until 2004, such data were not recorded at all, and even today, the altitudinal data from GPSs are estimated to be up to 23 m out in 95 % of measurements. Larger errors can be expected in 5 % of cases (Mehaffey, 2001; Creager, 2006). This poses a problem especially with low-gradient topographic features like pans and omirimbi. In order to fill gaps, Digital Elevation Models (DEMs) are utilised. One of the later products, the Shuttle Radar Topographic Mission (SRTM) data, has been cleaned and is estimated to have a vertical accuracy of about 6 m (albeit a special resolution of only 90 m – Jarvis, Reuter, Nelson & Guevara, 2008). Other suitable products like the ASTER Global DEM has a ground resolution of 30 m and an estimated vertical accuracy of 8,3 m (Hirano, Welch & Lang, 2003). Their suitability still needs to be tested.

Utilisation potential of the vegetation

Namibia, being a semi-arid country, is mostly used for extensive, livestock-based agriculture. The grazing capacity of the country is thus immensely important, with first summaries being published in 1979 (Departement Landbou Tegniese Dienste, 1979), and being recently intensively studied again as part of the Land Reform Programme of the Government of Namibia (Lubbe, 2005; Espach, 2006; Espach, Lubbe & Ganzin, 2006).

As rightly pointed out by Lubbe (2005), it is impossible to have a fixed grazing capacity map for Namibia – partially due to seasonal variations in rainfall, and partially due to long-term vegetation-dynamic changes, which affect the composition and productivity of the land. A vegetation map can thus not indicate grazing capacity – especially also seeing that estimated abundance ratings were used in the original surveys rather than tedious biomass determinations. However, a vegetation map could (and should) contribute towards the understanding of the influences the commodity ‘vegetation’ has on the grazing capacity. For this purpose, a suitability index has been calculated for each identified vegetation association, based on its habitat, structure and composition, as follows:

Habitat: The main driving force in any arid environment is the availability of water (Noy-Meir, 1973). This is obviously determined by the amount of rainfall – which is subject to considerable variability (Botha, 1996, 1998), but also the infiltration ability and storage capacity of the soils. The sub-index on habitat considers these factors as follows:

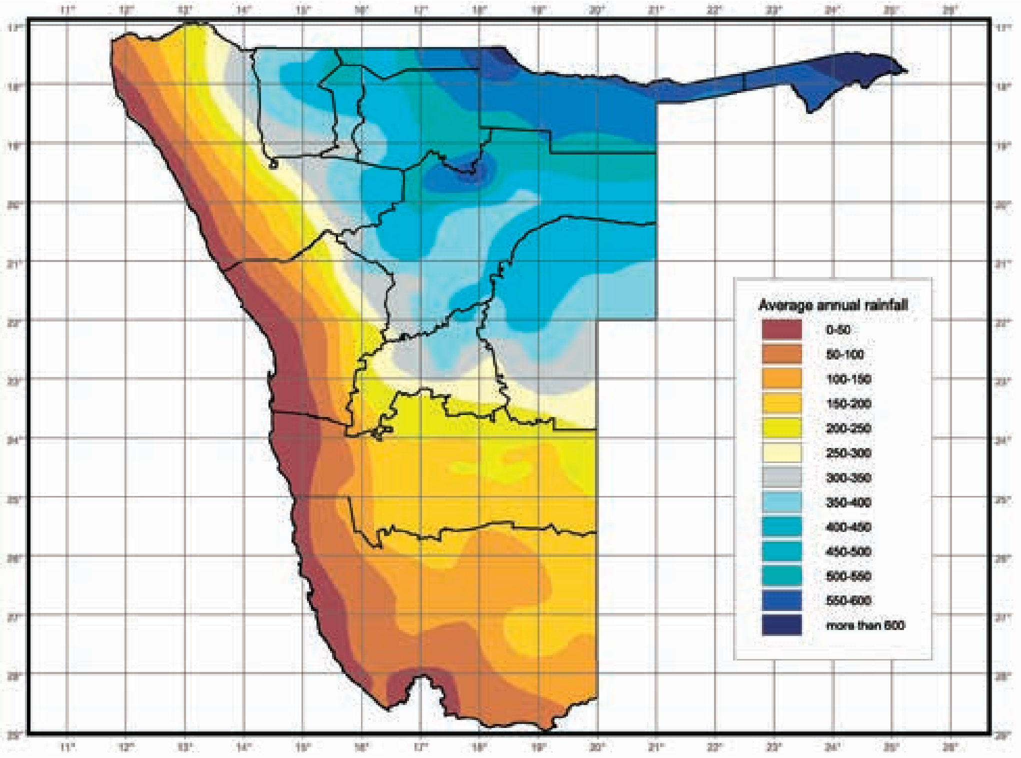

Figure 1. Average annual rainfall in Namibia (Mendelsohn *et al*., 2002).

1. *Rainfall*: Mean annual rainfall of the vegetation type. This was determined by superimposing the relevé positions over the rainfall map presented in the Atlas of Namibia (Mendelsohn *et al*., 2002) and copying the mean annual rainfall as value (Figure 1). For each vegetation association, a mean was calculated in this way. The mean annual rainfall was relativised regarding other values by halving it.

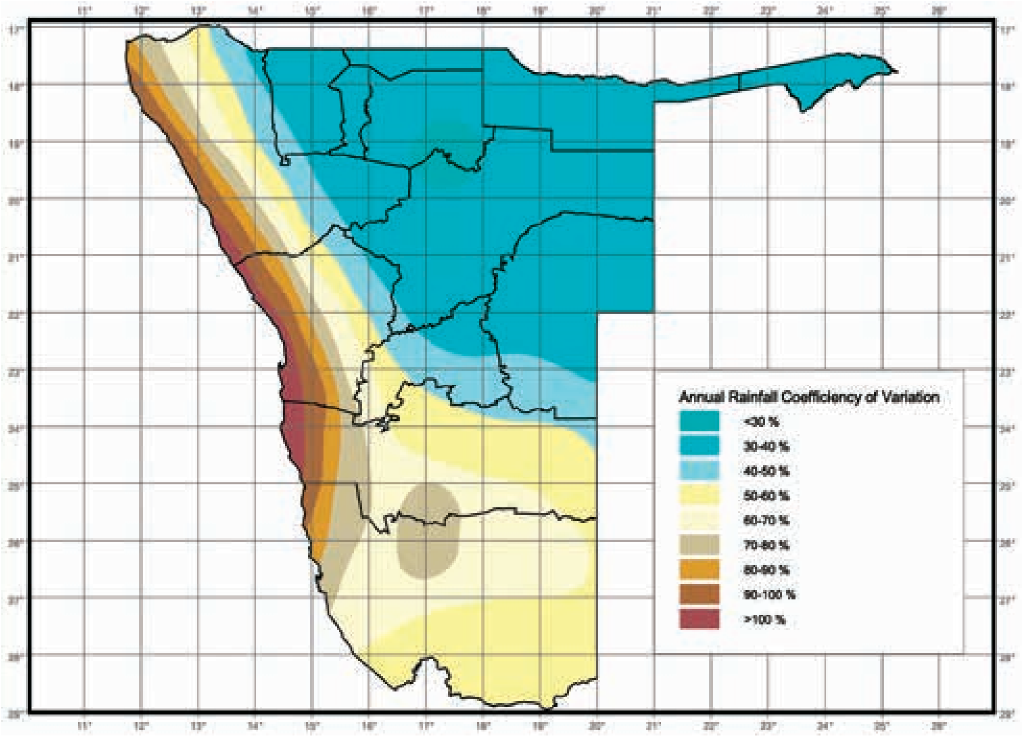

Figure 2. The coefficient of variation (CV) of annual rainfall is a measure of the reliability that the annual rains will fall. The higher the CV-value, the less likely is the chance that the annual average rainfall will be achieved (Botha, 1996).

2. *Rainfall dependability* refers to the variation in mean annual rainfall, i.e. how certain it is that a certain amount of rain will fall in a certain area in a given season. This has been proven to be a significant factor in Namibian climate by Botha (1996, 1998), and has been well illustrated in the Atlas of Namibia (Mendelsohn *et al.*, 2002). Data from Botha (1996) (Figure 2) have been extracted in a similar way as the mean annual rainfall in Figure 1. The average value has been deducted from 100, thus indicating the percentage chance that the mean annual rainfall will be received in a given season. This value was used as is in the final calculation.

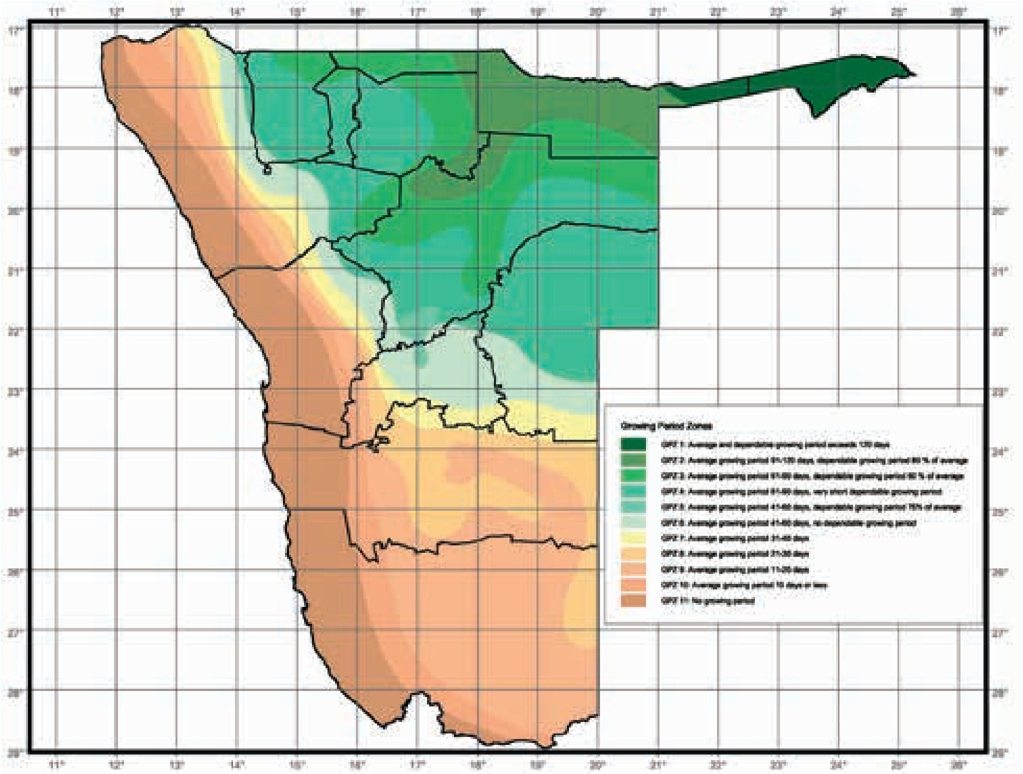

Figure 3. The growing period zones indicate just how long the annual growing period – also for rangelands – is (De Pauw *et al.*, 1998).

3. *Growing Period Zone*: Namibia has been divided into 11 growing period zones (De Pauw & Coetzee, 1998; De Pauw *et al.*, 1998), ranging from exceeding 120 days in the far North-East (Katima Mulilo station) (GPZ 1), to no growing period along the coast (GPZ 11) (Figure 3). Being strongly correlated with the mean annual rainfall, as well as the coefficient of variation of the mean annual rainfall, it reflects the length of the growing season for plants in which sufficient soil moisture is available, and the air temperature is high enough to permit growth. The inverse of the GPZ-number (1–11) was multiplied with 200 to relativise it compared to rainfall and rainfall dependability.

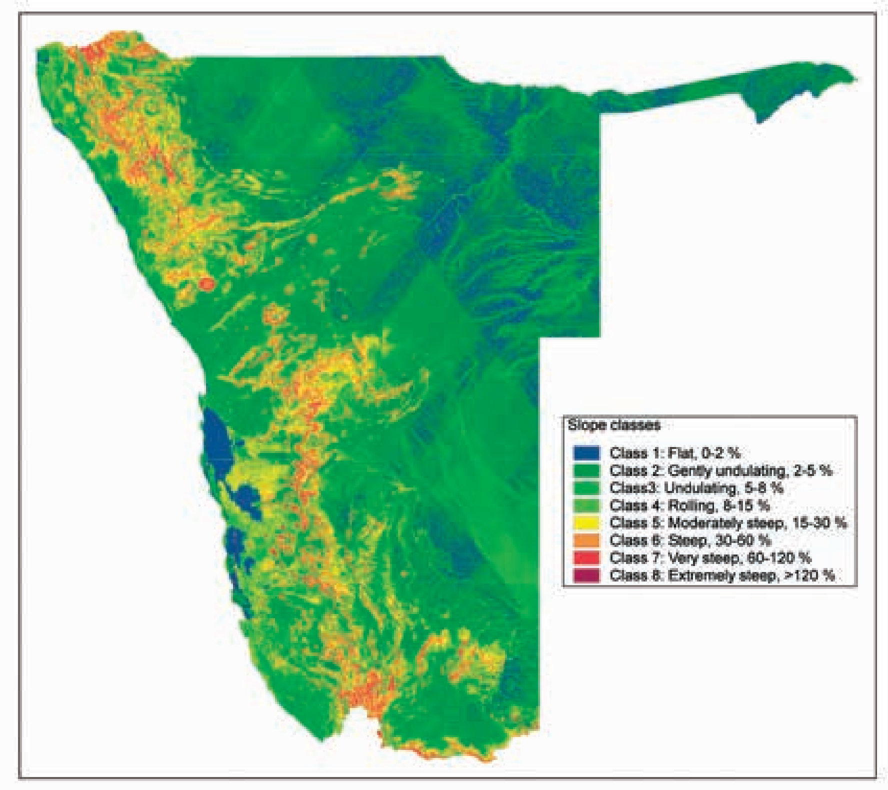

Figure 4. Steepness of the Namibian landscape, as derived from SRTM images (Jarvis *et al*., 2008).

4. *Slope*: The rationale for including slope in this habitat sub-index is as follows: (a) steep slopes are generally less accessible for both livestock and their owners/managers. Thus, landscapes with extreme steep slopes are virtually unusable for extensive grazing. (b) Steep slopes increase the run-off amount and decrease the infiltration ability of water received through rainfall. Steep slopes are thus likely to be drier/less productive than moderate slopes. (c) Due to the increased run-off, steeper slopes are also more prone to erosion (Chakela & Stocking, 1988; Stocking, Chakela & Elwell, 1988; Lal, 1994), meaning that steep landscapes need to be managed more conservatively than moderately sloped or flat landscapes, in order to prevent erosion.

Using an appropriate SRTM-image (Jarvis *et al*., 2008), slopes were calculated with the SURFACE module in IDRISI Andes (Eastman, 2006). The resulting map was reclassified into eight classes, using FAO SOTER system (FAO, 1995) (flat; gently undulating; undulating; rolling; moderately steep; steep; and very steep) for the first 7, and adding the 8th class as being extremely steep, or steeper than 120 % (Figure 4). For calculation purposes, only the FAO SOTER classes were used, numbering these from 1 to 7 (1 being flat; 7 very steep), and the inverse multiplied with 100 in order to relativise it regarding the other index values.

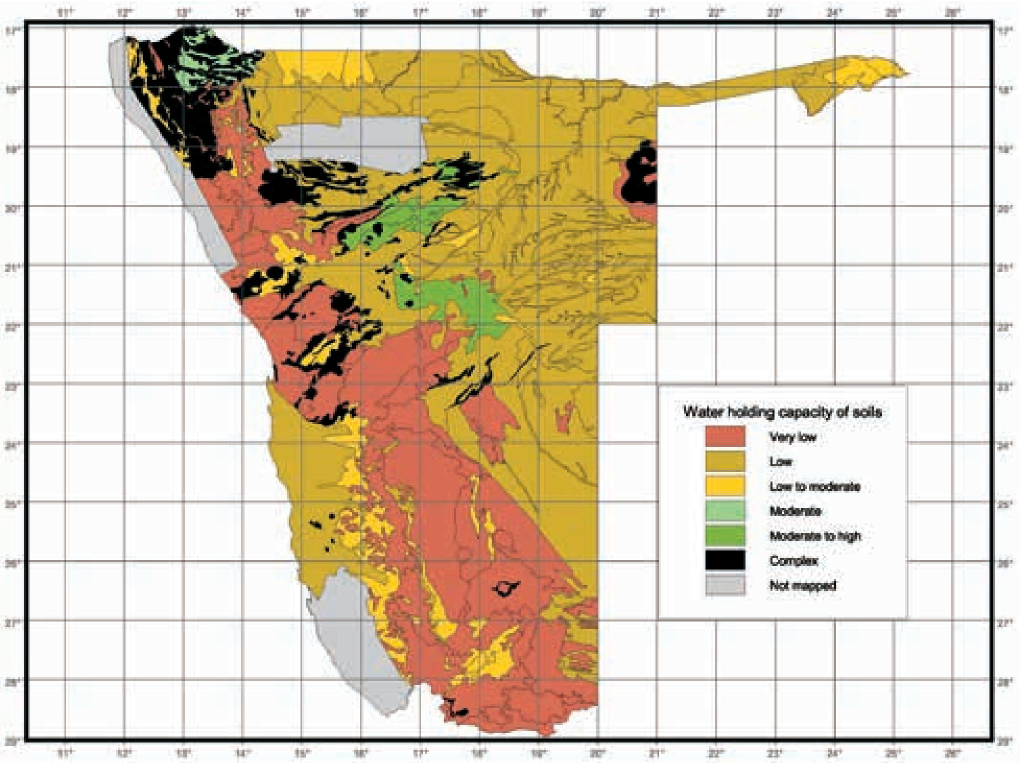

Figure 5. The estimated water holding capacity of Namibian soils, as a function of the soil depth and soil structure (ICC, MAWRD & AECI, 2000; Coetzee, 2003).

5. *Water holding capacity*: Soil water-holding capacity is related to infiltration rate and hydraulic conductivity soil properties (Coetzee, 2003). This data was extracted from the 1:1 000 000 National Soil Survey, and is available as part of the NARIS data set (Figure 5). Areas mapped as 'not applicable/complex' (i.e. most inselberg complexes) were given a value 20, 'very low' a value 40, 'low' a value 60, 'low to moderate' a value 80, 'moderate' a value 100, and 'moderate to high' a value 120.

These 5 values were summed. The maximum potential value is 835.

Structure: The vegetation structure is one of the most important factors contributing to grazing capacity, and an attempt has been made to map this, starting with a pilot area between Windhoek and Gobabis in a separate project (Espach, 2006).

The average covers of various structure layers have been used in calculating this sub-index, with two modifications:

*Perennial grass cov*er has been weighted (multiplied by) a factor 5. This was done, as the perennial grasses are those who will likely be available as fodder during adverse rainy seasons. Most desirable or high-value grazing species are perennial species (Müller, 2007).

Bare ground was deducted from 100, i.e. reflecting total vegetation cover rather than actual bare ground. This value was doubled.

Bush Encroachment Ratio: Bush encroachment, being one of the most severe problems livestock farmers are presently facing in Namibia (De Klerk, 2004), had to be in some way incorporated in the utilisation potential index. The bush encroachment ratio was calculated similar to the 'woody cover parameter' used for biomass production estimation from satellite data (Espach *et al*., 2006). This parameter essential is the ratio between grass cover and the sum of grass and woody cover. For the purpose of the present utilisation index, it was relativised to the total vegetative cover:

$$BER = ((C_a + C_p)/(C_a + C_p + C_s + C_t))*C_v$$

where:		
	BER	Bush Encroachment Ratio
	C_a	average annual grass cover
	C_p	average perennial grass cover
	C_s	average shrub cover (larger than 1 m)
	C_t	average tree cover
	C_v	average total vegetation cover

The structure sub-index was also a sum of the above values, with a maximum value of 800.

Composition: This sub-index reflects the quality of the vegetation related to livestock farming. Lacking comprehensive production values of species, e.g. the Grazing Value Index (GVI), used extensively in the Karoo region in South Africa (Du Toit, 1996, 1997a, 1997b, 2000), use was made of more subjective, but generally accepted, grazing values presented in Müller (2007). This makes the entire sub-index strongly biased towards cattle farming rather than small-stock or game farming. This problem has been realised before, and projects are underway to improve information regarding the grazing value of especially dwarf shrub species in Namibia (Lubbe, 2005).

The following weighting has been applied: A multiplying factor of 10 was applied to high-value grazing species; a multiplying factor of 4 was applied to grass species of moderate grazing value, and a multiplying factor of 2 for low-value grazing species. This weighting corresponds to the Ecological Index Method used widely in South Africa (Tainton, Edwards & Mentis, 1980; Vorster, 1982, 1987).

In addition to the grass composition, the presence of toxic plants (Mannheimer, Marais & Schubert, 2008) was also considered. The number of toxic plants found in an association was expressed as a percentage of the total number of observed species in the association, and deducted from 100 (i.e. the value reflects the percentual proportion of non-toxic species). This value was halved. Most of these species are, however, not of critical importance; only few are regarded as problematic. The average abundance of these problematic species was calculated, and the inverse of this abundance was halved. An absolute minimum cover of 0,01 % was always assumed, thus giving a maximum rating of 50 if no such problematic toxic species were found.

Although a maximum value of 1 100 is theoretically possible for this sub-index (i.e. no toxic plants and a 100 % cover by high-value grass species), this scenario is unlikely. Experience with the Ecological Index Method has shown 'good' veld to obtain a value of between 600 and 800 points based on relative frequency of grass species only. The present data, however, considers an estimated absolute cover of all species, thus it is assumed that the grass species composition will not reach a value of more than 500. The maximum value for this sub-index has therefore been set to 600, relativising it also regarding the values of the other two sub-indices.

The total suitability index has a maximum value of 2 235 and represents a sum of the sub-indices. The following value-ratings have been set arbitrarily:

• Unsuitable for livestock farming:	< 400
• Low potential for livestock farming:	400–800
• Moderate potential for livestock farming:	800–1 200
• High potential for livestock farming:	1 200–1 600
• Very high potential for livestock farming:	> 1 600

As example, the values calculated for six well-defined vegetation associations within the Khomas Hochland are presented in Table 2, as well as Figure 6. These associationas are the *Danthoniopsio ramosae – Osyrietum lanceolatae*[1] (open shrublands of the high mountains of the Khomas Hochland), the *Brachiario nigropedatae – Acacietum hereroensis* (open bushlands of the central Khomas Hochland), the *Dichrostachyo cinereae – Acacietum erubescentis* (Yellow-bark Acacia bushlands of the Khomas Hochland lowlands), the *Eragrostio nindensis – Acacietum melliferae* (bush-encroached lowlands of the Khomas Hochland), the *Schmidtio kalahariensis – Acacietum eriolobae* (Brakwater and Aris Camelthorn savanna) and as comparision, an arid environment association, the *Enneapogono desvauxii – Salsoletum* (gravel plains of the Vornamib). The characteristics of these six associations are presented in the Appendix.

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[1] The ending *–etum* of the second genus name indicates an association, meaning that the *Danthoniopsio ramosae – Osyrietum lanceolatae* could be translated as the *Danthoniopsis ramosa – Osyris lanceolata* association, or the rock oats – African sandalwood (*kliphawer – bergbas*) association. In addition to the ending *–etum*, a linking *–o* ending is added to the first genus name, whilst all specific epiphets are declined to the genetiv.

Table 2. Factors influencing the suitability of six associations within the Khomas Hochland for livestock farming.

		Danthoniopsio ramosae – Osyrietum lanceolatae		*Brachiario nigropedatae – Acacietum hereroensis*		*Dichrostachyo cinereae – Acacietum erubescentis*		*Eragrostio nindensis – Acacietum melliferae*		*Schmidtio kalahariensis – Acacietum eriolobae*		*Enneapogono desvauxii – Salsoletum*	
		Actual	**Index**	**Actual**	**Index**	**Actual**	**Index**	**Actual**	**Index**	**Actual**	**Index**	**Actual**	**Index**
Habitat	**GPZ**	6	15,2	6	15,2	7	10,4	6	15,2	6	15,2	11	0
	Rainfall	330	165	298	149	283	141,5	332	166	340	170	87	43,5
	Rainfall dependability (related to CV)	45	55	46	54	46	54	45	55	41	59	67	33
	Slope	6	0	5	2,4	3	10,7	3	10,7	1	35,7	2	19,0
	Water holding capacity	1	0	2	20	2	20	2	20	5	80	3	40
	Subtotal		235,2		240,5		236,6		266,9		359,9		135,5
Structure	**Perennial grass cover**	41,4	207	28,6	143,0	14,2	50,3	19,4	97,0	17,3	86,5	11,6	58,0
	Annual grass cover	1,1	1,1	13,2	13,2	26,0	26,0	10,9	10,9	23,3	23,3	6,2	6,2
	Herbaceous cover	25,7	25,7	13,9	13,0	17,2	17,2	18,6	18,6	27,3	27,3	8,0	8,0
	Dwarf shrub cover	6,6	6,6	7,8	7,8	5,9	5,9	9,4	9,4	6,8	6,8	2,1	2,1
	Shrub cover	16,6	16,6	19,5	19,5	37,1	37,1	13,9	13,9	16,6	16,6	0,6	0,6
	Tree cover	1,1	1,1	1,1	1,1	2,7	2,7	12,3	12,3	3,6	3,6	0,0	0,0
	Bare ground	16,0	168,0	30,2	139,6	23,5	122,7	38,4	123,3	21,9	156,2	74,6	50,8
	Bush encroachment ratio		59,8		46,8		31,1		36,1		52,2		24,6
	Subtotal		485,4		384,0		255,5		315,4		300,8		150,3
Composition	**Total no. of species**	232		497		296		220		225		68	
	No. of toxic species	14	47,0	29	47,1	18	47,0	13	47,0	16	46,4	2	48,5
	Abundance of toxic species	0,3	1,5	0,3	1,8	0,8	0,6	0,2	3,1	0,2	2,3	0,1	3,9
	High grazing value species	15,7	156,8	11,6	115,6	1,4	13,8	6,6	66,5	3,1	31,1	1,9	19,4
	Average grazing value species	21,2	84,8	22,1	88,5	12,1	48,3	10,0	40,1	13,1	52,4	4,5	17,8
	Low grazing value species	4,9	9,9	27,1	54,2	19,3	38,5	21,5	42,9	22,5	45,0	1,9	3,7
	Subtotal		300,0		307,3		148,2		199,6		177,3		93,4
	Index value		1020,6		931,7		640,3		781,9		909,6		379,2
	Suitability	Moderate		Moderate		Low		Low		Moderate		Unsuitable	

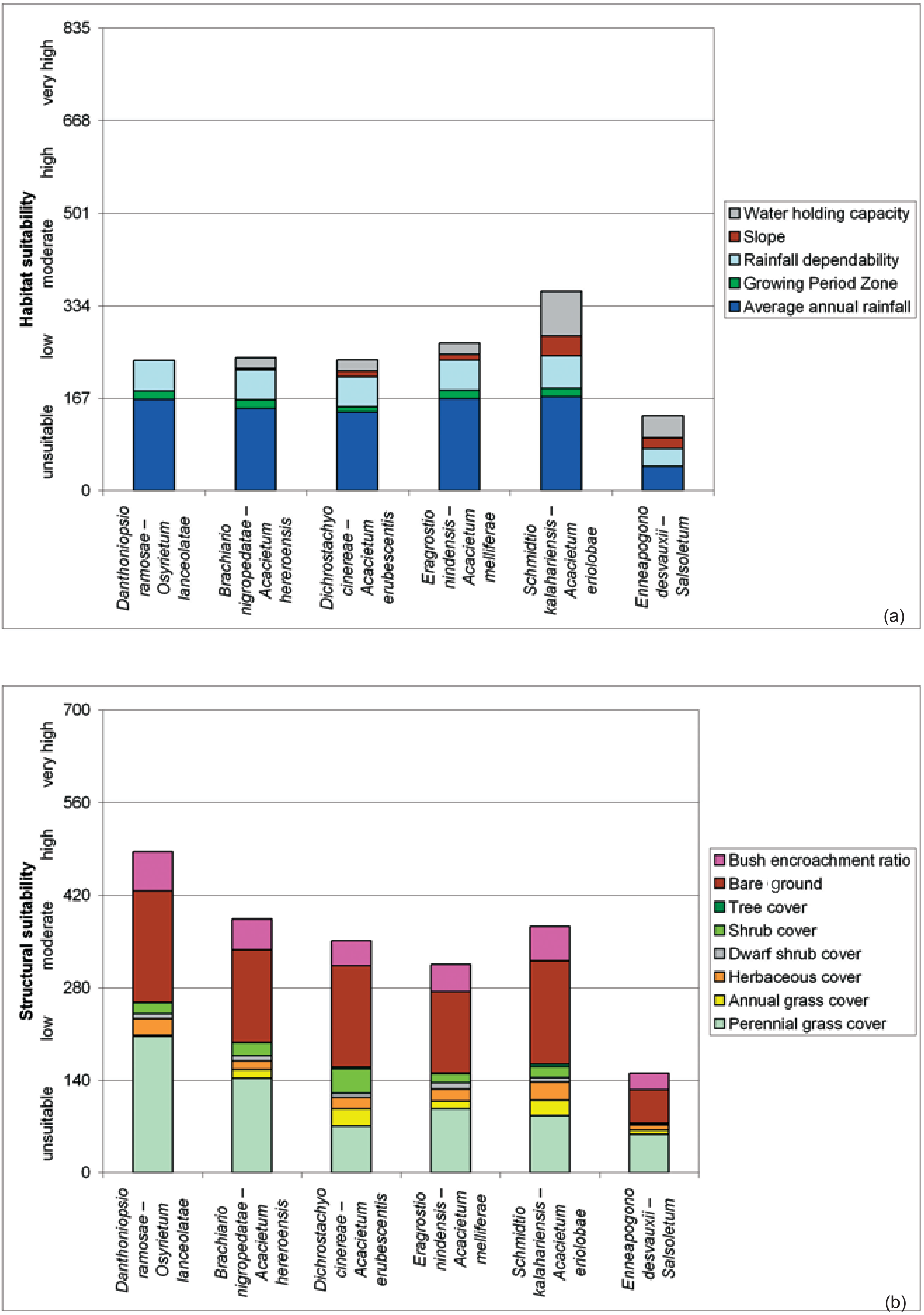
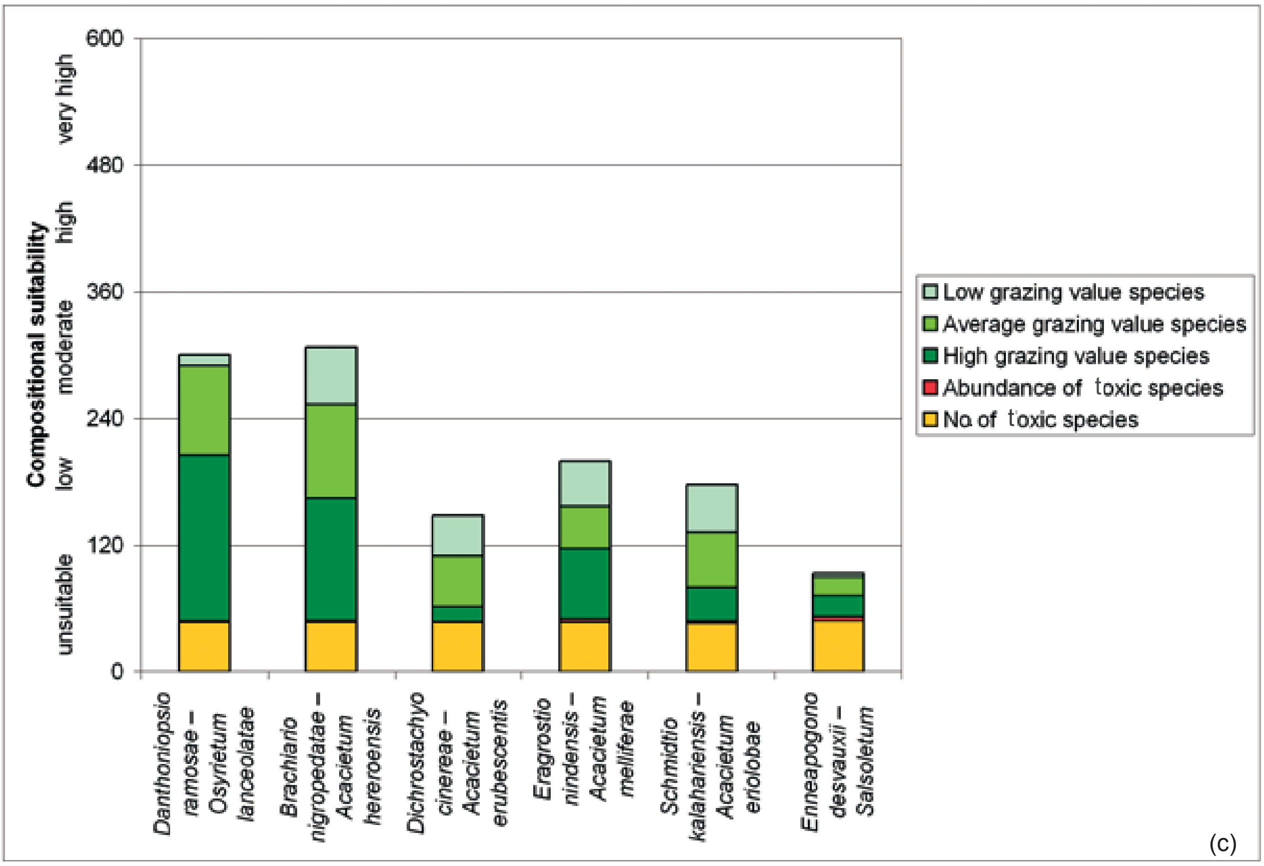


Figure 6 (a + b). Graphical representation of how various habitat- and compositional characteristics of the vegetation contribute towards the suitability rating (for livestock farming) of six example vegetation associations.



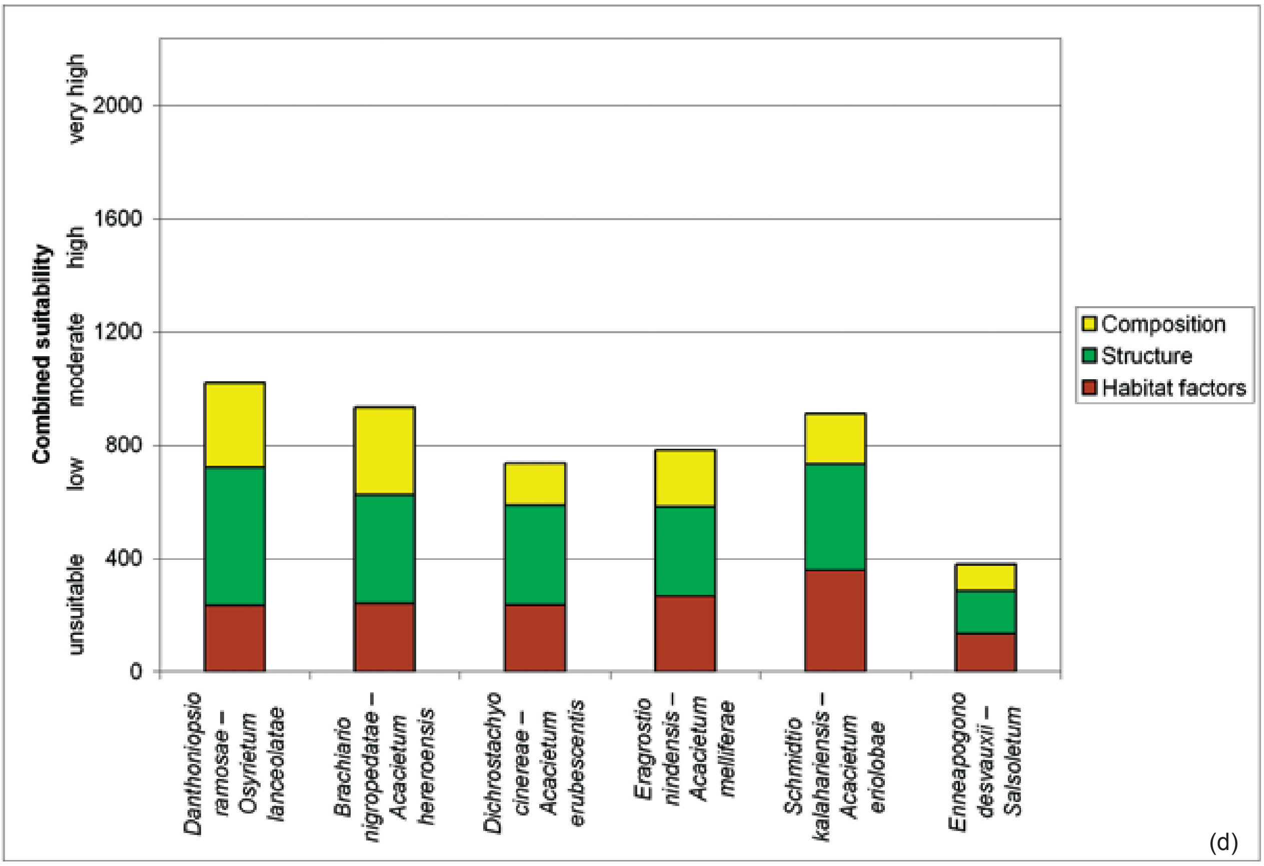


Figure 6 (c + d). Graphical representation of how various habitat- and compositional characteristics of the vegetation contribute towards the suitability rating (for livestock farming) of six example vegetation associations.

Sensitivity of the vegetation

As part of an environmental management tool, the vegetation map should indicate some information about the ecosystem sensitivity. This is important information necessary for large-scale land use planning, the planning of nature reserves (Barnard, Brown, Jarvis, Robertson & Van Rooyen, 1998), and also small-scale planning, especially in terms of Environmental Impact Assessments and Environmental Management Planning for developmental projects. Such assessments and management plans are a necessity under the Environmental Management Act (Act 7 of 2007) and regulations.

Important Plant Areas in Namibia were selected according to the following criteria (Hofmeyr, 2004):

- Criterion A – Threatened species: The site holds significant populations of one or more species or intraspecific taxa that are of conservation concern.
- Criterion B – Botanical diversity: The site contains a high number of species and/or species of special interest (e.g. restricted range or endemic species, or species of scientific interest or utilisation importance) that represent all vegetation types.
- Criterion C – Threatened habitats: The site contains one or more threatened habitat types.

In order to establish the conservation value of certain vegetation types within a mining area in the Central Namib, a set of criteria have been proposed, according to which the conservation importance of habitats can be calculated (Strohbach, 2009):

- Community conservation value: Communities are weighted according to the proportion of number of species observed in the community, in relation to the total number of species observed, as well as according to the proportion of the expected number of species in relation to the expected total number of species (based on Jackknife estimates).
- Endemnicity: A per-species weighting is given to communities containing endemics.
- Conservation: A per-species weighting is given to communities containing red-listed or protected species. Habitats/communities which contain such species, are further weighted whether similar habitats occur wide-spread, moderately available or restricted available in the Namib.
- Ecosystem functioning and –services: Habitats facilitating the redistribution of water, as well as habitats with a moisture retention capability, are weighted.
- Ecosystem traits and processes: This includes factors like the availability and diversity of niches, a per-species weighting for known key-stone species occurring, a per-species weighting for fodder plants, as well as a weighting according to the composition, taking into account whether dominantly annual or perennial species.
- Specific habitats: A ranked weighting whether specific habitats are common or restricted within the mining area, and whether such habitats are equally common or restricted in the greater Namib.
- Restoration potential of the habitat and its community: Differentiated weighting is made for repairable (albeit altered) versus irreparable/permanently lost habitats. Habitats with long-lived perennials (e.g. trees) are also heavily weighted.

These two examples of sensitivity ratings/ratings for conservation selection serve as basis for a sensitivity index for each association. This sensitivity index is based on two, roughly equal, sub-indices, reflecting biodiversity and habitat sensitivity.

Biodiversity: For this sub-index it is difficult to determine a maximum value, due to the fact that it is related mostly to number of species. An estimated maximum value of 250 is calculated as follows:

Number of species: The observed number of species is divided by 10.

Estimated number of species: The estimated number of species (using the Jackknife procedure) is related to the number of species in Namibia, as published by Craven (1999) (4 081 species). The percentage value has been used for calculation.

Species density: The average observed number of species on each relevé (i.e. number of species occurring per 1 000 m^2) has been used.

Number of endemic species: The number of endemic species found in each association has been used.

Number of Red Data Listed species: The number of species listed by Loots (2005) as (potentially) endangered occurring in an association, has been multiplied by a factor 10. Least Concern (LC) species were not included, as these species often occur wide-spread. (It was considered to differentially weigh these species according to their degree of rarity, but this was found to make no sense as the finding of such species would be random and would likely bias the sensitivity rating rather than contribute to a sensible rating.)

Number of protected species: The number of protected species observed within the association has been used in the calculation. No differentiation has been made as to which protection mechanism is applicable (Nature Conservation Ordinance, Ordinance 4 of 1975; Forestry Act, Act 12 of 2001; or listed under CITES).

Number of exotic species: The presence of exotic species is seen as a habitat-threatening factor and an indication of a degraded ecosystem (Boyer, 1989; Stohlgren, Binkley, Chong, Kalkhan, Schell, Bull, Otsuki, Newman, Bashkin & Son, 1999; Stohlgren, Otsuki, Villa, Lee & Belnap, 2001; Leung, Lodge, Finnoff, Shogren, Lewis & Lamberti, 2002; Richardson & Van Wilgen, 2004; Stohlgren & Schnase, 2006; Ndhlovu, Milton-Dean & Esler, 2011). For this reason, the presence of such species is seen as a negative factor within an association. Thus the inverse of the number of exotic species observed within an association is multiplied with 10 – the lower the number of exotic species, the higher the score, to a maximum of 10.

Habitat sensitivity: This sub-index has been problematic to develop due to a general lack of information. It was decided to base it on three basic factors: erosion hazard, the potential effect degradation has on water flow, and the utilisation potential calculated previously, as an example of but one ecosystem service. Information on keystone species, as done by Strohbach (2009), has not been included in the calculation of this sub-index. With a few exceptions e.g. Dean, Milton & Jeltsch (1999), virtually no data is available on such vegetative keystone species in Namibia. It is also likely that a specific keystone species in one part of the country would not be a keystone species elsewhere in the country.

This sub-index has a potential maximum value of 250, and is calculated as follows:

Erosion Hazard: was calculated following the SLEMSA model (Stocking *et al.*, 1988). This model takes four basic factors into account: The rainfall energy and the soil erosivity are combined as the potential soil loss factor (K), the topography (X) and the rainfall energy interception value (C).

- Rainfall energy was calculated using the average annual rainfall multiplied by the factor 18,846, based on values obtained for thunderstorm rain in Zimbabwe (Stocking & Elwell, 1976; Stocking *et al.*, 1988). This factor still needs to be refined for Namibia. The resulting value is mean seasonal rainfall energy, measured in J/m^2.

- Data for soil erosivity is not yet available for Namibia. Stocking *et al.* (1988) list ferralic Arenosols as being relatively stable, with an F-value of 6,5. This would apply to the sands of the Kalahari. Likewise, eutric Regosols found in parts of the Thornbush savanna have an F-value of 6, whereas chromic Cambisols (Hochfeld area) would have an F-value of between 3,5 and 4 (Mendelsohn *et al.*, 2002, compared to Stocking *et al.*, 1988). However, large parts of central and western Namibia are covered by various Leptosols, for which Stocking *et al.* (1988) provide no erodibility rating. It was decided, in order to have a consistent value, to use an erodibility rating (F-value) of 3 for all associations (denoting moderate erodibility).

- The potential soil loss factor (K) was calculated from the above as follows (Stocking *et al.*, 1988):

  $K = \exp((0,4681 + 0,7663\ F) \ln E + 2,884 - (8,1209\ F))$

- The topographical factor is a combination of slope length and slope steepness (in percentage). The slope length was set to 100 m, as is standard in the application of the SLEMSA model. For the slope steepness the maximum value of the SOTER steepness categories was used (FAO, 1995) (see also Figure 4):

Flat	2 %
Gently undulating	5 %
Undulating	8 %
Rolling	15 %
Moderately steep	30 %
Steep	60 %
Very steep	120 %

  (Very steep is defined as ≥ 60 %, and has arbitrarily set to 120 %, equalling 50°. Not many mountain slopes are steeper than this.)

  The topographic factor (X) has been calculated as follows (Stocking *et al.*, 1988):

  $X = L0,5\ (0,76 + 0,53S + 0,076\ S2) / 25,65$
  Where L is the slope length (set to 100 m), and
  S is the slope gradient in percentage.

- Rainfall energy interception (C): is a function of the vegetation cover, calculated as follows:

  $C = \exp(-0,06\ i)$
  Where i is the average vegetation cover of the association.

  The resulting erosion hazard (in erosion hazard units) is calculated as follows (Stocking *et al.*, 1988):

  $Z = K\ C\ X$
  Where Z is the erosion hazard
  K is the potential soil loss factor
  C is the rainfall energy interception factor
  X is the topographic factor

These results have been categorised and weighted as follows:

< 10	extremely low	1
10–25	very low	2
25–50	low	5
51–100	moderate	10
100–250	moderately high	20
250–500	high	30
500–1 000	very high	50
> 1 000	extremely high	70

(Categorisation follows in part that of Chakela & Stocking 1988, and Igwe, Akamigbo & Mbagwu, 1999.)

Water flow patterns: The rationale behind this part of the sub-index is as follows: Water is the most important resource in arid environments (Noy-Meir, 1973). Rainfall can either seep into the soil profile, or run off to adjacent areas/parts of the ecosystem. The course of flow rainfall takes is a function of the rainfall intensity, the slopes, the soil type and the vegetation (which intercepts raindrops and often channels these to their roots (Pressland, 1973; Martinez-Meza & Whitford, 1996; Whitford, Anderson & Rice, 1997; Dunkerley, 2002).

Pringle & Tinley (2003) show that a disturbance downstream in a catchment, altering the water flow regime in that particular river system, is likely to have an adverse effect on upstream parts of the catchment. Such adverse effects could include the forming of erosion gullies, bush encroachment, etc., simply through altering the water flow regime and thus the soil moisture content of adjacent, linked ecosystems. With this in mind, a series of scenarios were developed, based on perceived normal behaviour of water in basic elements of the landscape, as well as behaviour of water under degraded conditions (Table 3). For both, normal and degraded conditions, ratings were given between 0 (not happening) to 6 (happening very strongly) to perceived water behaviour in terms of run-off, run-on and infiltration – assuming that soil conditions are homogenous throughout the landscape. For each, run-off, run-on and infiltration, the difference in ratings between 'normal' and 'degraded' has been calculated. The sum of these differences (ignoring negative connotations) represents the final sensitivity score (Table 3). The discussed landscape elements are graphically presented in Figure 7.

Omirimbi (plural; singular: omuramba) is the vernacular name for broad, flat watercourses without any discernable stream bed or slope (King, 1963). These are analogous with the 'grassy flat drainage lines' (4a) mentioned by Pringle & Tinley (2003) from western Australia. According to them, and also substantiated locally by own observations, these watercourses are extremely sensitive to disturbances (Shamathe, Zimmermann, Pringle, Rusch & Rusch, 2008) and have thus received a very high sensitivity rating.

The derived sensitivity rating, multiplied by 10, was used as weight for the association (related to its predominant position in the landscape) in the habitat sensitivity sub-index.

Utilisation potential: This value was taken from the utilisation potential calculation, as a percentage of the total possible score.

The ecosystem sensitivity score was categorised as follows:

Low sensitivity:	< 125	(< 25 %)
Moderate sensitivity:	125–250	(25 %–50 %)
High sensitivity:	250–375	(50 %–75 %)
Very high sensitivity:	375–500	(> 75 %)

Ratings for these various sensitivity indicators are presented in Table 4 and Figure 8 for the same example associations as before.

Table 3. Scenarios of waterflow behaviour in various elements of the landscape, under normal and degraded conditions. See Figure 7 for a schematic overview of these landscape elements. Values are ranging from 0 (not happening / no effect) to 6 (happening very strongly)

Position in landscape	Normal condition			Degraded condition			Net change in pattern			Sensitivity
	Run-off	Run-on	Infiltration	Run-off	Run-on	Infiltration	Run-off	Run-on	Infiltration	
Plateau	2	0	0	3	0	0	1	0	0	1
Escarp	5	0	0	6	0	0	1	0	0	1
Upslope	4	1	1	5	1	0	1	0	–1	2
Midslope	3	2	2	5	3	1	2	1	–1	4
Footslope	2	3	3	4	4	2	2	1	–1	4
Pedeplain	1	4	4	3	5	3	2	1	–1	4
Floodplain	0	5	5	2	6	2	2	1	–3	6
Water courses:										
Pans & vleis	0	3	3	0	4	2	0	1	–1	2
Washes	2	3	2	3	4	1	1	1	–1	3
Omiramba	1	2	5	3	3	2	2	1	–3	6
Small ephemeral rivers	3	3	3	4	5	2	1	2	–1	4
Large ephemeral rivers (Khan, Swakop, Kuiseb, etc.)	4	5	3	5	6	2	1	1	–1	3

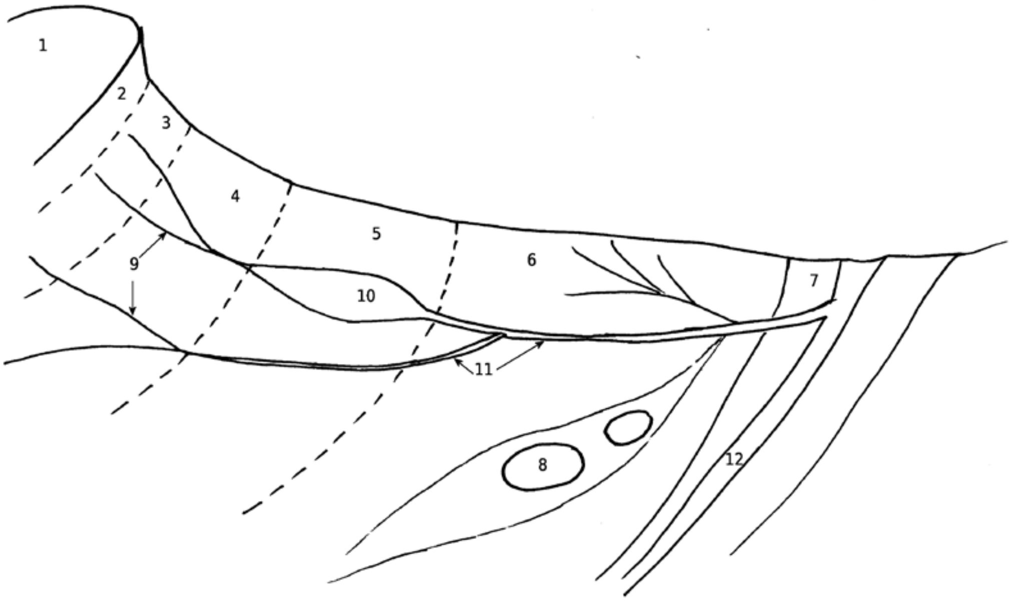


Figure 7. Schematic overview of various landscape elements. 1: plateau; 2: escarp; 3: upslope; 4: midslope; 5: footslope; 6: pedeplain; 7: floodplain. Water courses: 8: pans and vleis (often embedded in omirimbi); 9: washes, both on steeper and flatter landscape elements; 10: omirimbi; 11: small ephemeral rivers (gradually developing from washes); 12: large ephemeral rivers, which end up in the ocean as base level.

Table 4. Factors influencing the ecological sensitivity of six associations within the Khomas Hochland

		Weighting	Maximum	*Danthoniopsio ramosae – Osyrietum lanceolatae*		*Brachiario nigropedatae – Acacietum hereroensis*		*Dichrostachyo cinereae – Acacietum erubescentis*		*Eragrostio nindensis – Acacietum melliferae*		*Schmidtio kalahariensis – Acacietum eriolobae*		*Enneapogono desvauxii – Salsoletum*	
				Actual	**Index**	**Actual**	**Index**	**Actual**	**Index**	**Actual**	**Index**	**Actual**	**Index**	**Actual**	**Index**
Species diversity	**No. of species**		50	232	23,2	497	49,7	296	29,6	220	22	225	22,5	68	6,8
	Estimated no. of species			276		607		385		285		308		84	
	% Estimated no. of species to national		20		6,8		14,9		9,4		7,0		7,5		2,1
	Species density		50	39	39	38	38	32	32	37	37	41	41	16	16
	No. of endemic species		50	21	21	39	39	16	16	13	13	5	5	8	8
	No. of exotic species	inverse x 10	10	6	1,7	16	0,6	10	1	5	2	8	1,3	1	10
	No. of Red List species (excluding Least Concern – LC)		50		0		0		0		0		0		0
	No. of protected species		20	7	7	18	18	12	12	4	4	5	5	3	3
	Subtotal:		250		98,6		160,2		100,0		85,0		82,3		45,9
Ecosystem functionality															
	Erosion hazard (SLEMSA)				1361,8		267,7		17,0		26,0		2,2		1,9
	Slope (X)			6	4291,8	5	1079,4	3	70,1	3	70,1	1	8,7	2	20,9
	Cover (C)			64	0,0	63,4	0,0	61,4	0,0	61,6	0,0	69	0,0	23,2	0,2
	Rainfall (E)			330	6219,2	298	5616,1	283	5333,4	332	6256,9	340	6407,6	87	1639,6
	Soil erodibility (F)	no. data, set to 3			3		3		3		3		3		3
	Final rating		70		70		30		2		5		1		1
	Influence on other ecosystems														
	Position within catchment		60												
	Plateau	10			0		0		0		0		0		0
	Escarp	10			0		0		0		0		0		0
	Upslope	20		1	20		0		0		0		0		0
	Midslope	40			0	1	40		0	1	40		0		0
	Footslope	40			0		0	1	40		0		0		0
	Pedeplain	40			0		0		0		0		0	1	40
	Floodplain	60			0		0		0		0	1	60		0
	Rivers				0		0		0		0		0		0
	Pans & vleis	20			0		0		0		0		0		0
	Washes	30			0		0		0		0		0		0
	Omiramba	60			0		0		0		0		0		0
	Small ephemeral rivers	40			0		0		0		0		0		0
	Large ephemeral rivers (Khan, Swakop, Kuiseb, etc.)	30			0		0		0		0		0		0
	Productivity potential		100	39,2	39,2	37,4	37,4	28,6	28,6	33,4	33,4	37,5	37,5	16,0	16,0
	Subtotal		230		129,2		107,4		70,6		78,4		98,5		57,0
	Index value		480		194,8		267,6		170,7		163,4		180,8		102,8
	Sensitivity			Moderate		Moderate		Moderate		Moderate		Moderate		Low	

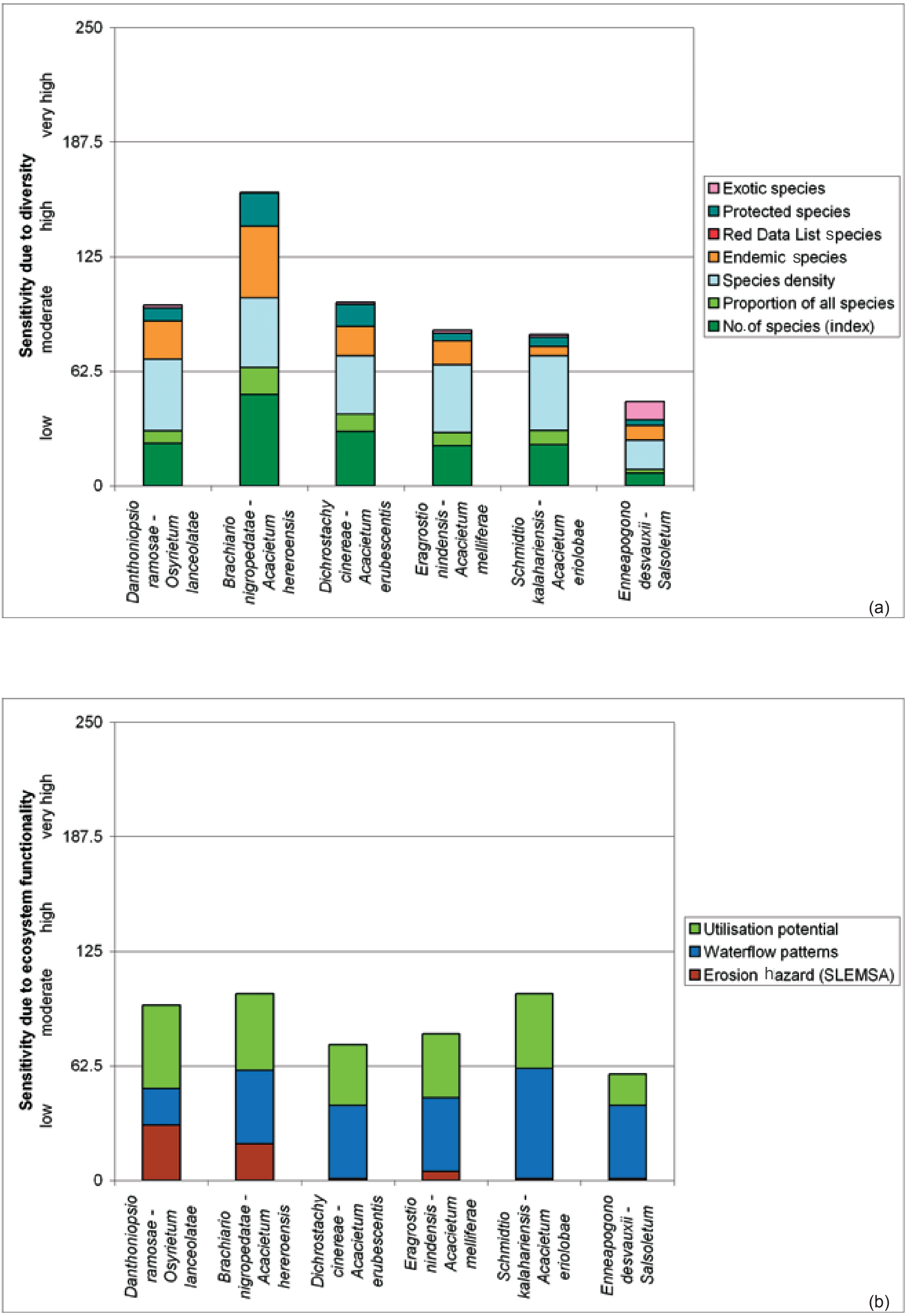


Figure 8 (a + b). Graphical representation of how various diversity- and ecosystem functional characteristics of the vegetation contribute towards the ecological sensitivity of six example vegetation associations.

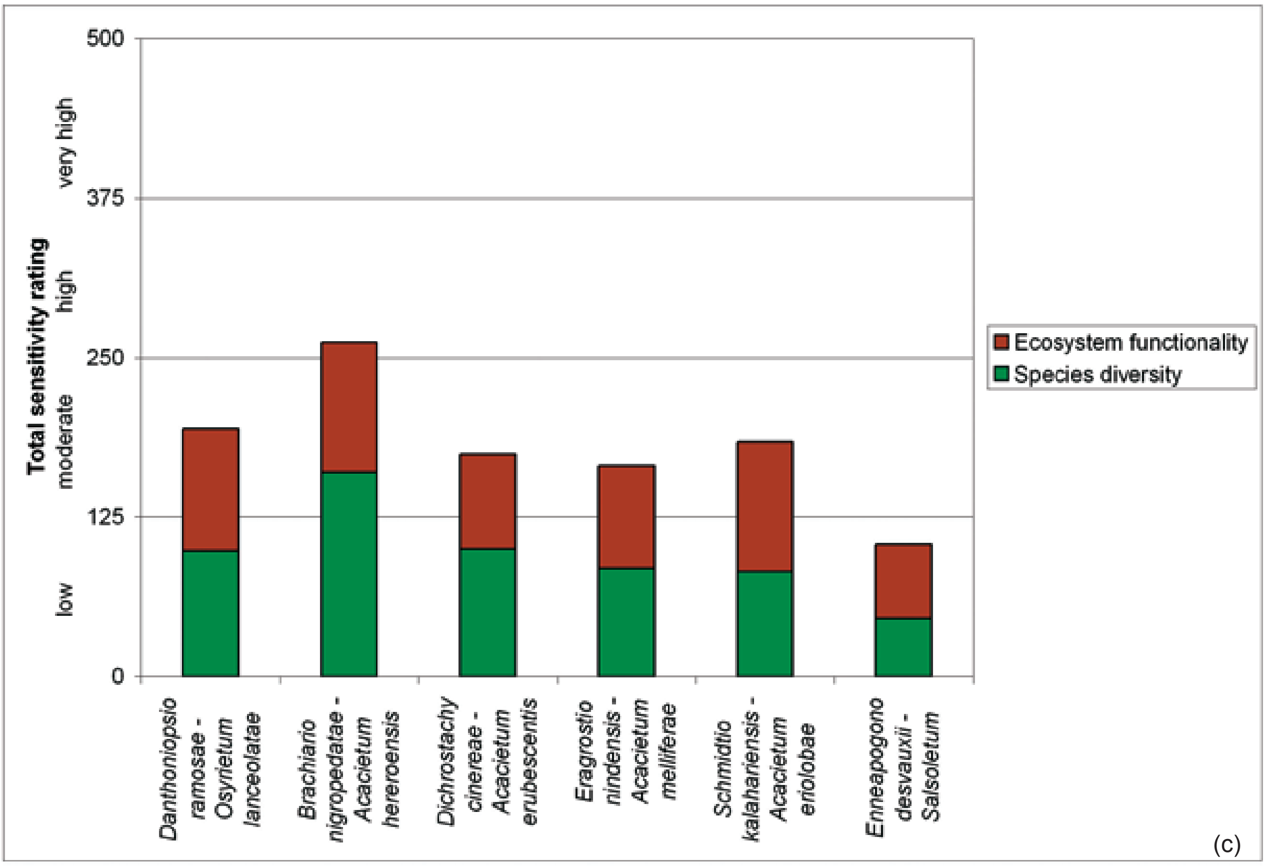


Figure 8 (c). Graphical representation of how various diversity- and ecosystem functional characteristics of the vegetation contribute towards the ecological sensitivity of six example vegetation associations.

DATA AND INFORMATION PRESENTATION

In order to present the data in an easy-to-read format, rather than a difficult-to-interpret phytosociological table, a fact sheet for each association has been developed. This fact sheet summarises the relevant information on the vegetation associations – the name (both scientific and a vernacular, landscape-linked name); the type relevé (including it's location and sampling date); the habitat; the suitability and sensitivity ratings; the structure; dominant species and character species; a photo; some general remarks on the association; and references to relevant literature.

These fact sheets are to be available on the internet (www.nbri.org.na) – both as a regular web-page, and downloadable as a pdf-file. The advantage of having this information on the internet is two-fold: it is a cheap medium to distribute the information to both local and international users, but it also allows the unpacking of information that is condensed on the fact sheet. In this way a full species list for the association can be presented, as well as specific lists of protected, toxic, red data listed or alien species. Also, the information behind the suitability and sensitivity ratings can be unpacked – thus making it easy to assess why a specific association has been rated relatively 'low' or 'high'.

Not all associations are mappable at larger scales. Typical scales for mapping association will be at the farm level, but not even then accurate distinctions between associations are always possible (Volk & Leippert, 1971; Strohbach & Jankowitz, 2012). An answer to this dilemma is to map landscapes in which the associations are typically occurring. This is recommended in the SOTER approach (FAO, 1993; Oldeman & Van Engelen, 1993), and has successfully been applied in the Eastern Communal Areas in the Otjozondjupa and Omaheke regions (Hüttich *et al.*, 2009), as well as in the Kalahari Gemsbok National Park in South Africa (Van Rooyen, Van Rooyen, Bothma & Van Den Berg, 2008). This same approach is also followed in the Khomas Hochland, with a number of smaller habitats and associations occurring in larger landscapes (Table 5, Figure 9). Such a map can be displayed in Google Earth, and in this way an impression on the spatial extent of the associations.

Table 5. Vegetation mapping units of the Khomas Hochland and adjacent farming areas. The most important included associations are listed in order of importance. Their approximate contribution to the mapping unit is indicated, with the exception of those which are prominent, but cover a negligible area

Mapping unit	**Included associations**	**Contribution**	**Area**
Gamsberg plateau	*Eriocephalo dinteri – Euryopetum walterorum*	100 %	183,7 ha
High mountains of the Khomas Hochland	*Danthoniopsio ramosae – Osyretium lanceolatae*	100 %	15 897 ha
Central Khomas Hochland bushland	*Brachiario nigropedatae – Acacietum hereroensis* *Penniseto foermerianum – Manuleopsietum dinteri* *Dichrostachyo cinereae – Acacietum erubescentis* *Cynodo dactylonis – Acacietum karroo* *Citrulo lanati – Stipagrostietum namaquanum*	85 % 15 %	726 523 ha
Khomas Hochland lowland shrublands	*Dichrostachyo cinereae – Acacietum erubescentis* *Cynodo dactylonis – Acacietum karroo* *Citrulo lanati – Stipagrostietum namaquanum*	100 %	470 121 ha
Southern Khomas shrublands	*Panico arbusculi – Acacietum melliferae* *Eragrostio nindensis – Acacietum meliferae* *Cynodo dactylonis – Acacietum karroo*	70 % 30 %	129 600 ha
Karooid shrublands of the upper Oanob catchment	*Panico lanipedis – Pteronietum eenii* *Cymbopogo plurinoidis – Themedetum triandrae* *Eragrostio nindensis – Acacietum meliferae* *Citrulo lanati – Stipagrostietum namaquanum* *Cynodo dactylonis – Acacietum karroo*	55 % 15 % 15 % 8 % 7 %	43 949 ha
Oamites mountains	*Ornithoglosso calcicolae – Euphorbietum lignosae*	100 %	1 075 ha
Duruchaus low shrubland	*Aizoo schellenbergii – Pseudogaltonietum clavatae* *Cynodo dactylonis – Acacietum karroo*	100 %	22 882 ha
Gölschau alluvial plains	*Aptosimo spinescentis – Galenietum africanae*	100 %	13 293 ha
Brakwater & Aris Camelthorn woodlands	*Schmidtio kalahariensis – Acacietum eriolobae* *Citrulo lanati – Stipagrostietum namaquanum* *Cynodo dactylonis – Acacietum karroo*	85 % 8 % 7 %	54 028 ha
Rooisand dune	*Requineo sphaerospermae – Tribulucarpetum dimorphanthi*	100 %	1 008 ha
Khomas escarpment	*Commiphoro tenuipetiolatae – Commiphoretum glaucescentis* *Cheilanthio – Myrothamnetum flabelifolius*	60 % 40 %	247 320 ha
Pre-Namib plains and hills	*Enneapogo desvauxii – Leucosphaeretum bainesii* *Monechmo clemoides – Commiphoretum dinteri*	60 % 40 %	120 739 ha
Western Khomas shrublands	*Catophracto alexandri – Acacietum reficientis* *Cynodo dactylonis – Acacietum karroo*	100 %	186 678 ha
Otjimbingwe plains	*Parkinsonio africanae – Commiphoretum pyrocanthoidis*	100 %	218 100 ha
Deep river gorges	*Commiphoro saxicolae – Commiphoretum virgatae*	Unknown (40–100 %?)	68 409 ha
Namib plains	*Enneapogono desvauxii – Salsoletum* *Stipagrostio obtusae – Stipagrostietum ciliatae*	70 % 30 %	214 498 ha
Karpfenkliffs	*Enneapogo desvauxii – Adenolobetum pechuelii*	100 %	21 013 ha
Large ephemeral rivers	*Eucleo pseudebenois – Faidherbietum albidae*	100 %	> 13 688 ha

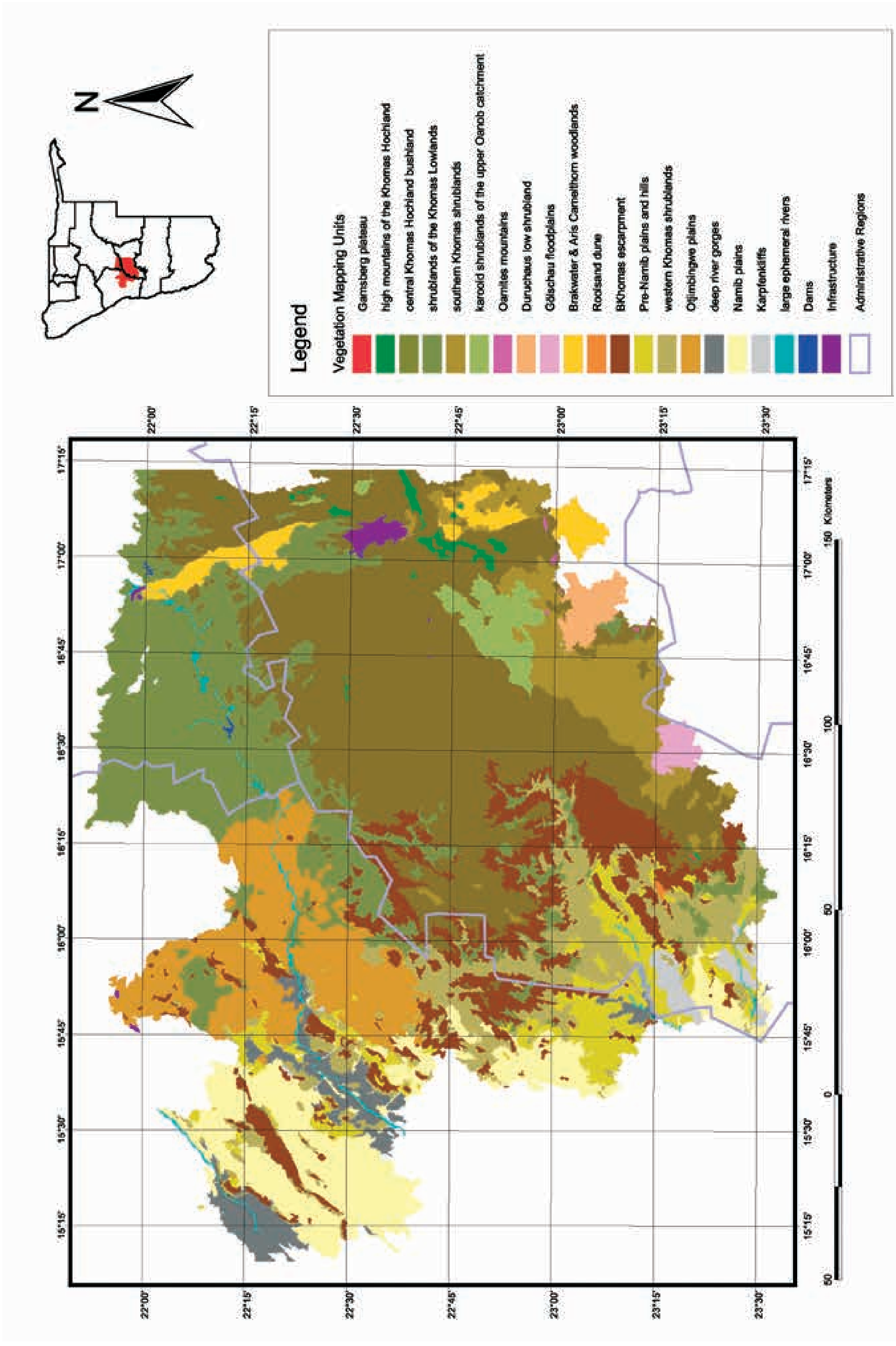


Figure 9. Vegetation map of the Khomas Hochland and adjacent farming areas.

Figure 10. The omirimbi in the Khomas Hochland are highly erodible, which increases the sensitivity rating.

Figure 11. The occurrence of rare and/or endemic species such as *Larryleachia marlothii* in an association, increases the need for conservation of the association, and therefore the overall sensitivity rating.

OUTLOOK

The internet presentation is still in the development phase. It is hoped to have a first prototype available on the website www.nbri.org.na during 2013. As further associations are described and mapped, these are to be added to the website. In the initial phase, data from the Khomas Hochland and the Farm Haribes near Mariental (Strohbach & Jankowitz, 2012) are to be used for internet presentation. Depending on the success of this, further data for the Sandveld areas of the Omaheke and Otjozondjupa areas are to be added (Strohbach *et al*., 2004; Hüttich *et al*., 2009). In the medium term, data for the Omusati and Oshana regions (Kangombe, 2010), the Karstveld (Oshikoto and Otjozondjupa regions) and large parts of the Thornbush savanna (Otjozondjupa region) (Strohbach, 2002) are to be added. One of the aims of the development is to have a relative easy input module for newly described associations, which at the same time can function as a register of syntaxonomic names. This will facilitate the speedy publishing of information on the vegetation of Namibia on the internet, as was envisaged already during the BIOTA project (Strohbach & Jürgens, 2010).

Information presented on the various vegetation associations can be refined in various ways:

- A useful addition will be information on fire frequencies and intensities. Such data were only available for limited areas in Etosha (Siegfried, 1981) and the Kavango and Caprivi Region (Mendelsohn & Roberts, 1997; Mendelsohn & El Obeid, 2003), but recently became available for the entire country (Le Roux, 2011).

- The suitability assessment for livestock grazing is to include the use of grazing index values (Du Toit, 1995, 1996, 1997a, 1997b), and potentially also the availability of browse (Smit, 1989a, 1989b; Smit, Rethman & Moore, 1996).

- In terms of the sensitivity of the association, it needs to be investigated whether the application of Red Data Listing criteria for ecosystems (Rodríguez, Rodríguez-Clark, Baillie, Ash, Benson, Boucher, Brown, Burgess, Collen, Jennings, Keith, Nicholson, Revenga, Reyers, Rouget, Smith, Spalding, Taber, Walpole, Zager & Zamim, 2011) or other conservation planning tools (e.g. MARXAN) (Watts, Ball, Stewart, Klein, Wilson, Steinback, Lourival, Kircher & Possingham, 2009) will be more suitable.

We trust that this vegetation map, as it develops, will become an important planning tool for the sustainable utilisation of our farming land.

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APPENDIX: EXAMPLE VEGETATION ASSOCIATION FACT SHEETS

Danthoniopsio ramosae – Osyrietum lanceolatae

Open shrublands of the high mountains of the Khomas Hochland

Mapping unit:	High mountains of the Khomas Hochland

No. of relevés:	34
Typus:	Relevé 994, 22°46’49”S, 17°00’23”E

Biodiversity:

No. of species observed:	232
Estimated number of species:	276
Species density (per 1 000 m^2):	39
No. of protected species:	7

No. of Red Data Listed species:	0
No. of endemic species:	21
No. exotic species:	6
No. of toxic species:	14 (4)

Habitat:

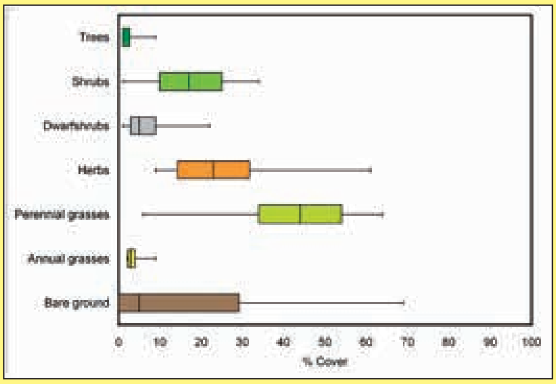
Location:	Auas mountains, Lichtenstein mountains, Eros mountains, upper slope of Gamsberg mountain
Geology:	quartzite, schist, sandstone of the Auas formation
Altitude:	2 050–2 420 m
Topography:	steep mountain
Slope:	very steep
Annual rainfall:	(250) 300–350 mm
Growing period:	41–60 days, 75 % dependable

Stone cover:	
Gravel:	0–2 %
Pebbles:	5–40 %
Medium stones:	5–15 %
Large stones:	15–40 %
Rock:	5–40 %
Soil depth:	very shallow

Sensitivity: moderate

Utilisation potential: moderate

Structure: low, semi-open bushland



Layer heights:

Trees:	3–5 m
Shrubs:	1–4 m
Dwarf shrubs:	0,4–1 m
Grasses:	40–60 cm

Dominant species:

Eragrostis scopelophyla	9 %
Tarchonanthus camphorathus	8 %
Danthoniopsis ramosa	8 %
Digitaria eriantha	7 %
Acacia hereroensis	5 %
Eragrostis nindensis	4 %
Hypoestes forskaolii	4 %
Melinis repens s. *repens*	3 %
Rhus marlothii	2 %
Maytenus heterophylla	2 %
Osyris lanceolata	2 %
Oxalis purpurascens	1 %

Diagnostic species and phi coefficient of association:

Osyris lanceolata	77,8	*Lopholaena cneorifolia*	53,5
Hypoestes forskaolii	77,6	*Heteromorpha stenophylla* v. *stenophylla*	53,2
Danthoniopsis ramosa	66,5	*Brachiaria serrata*	53,2
Maytenus heterophylla	60,1	*Eriocephalus scariosus*	52,6
Andropogon schirensis	58,1	*Olea europaea* s. *africana*	52,1
Hypoxis iridifolia	55,9	*Dianthus namaensis*	50,7
Stoebe plumosa	53,5		

Constant species and frequency of occurrence:

Digitaria eriantha	85 %	*Eragrostis scopelophila*	62 %
Tarchonanthus camphoratus	76 %	*Rhus marlothii*	59 %
Eragrostis nindensis	74 %	*Pellaea calomelanos*	59 %
Acacia hereroensis	74 %	*Melinis repens* s. *repens*	56 %
Oxalis purpurascens	65 %		

Relevé 994, typical example of the *Danthoniopsio ramosae – Osyrietum lanceolatae* association.
Photo VS48-26, taken on 15 March 2000 by B. Strohbach.

Remarks:

Burke & Wittneben (2008) recognised 4 variants of this association in the Auas Mountains, depending on the altitude. With increasing altitude, the shrub cover is reduced and the grass cover is greatly increased. Especially conspicuous are various grass species (but also herbs) typical of the mesic grassland biome in South Africa (e.g. *Andropogon schirensis*, *Brachiaria serrata* and *Digitaria eriantha*).

Further reading:

BURKE, A. & WITTNEBEN, M., 2008. A preliminary account of the vegetation of the Auas Mountains. *Dinteria* 30: 41–91.

Brachiario nigropedatae – Acacietum hereroensis

Open bushland of the Central Khomas Hochland

Mapping unit:	Central Khomas Hochland bushland

No. of relevés:	307
Typus:	1003 22°49’33”S, 16°50’00”E

Biodiversity:

No. of species observed:	497
Estimated number of species:	607
Species density (per 1 000 m^2):	38
No. of protected species:	18

No. of Red Data Listed species:	0
No. of endemic species:	39
No. exotic species:	16
No. of toxic species:	29 (3)

Habitat:

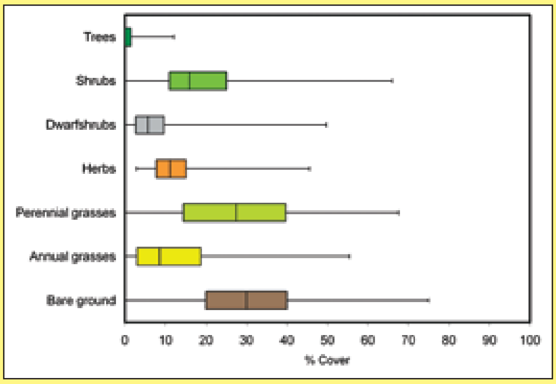
Location:	Central Khomas Hochland
Geology:	schist of the Kuiseb formation
Altitude:	1 330–2 150 m
Topography:	mountainous highland
Slope:	moderately steep to steep
Annual rainfall:	250–350 mm
Growing period:	31–60 days, 75 % to not dependable

Stone cover:	
Gravel:	0–2 %
Pebbles:	40–80 %
Medium stones:	5–15 %
Large stones:	5–15 %
Rock:	2–5 %
Soil depth:	very shallow to shallow

Sensitivity: moderate

Utilisation potential: moderate

Structure: low semi-open bushland



Layer heights:

Trees:	3–6 m
Shrubs:	1–4 m
Dwarf shrubs:	0,3–1 m
Grasses:	40–80 cm

Dominant species:

Enneapogon cenchroides	9 %
Eragrostis nindensis	8 %
Acacia hereroensis	5 %
Acacia mellifera s. *detinens*	4 %
Aristida adscensionis	4 %
Monelytrum luederitzianum	4 %
Stipagrostis uniplumis v. *uniplumis*	3 %
Melinis repens s. *grandiflora*	3 %
Aristida meridionalis	3 %
Anthephora pubescens	3 %
Cenchrus ciliaris	3 %
Brachiaria nigropedata	2 %

Constant species and frequency of occurrence:

Eragrostis nindensis	93 %	*Schmidtia pappophoroides*	65 %
Anthephora pubescens	84 %	*Aristida meridionalis*	65 %
Rhus marlothii	78 %	*Ziziphus mucronata*	64 %
Melinis repens s. *grandiflora*	78 %	*Monelytrum luederitzianum*	61 %
Stipagrostis uniplumis v. *uniplumis*	75 %	*Kyphocarpa angustifolia*	56 %
Acacia hereroensis	75 %	*Brachiaria nigropedata*	54 %
Enneapogon cenchroides	73 %	*Aristida adscensionis*	54 %
Cenchrus ciliaris	66 %	*Acacia mellifera* s. *detinens*	54 %

Relevé 1003, typical example of the *Brachiario nigropedatae – Acacietum hereroensis*.
Photo VS48-35, taken on 16 March 2000 by B. Strohbach.

Remarks:

This association occurs widespread throughout the Khomas Hochland, always on higher hillslopes. Bush density is often related to the frequency and intensity of fires in the area.

Further reading:

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Dichrostachyo cinereae – Acacietum erubescentis

Yellow-bark Acacia bushland of the Khomas Lowlands

Mapping unit:	Khomas Hochland lowland Shrublands Central Khomas Hochland bushland
No of relevés:	79
Typus:	Relevé 9564 22°24’34”S, 17°05’01”E

Biodiversity:

No. of species observed:	296
Estimated number of species:	385
Species density (per 1 000 m^2):	32
No. of protected species:	12
No. of Red Data Listed species:	0
No. of endemic species:	16
No. of exotic species:	10
No. of toxic species:	18 (3)

Habitat:

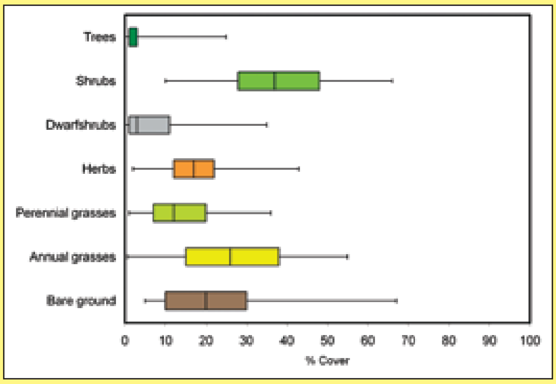
Location:	Lower parts of the Khomas Hochland, rolling hills north of the Khomas Hochland
Geology:	schists and granites (shallow soils)
Altitude:	800–1 700 m
Topography:	dissected plain or mountainous highland
Slope:	undulating to steep
Annual rainfall:	250–350 mm
Growing Period:	21–60 days, not dependable

Stone cover:	
Gravel:	5–15 %
Pebbles:	5–15 %
Medium stones:	5–15 %
Large stones:	2–5 %
Rock:	5–15 %
Soil depth:	shallow to moderately deep

Sensitivity: moderate

Utilisation potential: low

Structure: short semi-open bushland



Layer heights:

Trees:	3–6 m
Shrubs:	1–4 m
Dwarf shrubs:	0,5–1 m
Grasses:	30–60 cm

Dominant species:

Acacia erubescens	14 %
Schmidtia kalahariensis	10 %
Aristida adscensionis	8 %
Stipagrostis uniplumis s. *uniplumis*	7 %
Acacia reficiens	6 %
Eragrostis nindensis	6 %
Acacia mellifera s. *detinens*	6 %
Catophractes alexandri	6 %
Melinis repens s. *grandiflora*	4 %
Enneapogon cenchroides	4 %
Dichrostachys cinerea	3 %
Boscia albitrunca	1 %

Constant species and frequency of occurrence:

Stipagrostis uniplumis v. *uniplumis*	96 %	*Boscia albitrunca*	67 %
Catophractes alexandri	81 %	*Melinis repens* s. *grandiflora*	59 %
Acacia erubescens	76 %	*Acacia mellifera* s. *detinens*	58 %
Enneapogon cenchroides	71 %	*Dichrostachys cinerea*	54 %
Acacia reficiens	70 %	*Aptosimum arenarium*	51 %

Relevé 9564, typical example of the *Dichrostachyo cinereae – Acacietum erubescentis* –association.
Photo DSC2108, taken on 9 April 2009 by B. Strohbach.

Remarks:

Kellner described this as sub-association of the *Brachiario nigropedatae – Acacietum hereroensis*. Due to the widespread occurrence of this vegetation type, however, it is recognised as an own association. It is prone to bush encroachment, aggravated by severe disturbances like the removal of topsoil for building purposes within the townlands of Windhoek and surrounding farms. This makes the unit of low agricultural potential.

Further reading:

KELLNER, K., 1986. 'n Plantekologiese studie van die Daan Viljoen-wildtuin en gedeeltes van die plase Claratal en Neudamm in die Hooglandsavanna, SWA. *M.Sc. Thesis*, Potchefstroom Universiteit vir Christelike Hoër Onderwys, Potchefstroom.

Eragrostio nindensis – Acacietum melliferae

Bush-encroached lowlands of the Khomas Hochland

Mapping unit:	Southern Khomas shrublands; karooid shrublands of the upper Oanob catchment

No. of relevés:	26
Typus:	Relevé 960 22°51’24”S, 16°53’46”E

Biodiversity:

No. of species observed:	220
Estimated number of species:	285
Species density (per 1 000 m^2):	37
No. of protected species:	4

No. of Red Data Listed species:	0
No. of endemic species:	13
No. of exotic species:	5
No. of toxic species:	13 (1)

Habitat:

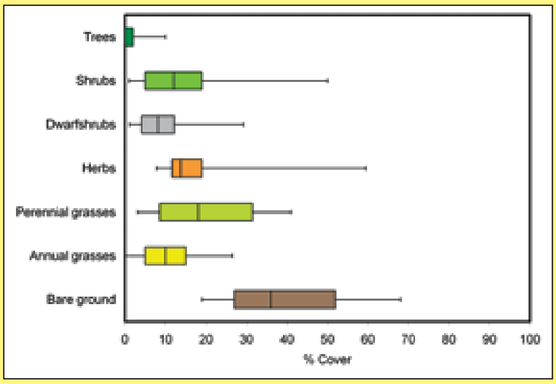
Location:	various patches in the Khomas Hochland, especially in Aris valley south of Windhoek
Geology:	schists of Kuiseb formation, gneiss of Hohewarte complex
Altitude:	1 770–1 850
Topography:	dissected plain
Slope:	rolling
Annual rainfall:	300–350 mm
Growing period:	41–60 days, not dependable

Stone cover:	
Gravel:	0–2 %
Pebbles:	5–15 %
Medium stones:	2–5 %
Large stones:	0–2 %
Rock:	none
Soil depth:	shallow

Sensitivity: moderate

Utilisation potential: low

Structure: low semi-open bushland



Layer heights:	
Trees:	4–5 m
Shrubs:	1–2 (– 4) m
Dwarf shrubs:	0,3–0,8 m
Grasses:	5–20 (– 60) cm

Dominant species:

Enneapogon cenchroides	16 %
Acacia mellifera s. *detinens*	10 %
Acacia karroo	8 %
Aristida congesta s. *congesta*	7 %
Eragrostis nindensis	6 %
Cenchrus cilliaris	4 %
Aristida adscensionis	4 %
Ziziphus mucronatha	4 %
Eragrostis porosa	3 %
Stipagrostis uniplumis v. *uniplumis*	3 %
Schmidtia pappophoroides	3 %
Lycium bosciifolium	3 %

Constant species and frequency of occurrence:

Stipagrostis uniplumis v. *uniplumis*	65 %	*Acacia karroo*	58 %
Acacia mellifera s. *detinens*	65 %	*Eragrostis nindensis*	58 %
Melinis repens s. *grandiflora*	65 %	*Aristida congesta* s. *congesta*	58 %
Cenchrus cilliaris	65 %	*Pogonarthria fleckii*	58 %
Aristida adscensionis	65 %	*Schmidtia pappophoroides*	58 %
Phaeoptilum spinosum	65 %	*Eragrostis porosa*	54 %
Enneapogon cenchroides	62 %	*Ziziphus mucronatha*	54 %

Relevé 960, typical example of the *Eragrostio nindensis – Acacietum melliferae.*
Photo VS54-27, taken on 18 April 2000 by B. Strohbach.

Remarks:

These dense shrublands often occur on footslopes or in the valleys of the Khomas Hochland.

Schmidtio kalahariensis – Acacietum eriolobae

Brakwater & Aris Camelthorn woodlands

Mapping unit:	Brakwater & Aris Camelthorn woodlands

No. of relevés:	18
Typus:	Relevé 1082 22°52’49”S, 17°06’13”E

Biodiversity:

No. of species observed:	225
Estimated number of species:	308
Species density (per 1 000 m^2):	41
No. of protected species:	5

No. of Red Data Listed species:	0
No. of endemic species:	5
No. of exotic species:	8
No. of toxic species:	16 (1)

Habitat:

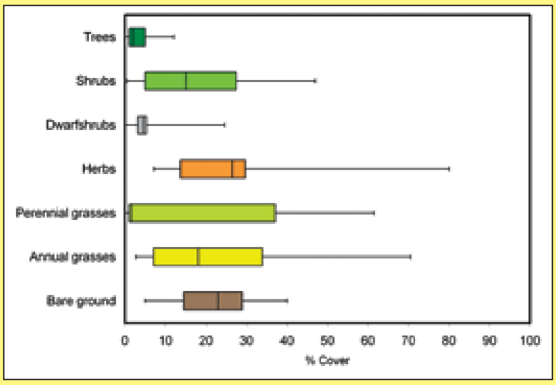
Location:	Alluvial plains in the Brakwater and Aris valleys
Geology:	Alluvial deposits
Altitude:	1 100–1 800 m
Topography:	plain
Slope:	gently undulating to undulating
Annual rainfall:	250–400 mm
Growing period:	41–60 days, 75 % dependable to not dependable

Stone cover:	
Gravel:	0–2 %
Pebbles:	0–2 %
Medium stones:	none
Large stones:	none
Rock:	none
Soil depth:	deep

Sensitivity: moderate

Utilisation potential: moderate

Structure: short semi-open bushland



Layer heights:

Trees:	5–8 m
Shrubs:	1–3 m
Dwarf shrubs:	0,3–1 m
Grasses:	40–50 cm

Dominant species:

Stipagrostis uniplumis v. *uniplumis*	19 %
Schmidtia kalahariensis	10 %
Nidorella resedifolia	8 %
Geigeria pectida	7 %
Lycium bosciifolium	5 %
Acacia mellifera s. *detinens*	4 %
Acacia erioloba	4 %
Kyllinga alata	3 %
Pogonarthria fleckii	3 %
Eragrostis porosa	3 %
Anthephora schinzii	3 %
Enneapogon cenchroides	2 %

Diagnostic species and phi coefficient of association:

Schmidtia kalahariensis	51,1

Constant species and frequency of occurrence:

Acacia erioloba	100 %	*Ocimum americanum* v. *americanum*	67 %
Lycium bosciifolium	94 %	*Melinis repens* s. *grandiflora*	67 %
Nidorella resedifolia	78 %	*Enneapogon cenchroides*	61 %
Kyphocarpa angustifolia	78 %	*Eragrostis lehmanniana*	56 %
Pogonarthria fleckii	72 %	*Acacia mellifera* s. *detinens*	56 %

Relevé 1082, typical example of the *Acacia erioloba – Schmidtia kalahariensis* association.
Photo VS98/10, taken on 22 April 2002 by B. Strohbach.

Remarks:

This association is greatly threatened by sand and building material mining, especially in the Brakwater – Döbra area north of Windhoek, but also by industrial and recreation facility development (the new container yard of TransNamib north of the Van Eck power station, the Omeya Golf Estate south of Aris, to mention a few). Also illegal wood harvesting (especially camelthorn trees) and encroachment by the alien invasive *Prosopis* are threats to this association.

The association has a relative low grazing potential due to a high number of poisonous plant species, specifically *Geigeria pectidea* and *Elephantorrhiza elephantine*, as well as a low perennial grass cover. Most grasses found here are of an annual nature.

Enneapogono desvauxii – Salsoletum

Gravel plains of the Vornamib

Mapping unit: Namib plains

No. of relevés:	28
Typus:	Relevé 9439 sampled 10 March 2009 at 22°54’06”S, 15°37’36”E

Biodiversity:

No. of species observed:	68
Estimated number of species:	84
Species density (per 1 000 m^2):	16
No. of protected species:	3
No. of Red Data Listed species:	0
No. of endemic species:	8
No. of exotic species:	0
No. of toxic species:	2

Habitat:

Location:	eastern gravel plains of the central Namib
Geology:	quaternary gravel deposits
Altitude:	740–1 130 m
Topography:	dissected plain
Slope:	rolling
Annual rainfall:	100–150 mm
Growing Period:	less than 10 days or none

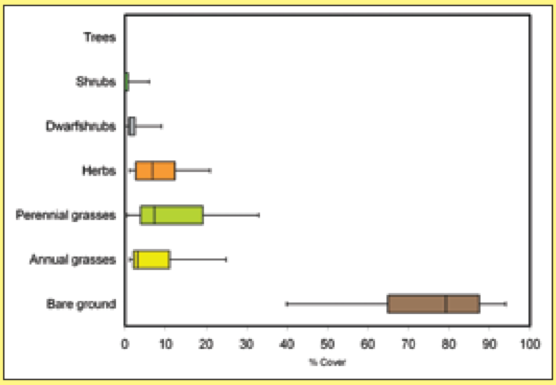
Stone cover:

Gravel:	15–40 %
Pebbles:	15–40 %
Medium stones:	2–5 %
Large stones:	2–5 %
Rock:	none
Soil depth:	very shallow to shallow

Sensitivity: low

Utilisation potential: unsuitable

Structure: low sparse shrubland



Layer heights:

Trees:	none
Shrubs:	1–1,5 m
Dwarf shrubs:	0,2–0,7 m
Grasses:	2–40 cm

Dominant species:

Eragrostis nindensis	6 %
Stipagrostis obtusa	6 %
Stipagrostis hirtigluma	3 %
Enneapogon desvauxii	3 %
Trianthema triquetra	2 %
Zygophyllum simplex	2 %
Calicorema capitata	2 %
Stipagrostis ciliata	2 %
Oropetium capense	2 %
Adenolobus pechuelii	2 %
Indigofera auricoma	2 %
Cleome suffruticosa	1 %

Diagnostic species and phi coefficient of association:

Zygophyllum simplex	63,0

Constant species and frequency of occurrence:

Enneapogon desvauxii	100 %	*Stipagrostis ciliata*	71 %
Stipagrostis hirtigluma	96 %	*Calicorema capitata*	61 %
Eragrostis nindensis	93 %	*Adenolobus pechuelii*	54 %
Stipagrostis obtusa	79 %		

Relevé 9439, typical example of the *Enneapogono desvauxii – Salsoletum*.
Photo DSC00395, taken on 10 March 2009 by B. Strohbach.

Remarks:

Sampling has been done in high rainfall years, with an above-average plant cover. Most of the grass species (including perennial grasses) die off during dry years, leaving little more than a barren desert.