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Local and national perceptions of environmental change in central Northern Namibia: Do they correspond?

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Abstract

A national-level land degradation risk monitoring system identified an important grazing area in central northern Namibia as an area at risk of environmental change. A time series analysis of primary indicators used for this monitoring system for the period 1971–2001 shows that increase in livestock pressure and high rainfall variability are potential threats. The study presented here compares these national-level results with those obtained by interviewing local farmers about their perceptions of past and present states of the environment in the grazing area. A majority of interviewees claim that grazing resources have decreased and deforestation has taken place since they first arrived. Increased livestock numbers and decreasing rainfall were thought to be major factors leading to perceived environmental changes. These perceptions support conclusions from national monitoring. The interviews reveal a more complex picture indicating that decreasing availability of grazing outside the study area, improved road access to the area, provision of permanent access to water, fencing of large areas of the commons, and prolonged dryness, in combination with non-adaptive land management, are major factors causing environmental changes. It is suggested that local knowledge contributes a sound basis for development and assessment of national monitoring initiatives.

Keywords: Semi-arid; Local knowledge; Rainfall variability; Water supply; Grazing; Land management

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1. Introduction

The debate about the threat of negative environmental change in Africa, often referred to as land degradation and desertification by various authors, caused by both natural and human factors has been high on the agenda of the United Nations, the international donor community, the scientific community, and national and local politicians since the early 1970s (Rapp, 1974; Rapp et al., 1976; UNCED, 1977; Hellden, 1991; Mainguet, 1994; Leach and Mearns, 1996; Koning and Smaling, 2005). In Namibia, desertification has been addressed under the umbrella of the United Nations Convention to Combat Desertification (UNCCD) since 1994 (Napcod, 1997, 1999). As part of the National Action Programme (NAP) national and local monitoring systems were developed attempting to quantify extent and rate of environmental change in Namibia, aimed at providing decision makers on both national and local levels with relevant information to enhance their decision making (Napcod, 1999). The national monitoring system is based on four primary indices: population pressure, livestock pressure, rainfall variability and erosion hazard, which are combined into a land degradation risk index (Klintenberg and Seely, 2004). This index has been calculated for the period 1971–2001 and identifies a main grazing area in central northern Namibia as being under high risk of negative environmental change. According to Klintenberg and Seely (2004), based on results of the national-level monitoring system, main causes of environmental change in the grazing area are increasing livestock numbers and below average rainfall for the last 15 years. As national-level monitoring is intended to support decision making on national and regional levels, it is essential to determine if results agree with actual environmental conditions and perceptions held by local land users.

Several authors have drawn attention to the importance of local knowledge and perceptions to improve understanding of often complex systems in arid environments (Seely, 1998; Verlinden and Dayot, 2005). In the Kalahari of southern Africa Thomas and Twyman (2004) investigated the relationship between perceptions about land degradation and change in savanna ecosystems held by scientists and land users. They concluded that a combination of local and scientific knowledge can lead to a more useful assessment of environmental change and its implications for local land users. In Botswana Kinlund (1996) and Dahlberg (2000) compared scientific thinking with local stakeholders' perceptions regarding environmental change and land degradation. Findings from these two studies suggest that local perceptions held by local land users can provide valuable insights into the extent and impact of environmental change, many times contradicting the common views of causes and effects of environmental change held by other stakeholders, e.g. the scientific community and policy makers. Verlinden and Dayot (2005) showed the existence of an elaborate environmental knowledge system used by local farmers in central northern Namibia for resource management (Verlinden and Dayot, 2005; Hillyer et al., in press). Ward et al. (2000) investigated perceptions of land degradation held by local farmers in Otjimbingwe, a communal ranging area in Namibia, concluding that some causes of environmental degradation perceived by local farmers were inconsistent with scientific assessments of the state of environment in the area. This discrepancy between local perception and scientific analysis illustrated the importance of understanding local views of how environments have changed, because they often include broader visions of changes considering such things as agricultural practices, human actions and history within their local perspectives, aspects that scientists do not generally consider in their evaluations of change (Gray and Morant, 2003). However, it is equally important to critically assess local perceptions against scientifically accepted principles and knowledge.

In an attempt to assess similarities between scientific investigations and local knowledge the objectives of this paper are to (1) investigate perceptions about environmental changes held by local land users in a main grazing area in central northern Namibia, and (2) to compare these perceptions with results from national-level monitoring, and (3) assess if information provided by local land users can contribute to an improved understanding of systems being monitored on the national-level. Throughout this paper the term 'environmental change' is used to encompass not only land degradation, a term used by many authors contributing to the debate, but also includes other forms of environmental change.

2. Materials and methods

2.1. Study area

This study was conducted in and around the Ombuga grassland in northern Namibia, one of three main grazing areas for about 600 000 people living in the four regions of northern Namibia encompassing about 85 000 km^2 (Mendelsohn et al., 2000). The study area was selected as national-level monitoring data indicate that the risk of land degradation in the area is high (Klintenberg and Seely, 2004). The local area investigated covers about 1600 km^2 and is referred to as the study area in this paper (Fig. 1).

2.2. Geology

Geologically the study area belongs to the Kalahari sequence, characterised by up to 500 m thick semi- to unconsolidated sediments (Thomas and Shaw, 1991). The study area is situated in a flat landscape at ~1100 m above sea level. Soils consist of clayey sodic sands in the lower parts of the landscape and sodic sands on surrounding relatively higher ground (Mendelsohn et al., 2000). The area typically has infertile sandy topsoil, between 0 and 1 m thick, underlain by a saline hardpan forming very distinct prismatic structures (Marsh and Seely, 1992).

2.3. Climate

The climate is semi-arid and the area receives an average annual precipitation of ~350 mm in the southwest and 450 mm in the northeast (Fig. 2) (Hutchinson, 1995). Rainfall is highly variable in time and space (Mendelsohn et al., 2000). Monthly mean temperature ranges from 26 °C in November to 16 °C in July. During the coolest period, June to August, the night temperature drops to 7 °C while day temperature may reach 40 °C (Hutchinson, 1995). Annual potential evaporation is estimated to exceed the annual precipitation by a factor of about five (Erkkilä, 2001; Mendelsohn et al., 2002).

The use of a 9-year moving average to filter out year-to-year variations in rainfall data to reveal long-term trends has been described by Wheeler and Martin-Vide (1992) and Salinger et al. (1995). Applying this technique to the rainfall data recorded at four rainfall stations closest to the study area reveals that these stations have recorded two wetter and two drier periods since the 1930s (Fig. 3). The first dry period lasted from around 1960 to

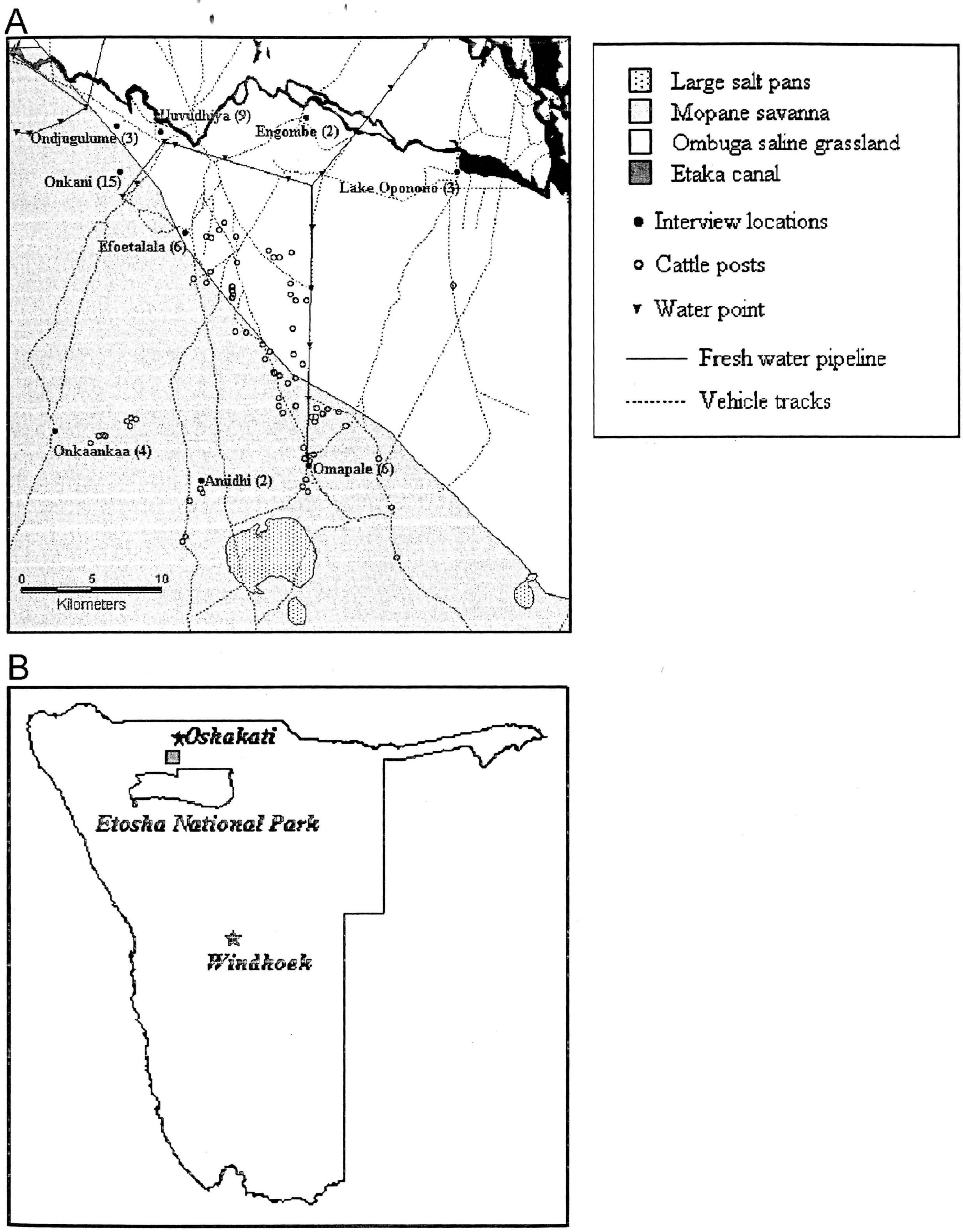

Fig. 1. (A) The extent of the study area, the Ombuga saline grassland, Mopane shrubland and location of settlements where interviews were made. Number of interviewees per settlement is indicated in parenthesis. (B) location of the study area in Namibia.

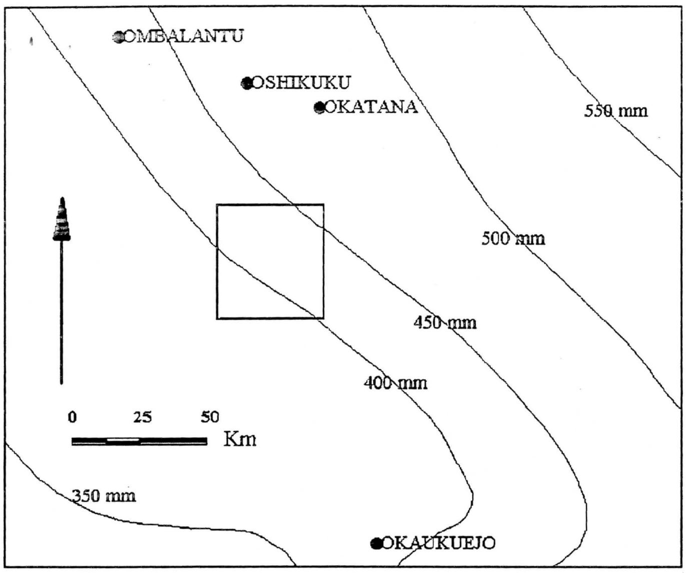

Fig. 2. Annual average rainfall in and around the study area (square in middle of figure). Isohyets are interpolated from ~260 rainfall stations located throughout the country.

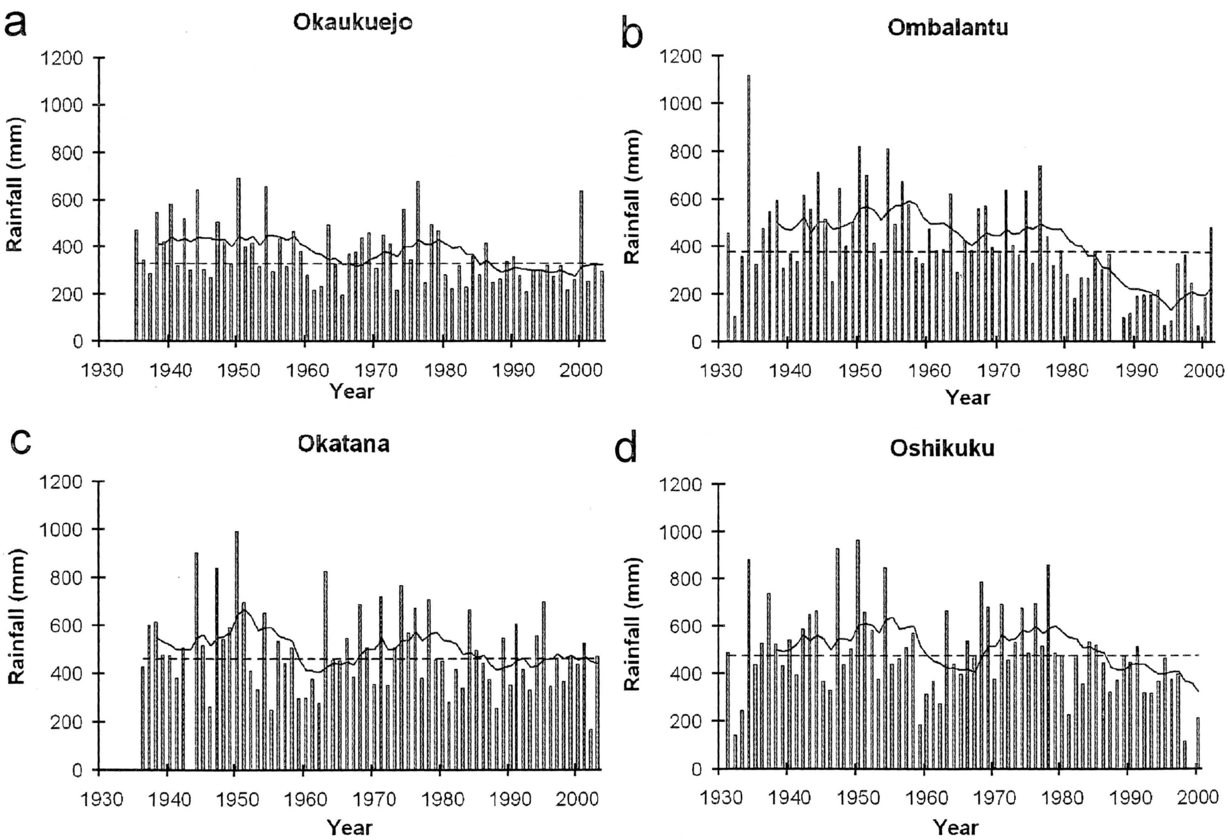

Fig. 3. Annual rainfall (bars), median (dashed line) and 9-year moving average (line) recorded at the four stations near the study area.

around 1970. The second dry period began in the later part of the 1980s and is still significantly different from the overall median (Mann–Whitney *U*-test, $p<0.05$) at all stations except Okatana. At Okaukuejo, Okatana and Oshikuku, rainfall below median was recorded during the first dry period of the 1960s while Ombalantu recorded "less" dry conditions. All four stations have recorded rainfall below median during the present dry period, starting with the 1984/85 season. The Ombalantu station recorded the largest negative deviation from the median rainfall and Okatana the least. However, the large negative deviation recorded at the Ombalantu station compared to the three other stations was treated with caution as it suggested a possible systematic measuring error or a faulty instrument.

2.4. Vegetation

Two distinct vegetation types occur in the study area, saline grassland and mopane savanna. The saline grassland, named Ombuga grassland, is a flat plain about 50 km wide with numerous pans. Perennial grasses dominate in less disturbed parts of the landscape. Growth of woody species is prevented by the shallow depth of the salty soils underlain by a hardpan (Mendelsohn et al., 2000). In the mopane savanna Colophospermum mopane is the dominant tree species and under well-developed stands grasses are sparse. The height of mopane and other trees is related to soil depth, with dense stands of tall trees only occurring in areas with deeper soil (over 1 m sand on top of the hardpan). In the more populated areas the mopane savanna has been converted to agricultural fields (Verlinden and Dayot, 2005).

2.5. Population and land tenure

In the past the Ombuga grassland was regularly visited by San hunter-gatherers and Ovahimba semi-nomadic pastoralists (Erkkilä, 2001). The grassland was crossed along traditional wagon tracks by missionaries and traders since the 1800s (Andersson, 1987). Since the 1940s the area was occasionally visited by Owambo people for hunting and grazing and crossed during salt collection expeditions to the salt pans in the southern part of the study area. The first permanent settlements in this part of central northern Namibia were established in 1968 (Christelis and Struckmeier, 2001) located around hand dug wells. By 1991 some 2000 individuals lived within the study area (Central Bureau of Statistics, 1994). By 2001, the population in the study area had increased to ~3300 inhabitants, living in about 670 households (NPC, 2002), which equals a population increase above 5% per year.

The study area is under communal tenure system, i.e. land is owned by the government and is, in principle, accessible to anyone but with no exclusive rights. Traditional norms and rules still regulate use of land and resources, especially in areas where wells are still the main supply of water (Verlinden and Dayot, 2000). In the commons individuals are allowed to fence off an area of 10 ha for crop production and reserve grazing (if the entire 10 ha is not ploughed). Availability of grazing in the northern communal lands is decreasing due to extensive establishment of homesteads and crop fields. According to Mendelsohn et al. (2000) livestock numbers in central northern Namibia reached a peak between 400 000 and 600 000 head of cattle already in the 1960s and early 1970s. These numbers have been more or less maintained since then. However, the diminishing availability of grazing in more populated areas has led to an increased number of cattle grazing in the Ombuga grassland and establishment of a large number of new cattle posts (Low et al., 1997; Denker and Schalken, 1998, 1999). A cattle post is a temporary dwelling occupied by one or several herders, located in an area where livestock have access to both water and grazing.

2.6. Water supply systems

There are no perennial watercourses in the area (Erkkilä, 2001). Due to the flat character of the landscape in central northern Namibia and poor infiltration owing to shallow soils underlain by hardpans, a large number of shallow, ephemeral, poorly defined but interconnected flood channels (oshanas) and pans occur in the Cuvelai drainage system (Christelis and Struckmeier, 2001). During the rain season and early dry season oshanas serve as fresh water reservoirs, providing drinking water for humans and livestock (Marsh and Seely, 1992). Due to population increase and the high salinity of the ground water, a pipeline system supplying purified water to local communities and to evenly spaced water points for livestock was constructed in 1992/93 (Fig. 1) (Mendelsohn et al., 2000; Christelis and Struckmeier, 2001; Directorate of Rural Water Supply, 2004).

2.7. Semi-structured interviews

The results presented in this paper are based on individual semi-structured interviews which were held with farmers in the study area in April 2003, October 2004 and February 2005. Fifty farmers (12 female and 38 male) representing 50 homesteads were interviewed in 9 villages (Fig. 1). Interviews were held throughout the study area to ensure that farmers living in different parts of the area were heard. Five key questions were asked at each interview, i.e. (1) When and why did you first come to this area? (2) What was the condition of the environment when you first came here? (3) Have you noticed any changes in the state of the environment since you came here, and if so, can you describe them? (4) Where have you observed these changes? (5) What are the causes of observed changes? These questions were complemented with questions asked to gain additional information about topics raised by the interviewees. A map of the study area, showing the location of settlements, cattle posts, water points and access roads, was presented during each interview. Each interviewee was asked to indicate on the map where in the study area he/she had identified changes in the environment. Two separate report back sessions were held with farmers from the study area. During these meetings the results of the interviews and the resulting environmental change map were discussed.

Results were analysed by dividing respondents into the following groups: (1) All interviewees; (2) interviewees that arrived in 1990 or before and interviewees arriving after 1990; and (3) interviewees depending on the pipeline water for all their needs and interviewees less dependent on pipeline water, also using hand dug wells. The comparison of responses given by farmers that arrived in 1990 or before and those arriving after 1990 is of interest as 1990 was the year when Namibia became independent and 1991 the year when the construction of the pipeline was initiated. At the time of our interviews farmers living in Okaankaa, Amidhi and at Lake Oponono were not so dependent on pipeline water, as their main source of water is privately owned traditional hand dug wells, shallow dams and water from Lake Oponono, compared to farmers living along the water pipeline in Ombuga grassland. The significance of responses given by interviewees depending on (1) when they first came to the area and (2) their dependence on pipeline water were tested using the Mann–Whitney *U*-test, accepting a significance level of $p<0.05$. Differences between responses given by interviewees that arrived in 1990 or before and interviewees arriving after 1990; and interviewees depending on the pipeline water for all their needs and interviewees less dependent on pipeline water while also using hand dug wells were tested.

3. Results

Nine of the interviewed farmers live in Amidhi (2), Okaankaa (4) or at Lake Oponono (3). These farmers depend less on pipeline water compared to farmers living in the other settlements visited, as they mainly use hand dug wells, dams and lake water for their water supply, and only occasionally use pipeline water. Forty-one of the interviewees arrived in the area in 1990 or before and 9 arrived after 1990.

A majority of the respondents came to the area searching for grazing and land to cultivate (Table 1). Almost all interviewees stated that palatable perennial grasses were plentiful in the area when they first arrived (Table 2). However, as many as 86% of the respondents stated that the abundance of grazing has decreased in the area since they first came there. Further, 66% of respondents said the quality of grasses has decreased; grasses were said to be weaker and shorter now. Twenty eight per cent of the interviewed farmers noted that palatable perennial grasses had disappeared from the area (Table 4).

Results show significant differences in responses given by farmers arriving in 1990 or before and farmers arriving after 1990 regarding the number of people and livestock in the area (Table 3). As many as 93% of the farmers arriving in 1990 or before said that there were few people and livestock when they first came to the area, while only 4 of the nine respondents arriving after 1990 did (Table 2), suggesting that the population increase in the study area took place after the construction of the pipeline in the beginning of the 1990s, concomitantly resulting in more livestock in the area.

The occurrence of many trees was only referred to by farmers arriving in the area in 1990 or before. Furthermore, 44% of these farmers mentioned that abundance of large trees has decreased, while none of the farmers arriving after 1990 mentioned this (Table 4), which suggests that most of the big trees were gone before 1991 (Table 2).

Answers related to quality of grazing given by farmers depending on pipeline water and farmers having access to other water sources show that grazing-related changes were mainly referred to by farmers depending on pipeline water (Tables 4 and 5). This suggests

Table 1
Main reasons for resident interviewees to first come to the area

Group	Search for grazing	Search for land to cultivate	Firewood	Looking for work
ALL ($n = 50$)	92	70	2	4
Arrival in 1990 or before ($n = 41$)	95	76	2	2
Arrival after 1990 ($n = 9$)	78	44	0	11
Settlement depending on pipeline ($n = 41$)	90	76	2	5
Settlement not depending on pipeline ($n = 9$)	100	44	0	0

Responses were compared by dividing respondents into the following groups: All interviewees, Arrival in 1990 or before and arrival after 1990; and respondents depending on and respondents less dependant on water from the pipeline. Values are % of respondents within each group referring to each variable.

Table 2
State of the environment at the time when resident interviewees first arrived in the area

Group	Plenty of palatable perennial grasses	Many trees	Many wild animals	Few people	Few livestock	Lack of water	Space for crop fields
ALL ($n = 50$)	98	38	22	84	84	30	44
Arrival in 1990 or before ($n = 41$)	98	46	27	93	93	34	41
Arrival after 1990 ($n = 9$)	100	0	0	44	44	11	56
Settlement depending on pipeline ($n = 41$)	98	39	22	85	85	32	44
Settlement less dependant on pipeline ($n = 9$)	100	33	22	78	78	22	44

Responses were compared by dividing respondents into the following groups: All interviewees; arrival in 1990 or before; and arrival after 1990; and respondents depending on and respondents less dependant on water from the pipeline. Values are % of respondents within each group referring to each variable.

Table 3
Significance test of differences between responses regarding the state of the environment at the time when they first came to the area, given by interviewees arriving in 1990 or before and interviewees arriving after 1990 (arrival), and interviewees dependant and less dependant on the water pipeline (pipeline dependency), using Mann–Whitney *U*-test

Variable	Arrival				Pipeline dependency			
	$n1$	$n2$	U	p-level	$n1$	$n2$	U	p-level
Plenty of palatable perennial grasses	41	9	180	N.S.	9	41	180	N.S.
Many trees	41	9	99	$p<0.05$	9	41	174	N.S.
Many wild animals	41	9	135	N.S.	9	41	184	N.S.
Few people	41	9	95.5	$p<0.05$	9	41	170.5	N.S.
Few livestock	41	9	95.5	$p<0.05$	9	41	170.5	N.S.
Lack of water	41	9	142	N.S.	9	41	167	N.S.
Plenty of space for crop fields	41	9	158.5	N.S.	9	41	183.5	N.S.

$n1$ = number of samples in first group, $n2$ = number of samples in second group, U = calculated sample statistic, N.S. = not significant.

that grazing quality has decreased more around water points along the pipeline in the Ombuga grassland than around traditional wells in the mopane savanna (Fig. 1a).

Seventy six per cent of the respondents stated that overgrazing is a cause of perceived environmental changes (Table 7). The impact of overgrazing was demonstrated by farmers depending on pipeline water by stating that the quality and abundance of grasses have decreased along the pipeline. Farmers in Okaankaa and Amidhi, who still mainly depend on surface water and hand dug wells, have not noted changes where they water their

Table 4
Environmental changes observed in the area by interviewed farmers

Group	Big trees decreasing or gone	No wildlife	Decreasing grazing	Decreasing quality of grasses, same species	Palatable perennial grass species disappear	Better quality water due to pipeline	Water in well turning salty
ALL ($n = 50$)	36	26	86	66	28	44	10
Arrival in 1990 or before ($n = 41$)	44	29	88	71	24	54	12
Arrival after 1990 ($n = 9$)	0	11	78	44	44	0	0
Settlement depending on pipeline ($n = 41$)	44	27	90	76	29	49	2
Settlement not depending on pipeline ($n = 9$)	0	22	67	22	22	22	44

Responses were compared by dividing respondents into the following groups: All interviewees, Arrival in 1990 or before and interviewees arriving after 1990; and respondents depending on and respondents less dependant on water from the pipeline. Values are % of respondents within each group referring to a specific change in the environment since they arrived in the area.

Table 5
Significance test of differences between responses about environmental changes observed since arriving in the area, given by interviewees arriving in 1990 or before and interviewees arriving after 1990 (Arrival), and interviewees highly and less dependant of the water pipeline (Pipeline dependency), using Mann–Whitney U-test

Variable	Arrival				Pipeline dependency			
	$n1$	$n2$	U	p-level	$n1$	$n2$	U	p-level
Big trees decreasing or disappearing	41	9	103.5	$p<0.05$	9	41	103.5	$p<0.05$
No wildlife	41	9	151	N.S.	9	41	176	N.S.
Decreasing grazing	41	9	136	N.S.	9	41	86	$p<0.05$
Decreasing quality of grasses, same species	41	9	136	N.S.	9	41	86	$p<0.05$
Palatable perennial grass species disappear	41	9	147.5	N.S.	9	41	171.5	N.S.
Better quality water due to pipeline	41	9	85.5	$p<0.05$	9	41	135.5	N.S.
Water in well is turning salty	41	9	162	N.S.	9	41	107	$p<0.05$

$n1$ = number of samples in first group, $n2$ = number of samples in second group. U = calculated sample statistic. N.S. = not significant.

Table 6
Grass species used as indicators of grazing value by local farmers interviewed

Vernacular name	Scientific name	Type	Local assessment	Scientific assessment
Okaheneidi	*Eragrostis viscose* (Retz.) Trin.	Annual	Low grazing value, not good for the livestock's digestion system	Hard, unpalatable grass with a low leaf production, seldom grazed
Olukateko	*Pogonarthria fleckii* Hackel	Annual	Not important for grazing	Hard unpalatable grass with low leaf production. Seldom consumed by grazers
Ombindangolo	*Eragrostis trichophora* Cosson and Durand	Perennial	Good for grazing Decreasing in the area	Consumed only in the absence of other, more palatable grasses. Produces little leaf material
Omunamaidhi	*Aristida stipioides* Lam.	Annual	Low grazing value and awns get into eyes of livestock	Practically worthless for grazing
Ongwena	*Odyssea paucinervis* (Nees) Stapf	Halophytic perennial	Good for grazing.	Little value for grazing. Consumed only while it is still young
Oshimombwe	*Dactyloctenium aegyptium* (L.) Beauv	Annual	Good for grazing Decreasing in the area	A palatable grass but seldom abundant enough to be a valuable grazing grass
Oshinamume	*Schmidtia kalahariensis* Stent	Annual	Relatively high grazing value. Blows away during dry season	Grazed before flowering stage and later, when dry. High nutritive value

Scientific assessment after Muller (1984) and Oudtshoorn (2002).

livestock (Fig. 1). More than half of the respondents stated that decreasing rainfall is causing the observed changes in the area (Table 7). The only significant differences in responses were between farmers arriving in 1990 or before and interviewees arriving after 1991, where only the former stated that construction of homesteads and the pipeline have led to observed changes (Table 8).

Apart from overgrazing and decreasing rainfall, interviewees also stated that the construction of the pipeline, building of homesteads, fencing of large parts of the commons (privatisation) and improved access to the area also were causes of perceived changes (Table 7). A majority of the farmers arriving before the construction of the pipeline claim that the pipeline has contributed to the observed environmental changes. Improved access to water has made it possible for more farmers to bring their cattle to the area to graze throughout the year, resulting in perceived negative changes in quantity and quality of grazing, mainly along the pipeline. Loss of grazing due to illegal fencing of the commons

Table 7
Causes of observed environmental changes according to interviewed farmers

Group	Increasing number of tracks	Construction	Wildlife chased into Etosha	Overgrazing due to more livestock	Pipeline	Fencing	Less rainfall
ALL ($n=50$)	8	40	22	76	42	20	54
Arrival in 1990 or before ($n=41$)	7	49	24	83	51	20	54
Arrival after 1990 ($n=9$)	11	0	11	44	0	22	56
Settlement depending on pipeline ($n=41$)	10	39	22	78	44	22	51
Settlement less dependant on pipeline ($n=9$)	0	44	22	67	33	11	67

Responses were compared by dividing respondents into the following groups: All interviewees, Arrival in 1990 or before and interviewees arriving after 1990; and respondents depending on and respondents less dependant on water from the pipeline. Values are % of respondents within each group referring to specific causes of environmental changes.

Table 8
Significance test of differences between responses about causes of observed environmental changes, given by interviewees arriving in 1990 or before and interviewees arriving after 1990 (Arrival), and interviewees highly and less dependant of the water pipeline (Pipeline dependency), using Mann–Whitney *U*-test

Variable	Arrival				Pipeline dependency			
	$n1$	$n2$	U	p-level	$n1$	$n2$	U	p-level
Increasing number of tracks	41	9	177.5	N.S.	9	41	166	N.S.
Construction	41	9	94.5	$p<0.05$	9	41	174.5	N.S.
Wildlife chased into Etosha	41	9	160	N.S.	9	41	184	N.S.
Overgrazing due to more livestock	41	9	113.5	N.S.	9	41	163.5	N.S.
Pipeline	41	9	90	$p<0.05$	9	41	165	N.S.
Fencing	41	9	179.5	N.S.	9	41	164.5	N.S.
Less rainfall	41	9	181	N.S.	9	41	156	N.S.

$n1$ = number of samples in first group, $n2$ = number of samples in second group, U = calculated sample statistic, p-level after adjusting Z, N.S. = not significant.

was referred to by farmers arriving in 1990 or before, and farmers arriving after 1990. The fences are making large parts of the commons unavailable for grazing and forcing cattle to pass in narrow corridors between fences, causing increased pressure on the land. According to some of the interviewees, increasing numbers of vehicle tracks make the area more accessible contributing to continued immigration to the area (Table 7) and, secondly, tracks remove the vegetation cover leading to increased erosion by both water and wind.

4. Discussion

4.1. State of the environment and perceived environmental changes

4.1.1. Grazing

The farmers' judgement of grass value presented in Table 6 corresponds well with the scientific valuation by Muller (1984) and Oudtshoorn (2002) for four of the seven species. However, farmers regard *Odyssea paucinervis*, *Eragrostis trichophora*, and *Dactyloctenium aegyptium* to be the most palatable grasses in the area, while the scientific literature categorises these species as having low grazing value. This suggests that grasses now found in the study area generally are of poor grazing quality with small but distinct quality differences.

The results indicate that degradation of the grazing resources is most evident around taps along the pipeline. One probable explanation to why these areas show more signs of degradation than areas surrounding hand dug wells is that access to hand dug wells is normally controlled by the farmer that dug the well, while access to taps along the pipeline is not controlled and is freely accessible to anyone (Vlachos, 1995). Changes in vegetation composition around permanent water points, caused by domestic animals as observed by farmers, correspond to observations made in semi-arid and arid environments in Australia. There James et al. (1999) observed decreasing abundance of palatable native perennial grasses due to selective grazing. In the Chihuahua desert of the USA Nash et al. (1999) found that the impact of livestock on soil properties and perennial vegetation is greatest close to water points and impact generally decreases exponentially with distance from water. According to Thrash et al. (1993) heavy grazing around water points in southern Africa leads to selective removal of perennial grass species, while annual grasses are promoted. Similarly Todd (2006) showed that grazing centred around permanent water points in the Nama-Karoo, South Africa, led to a decrease of species regarded as being highly palatable to livestock as far as 2 km from water points.

4.1.2. Population and livestock numbers in the area

Results of interviews indicate that a rapid population increase took place just after the water pipeline was constructed. These findings correspond with the marked population increase shown between the national population censuses of 1991 and 2002 (Central Bureau of Statistics, 1994; NPC, 2002). Interviewees also say that livestock numbers have increased concurrently with an increase in the human population. In central northern Namibia only aggregated livestock numbers are available, based on annual cattle vaccination campaigns done by the Directorate of Veterinary Services. Consequently more detailed information about livestock numbers is not available for the study area. However, Mendelsohn et al. (2000) showed that livestock numbers in central northern Namibia reached a plateau during the 1960s and early 1970s, at an approximate total number of cattle of 400 000–600 000. These numbers seem to have been more or less maintained since then (Mendelsohn et al., 2000). However, the most recent drought in the area in 1992–93 resulted in a loss of about a quarter of all cattle (Sweet, 1998). Statistics for the central northern Namibia show that livestock numbers have increased steadily after the drought (Mendelsohn et al., 2000). This suggests that recovery of cattle herds since the early 1990s and redistribution of livestock to the study area from the more densely populated areas in the north most likely led to a local increase of livestock which supports information provided by interviewed farmers.

4.1.3. Occurrence of trees and deforestation

Only farmers arriving in 1990 or before and now depending on the pipeline water referred to deforestation in the study area. When investigating changes in forest cover in central northern Namibia, Erkkilä (2001) found that deforestation was caused almost entirely by clearing of land for permanent agriculture. He estimated that a population increase of one person led to about 1 ha of deforestation. According to Erkkilä (2001) the construction of a typical farm represents a removal of 45 tons of wood and annual felling for maintenance is ~0.5 tons per capita. Results suggest that most large trees disappeared in the early 1990s. This coincides with the rapid population increase that took place after the construction of the water pipeline, which is likely to have led to an accelerated rate of deforestation. This is supported by a recent investigation by Pettersson and Heurgren (2006) who, by measuring dimensions of tree trunks used for construction of homesteads in the study area, could show a significant decrease in pole dimensions used in palisades surrounding homesteads built after 1990 compared to homesteads built before 1990.

Mainly farmers arriving in 1990 or before referred to lack of water when they first came to the area. This suggests that farmers arriving after 1990 mostly settled in places in reach of the pipeline water. Therefore they are less likely to experience problems of poor quality and shortage of water which are common with traditional wells and shallow water bodies during the drier part of the year (Williams, 1991; Vlachos, 1995; Mendelsohn et al., 2000).

4.2. Causes of perceived environmental changes

According to Klintenberg and Seely (2004), results of the national-level monitoring system indicate that increasing livestock numbers and below average rainfall for the last 15 years (1986–2001) are main causes of environmental change in the Ombuga grassland. Farmers interviewed in this study perceive overgrazing, less rainfall, construction of the pipeline, extensive use of wood for construction, illegal fencing and increasing number of tracks to be causes of environmental change in the study area (Fig. 4).

4.2.1. Overgrazing and construction of water pipeline

Construction of the water pipeline is central in development of the study area. Before it was constructed availability of fresh water in shallow ponds and wells recharged by highly variable rainfall was the main factor restricting grazing. However, construction of the water pipeline allowed cattle to graze permanently in areas that previously were used only when rainwater was available. The relationship between grazing and negative environmental change around permanent water sources has been shown along the water pipeline in this study area (Langanke, 2000; Larsson, 2003), in southern Namibia (Kuiper and Meadows, 2002) and at other locations in southern Africa (Perkins and Thomas, 1993; Verlinden et al., 1998; Dougill et al., 1999; Todd and Hoffman, 1999; Riginos and Hoffman, 2003). Larsson's investigation of 2003, based on remote sensing and field observations, concluded that intensive grazing around permanent water points in the Ombuga grassland has a negative effect on the rangeland. Vegetation was shown to

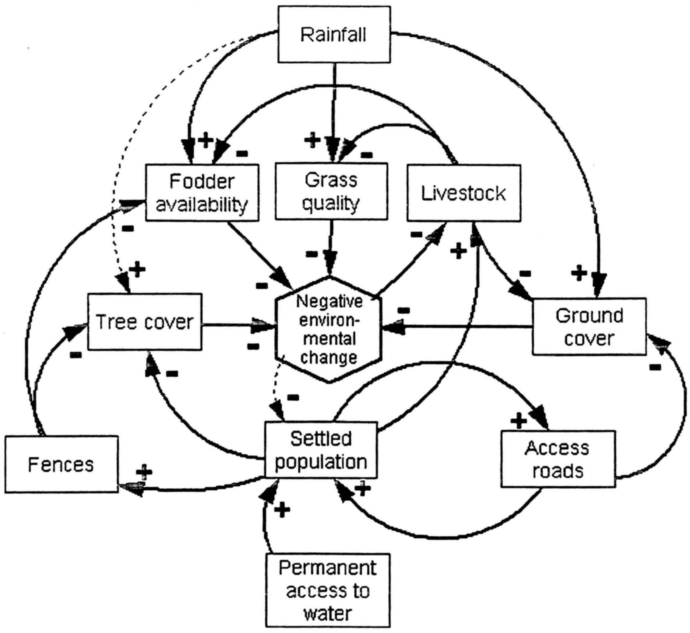

Fig. 4. Relationships between manifestations and causes of perceived environmental changes in the study area according to interviewed farmers. Thick lines indicate strong relationships between variables, while dashed lines indicate weaker relationships. Variables responding in similar directions are linked with (+) and variables responding in opposite directions are linked with (−).

gradually decline with (1) proximity of water points, (2) length of period of use and, (3) increased grazing intensity (Larsson, 2003). Nangula and Oba (2004) investigated whether grazing around water points had caused a shift from perennial to annual grasses in the Ombuga grassland by sampling vegetation along transects radiating from water points along the pipeline. They concluded that no change from perennial to annual grass species due to increased grazing pressure could be detected. It should be noted that their study only focused on the closest 1 km around the water point, comparing these results with observations made at reference sites, considered to be undisturbed by grazing, located at a maximum distance of 5 km from permanent water points. According to Fusco et al. (1995) and Nash et al. (1999) impacts of grazing around water points generally decrease exponentially with distance from water. However, vegetation changes caused by grazing domestic stock have been observed as far as 8 km from permanent water points in the Kalahari of Botswana (Dougill et al., 1999). Similar observations have been made in central Namibia, Botswana and South Africa (Perkins and Thomas, 1993; James et al., 1999; Ward et al., 2000; Todd, 2006). These findings correspond to extent of environmental changes indicated by interviewees around permanent water sources in the study area (Fig. 3). This suggests that the reference sites used by Nangula and Oba (2004) most likely were located in areas also disturbed by grazing, disguising a change in the ratio between perennial and annual grasses, which might have been apparent if they used reference sites on a similar substrate but further away from water points.

4.2.2. *Decreasing rainfall*

Interviewees perceive that decreasing rainfall in the study area is causing degradation. Rainfall records suggest a periodicity of drier and wetter conditions, similar to the southern African 18-year rainfall cycle described by Tyson (1986, 1991). Distribution and productivity of vegetation in central northern Namibia is strongly linked to rainfall (Giess, 1971). This implies that years with low rainfall will result in temporarily less grass. However, the rainfall records indicate that the present drier conditions are not unique and that drier periods are part of normal conditions in central northern Namibia. Therefore it is doubtful that normal rainfall variability, leading to a short-term decrease in productivity, would cause the perceived change (Swift, 1996). This corresponds to findings by Ward et al. (2000) who concluded that perceptions held by local farmers in Otjimbingwe about decreasing rainfall causing environmental changes in that area were not consistent with scientific records. Therefore a more probable explanation is that non-adaptive land management during prolonged dryness, allowing cattle to continuously graze the area along the pipeline is causing perceived environmental change in the study area.

4.2.3. Extensive fencing of the commons and improved access to the area

Illegal fencing of the commons and improved access were stated to be growing problems in the study area. The impact of fencing has been reported from other parts of central northern Namibia (Mendelsohn et al., 2000) and eastern Namibia (Twyman et al., 2001). According to Twyman et al. (2001) fencing of communal land, initially done mainly by more wealthy people, is most probably a result of increasing pressure on resources from rising human and livestock populations. The negative influence of tracks on the vegetation cover, leading to accelerated soil erosion, is evident while travelling in the area. New tracks are normally created during the rainy season when the area is flooded and tracks used during the dry season are deep under water.

As a final point in the discussion, it is clear that the information received from interviewees reveals a complex picture of causes and effects leading to environmental changes in the study area. The results suggest that the introduction of permanent water supply made areas available for grazing and settlement, which previously were unexploited due to lack of water. Increasing human and livestock populations were said to cause negative environmental change. This contradicts findings of Tiffen et al. (1994) who showed that growth of the rural population in Machakos, Kenya led to reversal of degradation, rising productivity and living standards, and successful exploitation of land previously deemed unfit for agricultural use. Increasing population and decreasing availability of land was shown to force farmers to develop innovative management methods, promoting soil conservation and livelihood diversification by non-farm activities. This follows the model by Boserup (1965), stating that decreasing resources in combination with increasing agrarian populations stimulates invention and diversification. However, even though population pressure has increased in the study area, resulting in negative environmental changes, there is still enough land available for farmers to move to when the quality of grazing decreases, as long as they can access ground water through hand dug wells or the pipeline system is extended. The situation resembles the westward frontier movement that took place in USA during the 18th and 19th century (Putnam, 1976; Otterstrom, 2001). According to Otterstrom (2001) the great migration in USA was initiated by the relatively high population densities along the eastern seaboard, resulting in people migrating to the sparsely populated west in search of land and grazing. In central northern Namibia it appears as if farmers will be forced to change their management practices, in a similar way to farmers in Machakos, Kenya, only when there is no more land available to move to.

5. Conclusion

According to the farmers interviewed, overgrazing and low rainfall since the beginning of the 1990s are causes of land degradation in the study area, which corresponds with the results of Namibia's national-level monitoring system (Klintenberg and Seely, 2004). However results from interviews presented here reveal a more complex picture of causes and effects leading to environmental changes in the area compared to the one given by the national-level monitoring system. These results suggest that (1) decreasing availability of grazing in areas north of the Ombuga grassland, (2) improved access to the area (3) permanent access to water after the water pipeline was constructed making it possible for more farmers to settle in the area, leading to increased numbers of livestock and extensive grazing in areas that previously only were used when surface water was available, and (4) fencing of large areas of the commons, are major factors causing the environmental changes referred to by the interviewees. Results of interviews suggest that introduction of permanent water supply was the single most important factor, allowing more people and livestock into the area.

As a concluding observation, the information provided by farmers interviewed contributed to improved understanding of factors leading to environmental changes in and around the Ombuga grassland. These results reflect the conditions in the study area but the factors identified by the interviewees as causing environmental changes are most likely also applicable for other semi-arid areas where inhabitants rely on natural resources. This suggests that assessments of local knowledge in a relatively small area can provide a valuable contribution to development and assessment of national monitoring initiatives.

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References

Andersson, C.J., 1987. Lake Nagami or explorations and discovery during four years of wandering in wilds of South–Western Africa. C. Struik, 546pp.

Boserup, E., 1965. The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure. Earthscan publications, London, 128pp.

Central Bureau of Statistics, 1994. 1991 Population and Housing Census. National Planning Commission, Windhoek.

Christelis, G., Struckmeier, W. (Eds.), 2001. Groundwater in Namibia—An Explanation to the Hydrogeological Map. Windhoek, Namibia, 128pp.

Dahlberg, A.C., 2000. Interpretations of environmental change and diversity: a critical approach to indicators of degradation—the case of Kalakamate, northeast Botswana. Land Degradation and Development 11, 549–562.

Denker, H., Schalken, W., 1998. Tourism Survey of the Four "O" Regions. Northern Namibia Environmental Project, Oshakati, Namibia.

Denker, H., Schalken, W., 1999. Tourism Development Plan for the Ohangwena, Omusati, Oshana and Oshikoto Regions. Northern Namibia Environmental Project, Oshakati, Namibia.
Directorate of Rural Water Supply, 2004. 10 Years: Directorate of Rural Water Supply 1993–2003. Ministry of Agriculture, Water and Rural Development, Windhoek, Namibia, 64pp.
Dougill, A.J., Thomas, D.S.G., Heathwaite, A.L., 1999. Environmental change in the Kalahari: integrated land degradation studies for nonequilibrium dryland environments. Annals of the Association of American Geographers 89 (3), 420–442.
Erkkilä, A., 2001. Living on the land: change in forest cover in north-central Namibia 1943–1996. Ph.D. Thesis, University of Joensuu, Joensuu, Finland, 118pp.
Fusco, M., Holechek, J., Tembo, A., Daniel, A., Cardenas, M., 1995. Grazing influence on watering point vegetation in the Chihuahuan desert. Journal of Range Management 48, 32–38.
Giess, W., 1971. A preliminary vegetation map of South West Africa. Dinteria 4, 1–114.
Gray, L.C., Morant, P., 2003. Reconciling indigenous knowledge with scientific assessment of soil fertility changes in southwestern Burkina Faso. Geoderma 111, 425–437.
Hellden, U., 1991. Desertification: time for an assessment? Ambio 20, 372–383.
Hillyer, A.E.M., McDonagh, J.F., Verlinden, A., in press. Land use and legumes in Northern Namibia—The value o a local classification system. Agriculture, Ecosystems and Environment.
Hutchinson, P., 1995. The climatology of Namibia and its relevance to the drought situation. In: Moorsom, R., Franz, J., Mupotola, M. (Eds.), Coping with Aridity: Drought Impacts and Preparedness in Namibia. Brandes & Apsel Verlag/Nepru, Frankfurt, pp. 17–38.
James, C.D., Landsberg, J., Morton, S.R., 1999. Provision of watering points in the Australian arid zone: a review of effects on biota. Journal of Arid Environments 41, 87–121.
Kinlund, P., 1996. Does land degradation matter? Perspectives on environmental change in north–eastern Botswana. Ph.D. Thesis, Stockholm University, Stockholm, 246pp.
Klintenberg, P., Seely, M.K., 2004. Land degradation monitoring in Namibia: a first approximation. Environmental Monitoring and Assessment 99, 5–21.
Koning, N., Smaling, E., 2005. Environmental crisis or 'lie of the land'? The debate on soil degradation in Africa. Land Use Policy 22 (1), 3–11.
Kuiper, S.M., Meadows, M.E., 2002. Sustainability of livestock farming in the communal lands of southern Namibia. Land Degradation and Development 13 (1), 1–15.
Langanke, T., 2000. Indicators for national-level monitoring of Desertification. Towards linking local level and national-level monitoring: an example from north-central Namibia, Johannes Gutenberg-Universität Mainz Fachbereich Geowissenschaften Geographisches Institut, Mainz, Germany, 125pp.
Larsson, H., 2003. Water distribution, grazing intensity and alterations in vegetation around different water points, in Ombuga grassland, northern Namibia. M.Sc. Thesis, Stockholm University, Sweden, Stockholm, 54pp.
Leach, M., Mearns, R., 1996. The Lie of the Land: Challenging Received Wisdom on the African Environment. The International African Institute, London, 240pp.
Low, A., Werner, W., Embundile, M., Haashoongo, N., 1997. An evaluation of the orientation phase of the SARDEP-North programme. vol. 1 Main Report, Namibian Economic Policy Research Unit, Windhoek.
Mainguet, M., 1994. Desertification: Natural Background and Human Mismanagement. Springer, New York, 314pp.
Marsh, A., Seely, M.K. (Eds.), 1992. Oshanas, sustaining people, environment and development in central Owambo, Namibia, Windhoek, Namibia, 52pp.
Mendelsohn, J., el Obeid, S., Roberts, C., 2000. A Profile of North-Central Namibia. Environmental Profiles Project. Gamsberg Macmillan Publishers, Windhoek, Namibia, 79pp.
Mendelsohn, J., Jarvis, A., Roberts, C., Robertson, T., 2002. Atlas of Namibia: A Portrait of the Land and its People. David Philip Publishers, Cape Town, 200pp.
Muller, M.A.N., 1984. Grasses of Southwest Africa/Namibia. Directorate of Agriculture and Forestry, Department of Agriculture and Nature Conservation, Windhoek, 287pp.
Nangula, S., Oba, G., 2004. Effect of artificial water points on the Oshana ecosystem in Namibia. Environmental Conservation 31 (1), 47–54.
Napcod, 1997. Namibia's National Programme to Combat Desertification: Fighting Desertification Together. Desert Research Foundation of Namibia, Windhoek, 15pp. Unpublished.
Napcod, 1999. First National Report on the Implementation of the United Nations Convention to Combat Desertification. Ministry of Environment and Tourism, Windhoek, 23pp.

Nash, M.S., Whitford, W.G., de Soyza, A.G., Van Zee, J.W., Havstad, K.M., 1999. Livestock activity and Chihuahuan desert annual plant communities: boundary analysis of disturbance gradients. Ecological Applications 9 (3), 814–823.

NPC, 2002. 2001 Population and Housing Census: Preliminary Report. Census office, National Planning Commission, Windhoek, 46pp.

Otterstrom, S.M., 2001. Trends in national and regional population concentration in the United States from 1790 to 1990: from the frontier to the urban transformation. The Social Science Journal 38 (3), 393–407.

Oudtshoorn, F.V., 2002. Guide to Grasses of Southern Africa. Briza Publications, Pretoria, 288pp.

Perkins, J.S., Thomas, D.S.G., 1993. Spreading deserts or spatially confined environmental impacts: land degradation and cattle ranching in the Kalahari desert of Botswana. Land Degradation and Rehabilitation 4, 179–194.

Pettersson, A., Heurgren, L., 2006. Deforestation or a landscape in transition? Human influence on the mopane woodland in northern Namibia. BA Thesis, Stockholm University, Stockholm, 31pp, unpublished manuscript.

Putnam, J.K., 1976. The Turner thesis and the westward movement: a reappraisal. Western Historical Quarterly 7 (4), 377–404.

Rapp, A., 1974. A review of desertization in Africa - Water, vegetation and man, SIES Report No. 1, Stockholm, 77pp.

Rapp, A., Le Houerou, H.N., Lundholm, B. (Eds.), 1976. Can Desert Encroachment be Stopped? A Study with Emphasis on Africa. Swedish Natural Science Research Council, Stockholm, 241pp.

Riginos, C., Hoffman, M.T., 2003. Changes in population biology of two succulent shrubs along a grazing gradient. Journal of Applied Ecology 40, 615–625.

Salinger, M.J., Basher, R.E., Fitzharris, B.B., Hay, J.E., Jones, P.D., Macveigh, J.P., Schmidely-Leleu, I, 1995. Climate trends in the South–West Pacific. International Journal of Climatology 15, 285–302.

Seely, M.K., 1998. Can science and community action connect to combat desertification? Journal of Arid Environments 39, 267–277.

Sweet, J., 1998. Livestock—Coping with Drought: Namibia—A Case Study. Northern Regions Livestock Development Project, Tsumeb, Namibia, 32pp.

Swift, J., 1996. Desertification: narratives, winners and losers. In: Leach, M., Means, R. (Eds.), The Lie of the Land: Challenging Received Wisdom on the African Environment. The International African Institute, James Currey and Heinemann, London, Oxford and Portsmouth, pp. 73–90.

Thomas, D.S.G., Shaw, P.A., 1991. The Kalahari Environment. Cambridge University Press, Cambridge, 284pp.

Thomas, D.S.G., Twyman, C., 2004. Good or bad rangeland? Hybrid knowledge, science and local understandings of vegetation dynamics in the Kalahari. Land Degradation and Development 15, 215–231.

Thrash, I., Theron, G.K., du Bothma, J.P., 1993. Impact of water provision on herbaceous plant community composition in Kruger National Park. African Journal of Range & Forage Science 10, 31–35.

Tiffen, M., Mortimore, M., Gichuki, F., 1994. More People, Less Erosion: Environmental Recovery in Kenya. Wiley, Chichester, 311pp.

Todd, S.W., 2006. Gradients in vegetation cover, structure and species richness of Nama-Karoo shrublands in relation to distance from livestock watering points. Journal of Applied Ecology 43, 293–304.

Todd, S.W., Hoffman, M.T., 1999. A fence-line contrast reveals effects of heavy grazing on plant diversity and community composition in Namaqualand, South Africa. Plant Ecology 142, 169–178.

Twyman, C., Dougill, A., Sporton, D., Thomas, D., 2001. Community fencing in open rangelands: self-empowerment in Eastern Namibia. Review of African Political Economy 87, 9–26.

Tyson, P.D., 1986. Climatic Change and Variability in Southern Africa. Oxford University Press, Cape Town, 217pp.

Tyson, P.D., 1991. Climate change in southern Africa: past and present conditions and possible future scenarios. Climate Change 18, 241–258.

UNCED, (Ed.), 1977. Desertification: Its Causes and Consequences, 1977, Pergamon Press, Oxford, 448pp.

Verlinden, A., Dayot, B., 2000. Working with local knowledge systems in a GIS for natural resource assessment, planning and management in North Central Namibia. In: Caron, P., Swanepoel, F., Stroebel, A. (Eds.), Regional Workshop on Spatial Approaches for Land Use and Local Governance. SACCAR and the University of Pretoria, post-graduate school of Agriculture and Development, Pretoria.

Verlinden, A., Dayot, B., 2005. A comparison between indigenous environmental knowledge and a conventional vegetation analysis in north central Namibia. Journal of Arid Environments 62, 143–175.

Verlinden, A., Perkins, J.S., Murray, M., Masunga, G., 1998. How are people affecting the distribution of less migratory wildlife in the southern Kalahari of Botswana? A spatial analysis. Journal of Arid Environments 38, 129–141.
Vlachos, J., 1995. Communal land tenure and land degradation: a minor field study of the Elim constituency, Omusati region, Namibia. M.Sc. Thesis, Lund University, Sweden, Lund, 53pp.
Ward, D., Ngairorue, B.T., Apollus, A., Tjiveze, H., 2000. Perceptions and realities of land degradation in arid Otjimbingwe, Namibia. Journal of Arid Environments 45, 337–356.
Wheeler, D., Martin-Vide, J., 1992. Rainfall characteristics of mainland Europe's most southern stations. International Journal of Climatology 12, 69–76.
Williams, F.N., 1991. Precolonial communities of Southwestern Africa: A history of Owambo Kingdoms 1600–1920. ARCHEIA. National Archives of Namibia, 204pp.