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Effects of artificial water points on the Oshana ecosystem in Namibia

S. NANGULA[1] AND G. OBA[2]*

[1]*Life Sciences Division, Multidisciplinary Research and Consultancy Centre, The University of Namibia, Private Bag, 13301, 340 MN. Avenue, Windhoek, Namibia, and* [2]*Noragric, Centre for International Environment and Development Studies, The Agricultural University of Norway, PO Box 5001, N-1432 Ås, Norway*

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SUMMARY

In the semi-arid rangelands of the Oshana ecosystem in Northern Namibia, there are general concerns that artificial water points for domestic use contribute to the processes that lead to desertification. The processes begin in piospheres of artificial water points. Among the processes suggested to correlate with radial distance and age of water points are loss of perennial grass species, an increase in annuals, and general loss of herbaceous species richness, herbaceous biomass and grass cover, as well as an increase in forb cover and in bare ground and litter cover. Radial distance and age of artificial water points impacts were compared using these indicators with benchmarks in saline grassland and *mopane* landscape at the end of the wet season. Radial distance influenced herbaceous species richness, grass cover and bare ground, while the variability of the perennial:annual grass ratio, herbaceous biomass, forb and litter cover were attributed to differences between landscape types. Age of water points influenced only herbaceous species richness, while forb cover was associated more with water points than benchmarks. Forb cover was sporadic in relation to age of water points. In the Oshana ecosystem, therefore, radial-grazing distance could not be used to explain changes in the perennial:annual grass ratio. Many of the changes were explained by differences between landscape types. The *mopane* landscape was more vulnerable to degradation induced by artificial water points than the grassland landscape. The implication is that, in the future, greater care should be taken to space water points in the *mopane* landscape.

Keywords: artificial water points, desertification, herbaceous biomass, herbaceous species richness, *mopane*, Namibia, Oshana ecosystem, piosphere

INTRODUCTION

Provision of artificial water points through sinking of boreholes (Jeltsch *et al.* 1997), development of water pans (Owen-Smith 1996) and laying pipeline systems (Nangula 2001) in the arid zones are often used to increase year-round grazing by livestock and wildlife. Water points promote heavy concentrations of livestock and wildlife (Van Rooyen *et al.* 1990; Hanan *et al.* 1991; Thomas *et al.* 2000), causing heavy trampling and overgrazing (Lange 1969; Jeltsch *et al.* 1997). It has been suggested that continuous heavy grazing and trampling around water points create radial patterns of degradation called piospheres (Andrew 1988; Barker *et al.* 1989; Thrash *et al.* 1995; Jeltsch *et al.* 1997; Pickup *et al.* 1998; James *et al.* 1999; Parker & Witkowski, 1999; Brits *et al.* 2002). Additionally, heavy grazing around water points is reported to selectively remove perennial grass species, while annual grasses are promoted (Thrash *et al.* 1993). The cumulative effects of livestock grazing and trampling are suggested to induce changes in plant species composition (Thrash 2000) and to result in reduction of plant species richness, plant cover and biomass, while bare ground increases (Pickup *et al.* 1998; Parker & Witkowski 1999). The presumption is that any observed changes with increasing distance from water points can directly be explained by grazing pressure gradients alone (Hanan *et al.* 1991; Thrash 1998). The dynamics of herbaceous species richness, grass cover, forb cover, biomass, bare ground and litter cover might vary with the age of artificial water points (Andrew 1988). To understand if the effects observed are associated with water points alone, benchmark sites are usually used as controls. Thus, effects of radial grazing distance, age of water points as well as differences between water point sites and benchmarks and landscape types may be used to understand the role artificial water points play in the dynamics of herbaceous vegetation in the arid zones.

The majority of the studies in southern Africa have been concerned with wildlife impacts (see Van Rooyen *et al.* 1990; Thrash *et al.* 1995; Parker & Witkowski 1999; Thrash 2000), while few have examined the effects of domestic water on changes in herbaceous vegetation around piospheres (see Thomas *et al.* 2000; Muvangua 1998; Nangula 2001). Our objective was to investigate the effects of artificial water points established for domestic use on the herbaceous vegetation of the semi-arid rangelands of the Oshana ecosystem in Northern Namibia. During the wet season, water from the upper catchments in Angola contributes to the flow of the Oshana drainage system (Clarke & Rayner 1999), while during the dry season (i.e. after the surface water has evaporated) water scarcity is a major problem for both livestock and human consumption. Because of the limitation of drinkable water during the dry season, shallow aquifers are often excavated to provide local water supplies. The deeper groundwater is

*Correspondence: Dr Gufu Oba Fax: +47 6494 0760 e-mail: gufu.oba@noragric.nlh.no

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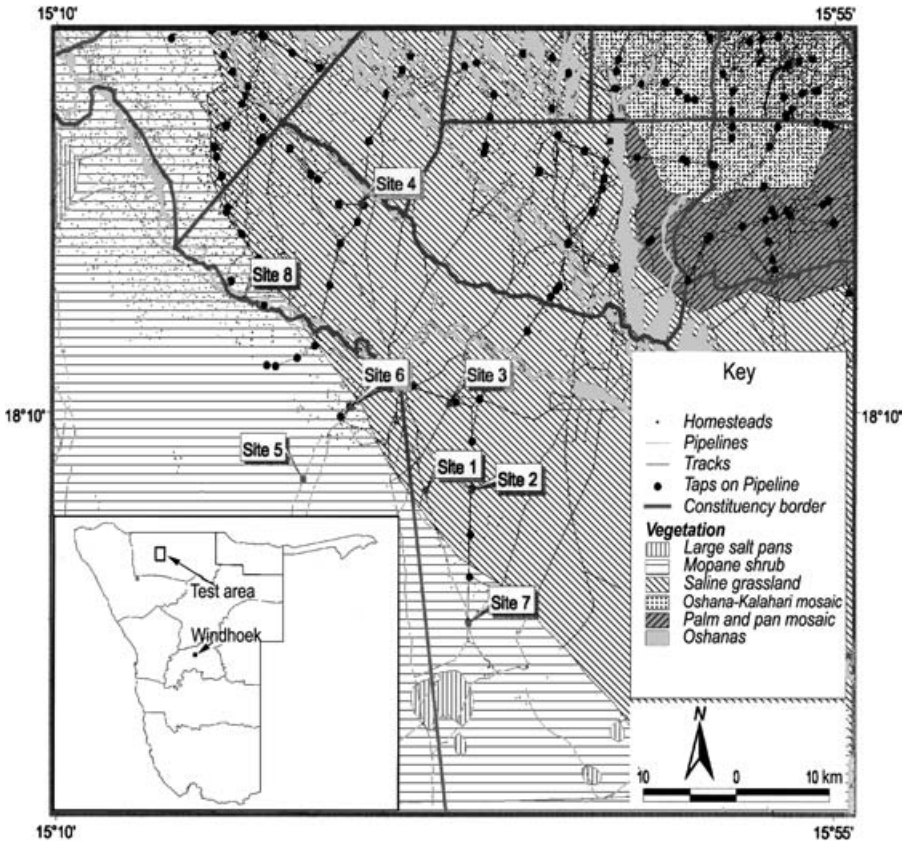


Figure 1 Map of Northern Namibia, showing locations of water points and benchmarks. Sites 2, 3, 4, 6, 7 and 8 represent artificial water points, and sites 1 and 5 represent the benchmarks. Source: Desert Research Foundation of Namibia. Descriptions of the water point and benchmark sites are provided in Table 1.

highly saline and is seldom used for domestic consumption. In order to address the problem of water scarcity during the dry season, networks of pipelines and systems of canals from the Cunene River on the border with Angola are used to redistribute drinking water for human and livestock use. There are more than 2600 km of pipelines in Northern Namibia that serve livestock and human populations (Marsh & Seely 1992; Nangula 2001).

The new water points induced a system of land use radically different from that traditionally practised by the Owambo agro-pastoralists (Williams 1991). The distances livestock and humans must travel to a water point have been shortened, with individual settlements located approximately 3 km from water points, while livestock may travel 7 km to water points (Nangula 2001). Because of greater pressure on the rangelands around water points, there are concerns that permanent water points might accelerate the processes that lead to desertification (Marsh & Seely 1992; Muvangua 1998; Nangula 2001). The major vegetation types affected are the saline grassland and *mopane* shrubland. We investigated whether radial grazing distance and age of water points could be used to describe the desertification process that reduces the ratio of perennial:annual grass species, frequencies of individual grass species, herbaceous species richness, herbaceous biomass and grass cover, and increases forb cover, bare ground and litter cover in piospheres of artificial water points relative to benchmarks in the two landscape types.

METHODS

Study area

The study was conducted in the Uuvuthiya Constituency in Northern Namibia (Fig. 1). The climate is classified as semi-arid, with 99% of the rain falling in the summer months between October and April and the rest in June/July. Rainfall is variable, ranging from 300–400 mm yr^{-1} (Ward *et al.* 2000). The soils are comprised of the Kalahari sands and sandstones. The landscapes gently undulate between 1100–1200 m altitude (Marsh & Seely 1992). The *mopane* shrubland and saline grasslands (hereafter called *mopane* and grassland landscapes, respectively) are major grazing resources in the Oshana ecosystem (Mendelsen *et al.* 2000). The mopane landscape type is dominated by *Colophospermum mopane* that forms patches on loamy sands. Other woody species include *Catophractes alexandri* and *Commiphora* species. The woody layer has greater cover in the mopane landscape (39.9 ± 4.7%) compared to the grassland landscape (3.3 ± 4.6%) (Nangula 2001). The saline grassland serves as an important dry season grazing resource for the mobile cattle posts and livestock from the homesteads (Mendelsen *et al.* 2000).

Artificial water points

Six artificial water points were selected at random (Fig. 1). Brief descriptions for the water points established between

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Table 1 Brief description of water point and benchmark sites in northern Namibia (as shown in Fig. 1).

Sites	*Location*	*Year*	*Description*
Site 1	Uuvudhiya	Benchmark	Benchmark site located in saline grassland, about 5 km from Site 2. Little evidence of livestock grazing at the time of the survey.
Site 2	Omapale	1996	Water point situated in saline grassland on the Oshakati-Omapale pipeline. The area served as a cattle post (for mobile herds), as well as being grazed by livestock from the homesteads.
Site 3	Eengombe	1996	Water point located in grassland on the Oshakati-Omapale pipeline. The area was used for grazing by livestock from cattle posts and the homesteads.
Site 4	Omapopo	1993	One of the oldest water points. Supplies water to the homesteads and for cattle. Located in grassland. The site has some bush invasion.
Site 5	Onkani	Benchmark	Benchmark site located in mopane. Showed little evidence of grazing during the survey.
Site 6	Onkani-centre	1998	Water point located on the Oshakati-Omapale pipeline. Used for domestic consumption. Main landscape is mopane.
Site 7	Omapale	1996	Water point on the Oshakati-Omapale pipeline. Used only by livestock from the far south of the Uuvudhiya constituency. Main landscape is mopane, with bushes between 1–5 m in height.
Site 8	Onaushe	1993	Amongst the oldest water points located on different pipeline systems. Water point located near canal that supplied water for livestock. Landscape mainly mopane.

1993 and 1998 are provided (Table 1). In the study area, because of widespread grazing pressure and lack of large-scale protected areas, suitable benchmarks for each water point were unavailable. Instead, we used two benchmark sites (one representing the grassland and the other mopane landscape types) that showed no evidence of recent grazing pressure to serve as controls for the water point sites. In order to better understand whether water point age affected herbaceous vegetation, we compared both recently established and older water points. The effects of radial grazing patterns on frequencies of grasses, total herbaceous species richness, grass cover, forb cover, herbaceous biomass, bare ground and litter cover were investigated during July–August 2000, which coincided with the end of rainy season and the return of livestock to water points.

For each water point, we located four 1-km long transects for the four compass directions, north, south, east and west. We sampled the transects at concentric distances of 100 m, 300 m, 500 m and 1000 m from water points. For the two-benchmark sites, we sampled eight 1-km long transects (without radial distances). We used a point sampling method to record vegetation (perennial grasses, annual grasses and forbs), bare ground and plant litter (see Floyd & Anderson 1987). Firstly, the direction of each transect was fixed. Secondly, using steps along each transect (each step was about 1 m), foliar cover (i.e. grasses and forbs), bare ground and litter were sampled as 'hits'. Each hit was recorded for each variable. The total number of hits (frequency) for each variable was used to calculate relative cover for the distance interval. Thirdly, the grass species found within 30 cm radius of each transect point were categorized as perennial or annual. For individual perennial and annual grass species we used the frequency data to determine composition. At 50 m points along the radial distance, we determined herbaceous biomass and herbaceous species richness in 1×1 m plots.

Statistical analysis

We used a general linear model (GLM) to analyse the variations in mean ratio of perennial:annual grass species, frequency of individual grass species, total herbaceous species richness, herbaceous biomass, grass cover, forb cover, bare ground and litter cover (all being dependent variables). We used radial grazing distance from water points (four levels by 24 transects), age of water points (three levels by 24 transects) and landscape type (two levels by 24 transects) as predictors. Given that the number of water point sites and benchmark sites were not equal, we chose GLM to analyse the data and determine whether the response variables varied between the water point sites and benchmarks (two levels). The response represented the effects of land management (i.e. benchmarks versus grazed water points). We included landscape types in all analyses using SYSTAT (2002) version 10.2, with significance fixed at $p < 0.05$.

RESULTS

Effects on herbaceous species

Radial grazing distance had no significant influence on the ratio of perennial:annual grass species (all $p > 0.05$; Fig. 2*a*). Moreover, differences associated with age of water points did not produce consistent patterns. Rather, mean differences for grass species ratio between the recently established and older water points appeared to be sporadic (Fig. 2*b*). The ratio did not show variations between the water point sites and the benchmarks (all $p > 0.05$). However, at the benchmark sites, grassland landscape showed a greater mean ratio, while at the water point sites, there was a higher mean ratio for the mopane landscape (Fig. 2*c*). At the species level, only the frequency of the annual grass *Pogonarthria fleckii* ($F_{2,20} = 5.259$, $p = 0.017$) appeared to increase in response to age of

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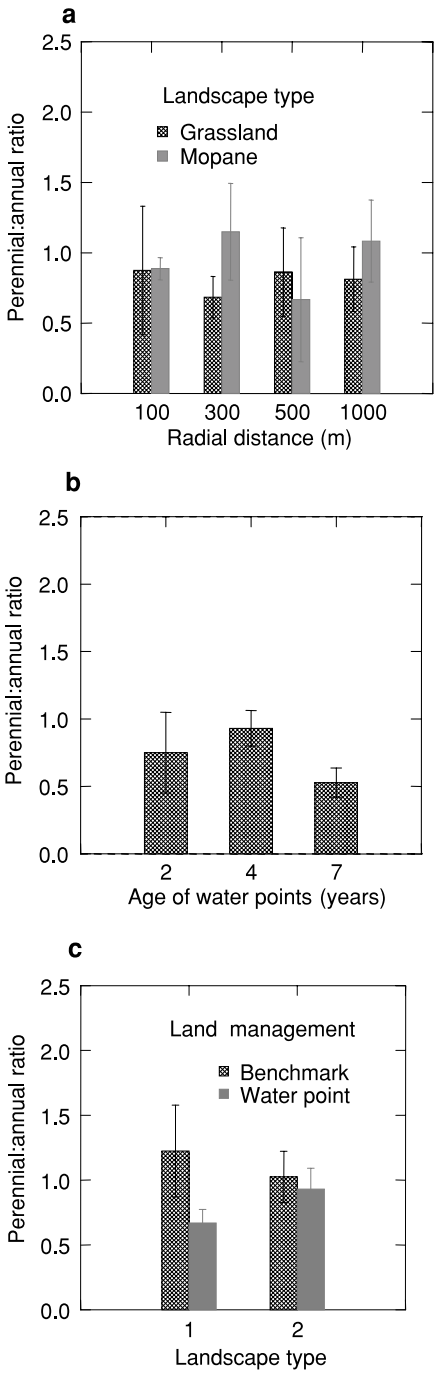


Figure 2 Mean (± SE) perennial:annual grass species ratio showing responses to (*a*) radial distance, (*b*) age of water points and (*c*) land management (1 = saline grassland, 2 = mopane landscape) by landscape type.

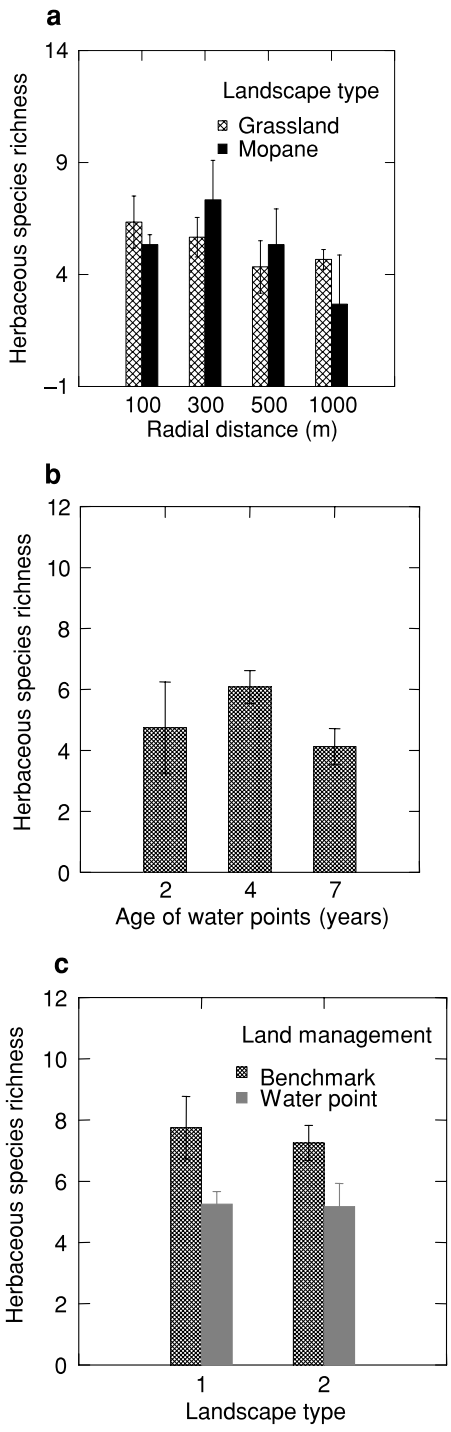


Figure 3 Mean (± SE) herbaceous species richness showing responses to (*a*) radial distance, (*b*) age of water points and (*c*) land management (1= saline grassland, 2 = mopane landscape) by landscape type.

water points. Between benchmarks and water point sites, the frequencies of the perennial grass species *Anthephora pubescens* ($p = 0.006$), *Eragrostis tricophora* ($p < 0.001$) and *Eragrostis* spp. ($p = 0.016$), and the annual grasses *Eragrostis porosa* ($p = 0.027$) and *Aristida effusa* ($p < 0.001$) showed significant spatial variability (Table 2). Frequencies of the remaining grass species, *Anthephora pubescens* ($p = 0.001$), *Anthephora schinzii* ($p = 0.006$), *Eragrostis tricophora* ($p = 0.029$), *Pogonarthria fleckii* ($p = 0.013$), *Odyssea paucinervis* ($p = 0.02$), *Wilkommia sarmentosa* ($p = 0.026$) and *Wilkommia annua* ($p = 0.001$) were significantly influenced by the landscape types (Table 2).

Effects on herbaceous species richness and biomass

Radial distance had a significant effect on herbaceous species richness ($F_{3,20} = 3.698$, $p = 0.032$; Fig. 3*a*), and age of water

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Table 2 Grass species frequency (mean ± SE) in relation to radial distances from water points and benchmarks in grassland and mopane in the Oshana ecosystem, northern Namibia

Grass species	*Life form*	*Radial distances (m)*				*Benchmarks*	
		100	*300*	*500*	*1000*	*Grassland*	*Mopane*
Anthephora pubescens	Perennial	0	0	0	0.13 ± 0.4	0.1 ± 0.04	0
Anthephora schinzii	Annual	1.0 ± 2.8	1.1 ± 3.2	1.3 ± 3.5	0	0	1.7 ± 0.7
Aristida effusa	Annual	8.5 ± 15.4	13.8 ± 14.5	18.5 ± 22.6	21.6 ± 22.2	28.7 ± 3.2	2.5 ± 3.2
Chloris virgata	Annual	1.9 ± 3.5	0.3 ± 0.5	0	0	1.1 ± 0.4	0
Eragrostis tricophora	Perennial	11.4 ± 11.4	7.1 ± 5.8	5.8 ± 4.2	6.8 ± 7.1	6.6 ± 5.1	8.8 ± 9.5
Eragrostis viscosa	Annual	7.0 ± 7.4	6.4 ± 6.2	4.9 ± 5.4	2.0 ± 3.0	6.6 ± 1.9	8.9 ± 1.9
Eragrostis rotifer	Perennial	0	0	0.3 ± 0.5	0.25 ± 0.5	2.4 ± 1.2	7.8 ± 1.2
Eragrostis porosa	Annual	3.6 ± 4.4	3.0 ± 4.3	2.6 ± 4.4	6.4 ± 13.5	1.4 ± 1.8	6.4 ± 1.8
Eragrostis spp.	Perennial	0.5 ± 1.4	1.1 ± 1.9	0.6 ± 1.8	0.4 ± 1.1	0.6 ± 0.4	0.8 ± 0.0
Microchloa caffra	Perennial	2.4 ± 6.7	2.1 ± 4.6	4.1 ± 7.6	1.9 ± 5.3	0	5.3 ± 1.4
Pogonarthria fleckii	Annual	8.1 ± 9.0	18.0 ± 15.2	16.7 ± 14.1	12.3 ± 12.6	8.4 ± 3.0	19.2 ± 3.0
Scmidtia kalaharensis	Annual	22.5 ± 19.5	22.9 ± 10.5	28.4 ± 18.9	17.4 ± 16.1	30.1 ± 3.7	15.4 ± 3.7
Odyssea paucinervis	Perennial	8.9 ± 10.3	7.6 ± 6.8	7.8 ± 9.9	2.3 ± 3.9	10.7 ± 1.7	2.6 ± 1.7
Wilkommia sarmentosa	Perennial	1.5 ± 3.9	5.8 ± 14.4	5.1 ± 9.2	0.9 ± 1.6	1.9 ± 2.2	4.8 ± 2.2
Wilkommia annua	Annual	12.4 ± 10.4	9.1 ± 6.8	7.8 ± 5.2	8.8 ± 8.13	5.6 ± 5.1	7.8 ± 6.5

points played an influential role ($F_{2,18} = 4.117$, $p = 0.035$). The means for all water point sites showed herbaceous species richness declined in response to water point age (Fig. 3*b*). When we considered both benchmark and water point sites, however, the mean species richness for each landscape type was comparable ($p = 0.006$; Fig. 3*c*). However, biomass failed to respond to radial distance (Fig. 4*a*) and water point age (Fig. 4*b*) or to show differences between benchmark and water point sites (all $p > 0.05$). Differences were largely attributed to landscape type (Fig. 4*c*).

Effects on herbaceous cover

Grass cover showed significant increases with increasing distance from water points ($F_{3,28} = 6.760$. $p = 0.003$). The response was not influenced by age of water points ($p > 0.05$). Moreover, management did not appear to influence grass cover when comparing benchmark and water point sites. The differences were weakly related to landscape type ($p = 0.06$). By contrast, forb cover was sporadic and did not appear to be influenced by radial distance ($p > 0.05$). Generally, forb cover responded in a non-linear fashion to age of water points ($F_{2,21} = 8.229$, $p = 0.002$). Forb cover showed greater means for the water point sites (10.4%) than the benchmark sites (1.3%).

Effects on bare ground and litter cover

Bare ground showed sensitivity to radial grazing distance from water points ($F_{3,28} = 8.329$, $p = 0.004$; Fig. 5*a*) but was not influenced by age of water points ($p > 0.05$; Fig. 5*b*) or showed no significant differences between benchmark and water point sites ($p > 0.05$), although mean values for the mopane landscape were higher than those of saline grassland (Fig. 5*c*). Litter cover failed to show significant responses to radial-grazing distance and age of water points, or differences between water point and benchmark sites (*F*-tests, all $p > 0.05$).

DISCUSSION

The findings of the study did not support the hypothesis that radial grazing distances promote annual grasses over the perennial grass species in the piospheres of artificial water points in the Oshana ecosystem. We did not observe a declining trend in the perennial:annual grass ratio with increasing radial distance or age of water points, suggesting that current distributions of perennial and annual grasses species could not be explained by effects of management alone. Moreover, because of the lack of differences in the perennial:annual grass species ratio between the benchmark and the water point sites, we suggest that water points had limited influence on grass species occurrences. Among the 15 grass species, only one annual grass species appeared to serve as an indicator of water point age. For individual grass species, differences could be attributed to landscape type.

We observed a direct relationship between herbaceous species richness and radial grazing distance, as well as between herbaceous species richness and water point age, suggesting that management might have had an influence. This is, however, contradicted by the lack of differences between the benchmark and water point sites, which suggests that the changes could not be attributed to management alone. As a further corroboration, herbaceous biomass production did not respond to radial distance or water point age. Differences in herbaceous biomass production may be attributed to differences between landscape types. Herbaceous biomass alone cannot, therefore, be used to assess the effects of grazing pressure around water points in the Oshana ecosystem. Rather, the analyses would be more informative if environmental factors were considered (Heshmatti *et al.* 2002). The response of grass cover to radial grazing distances,

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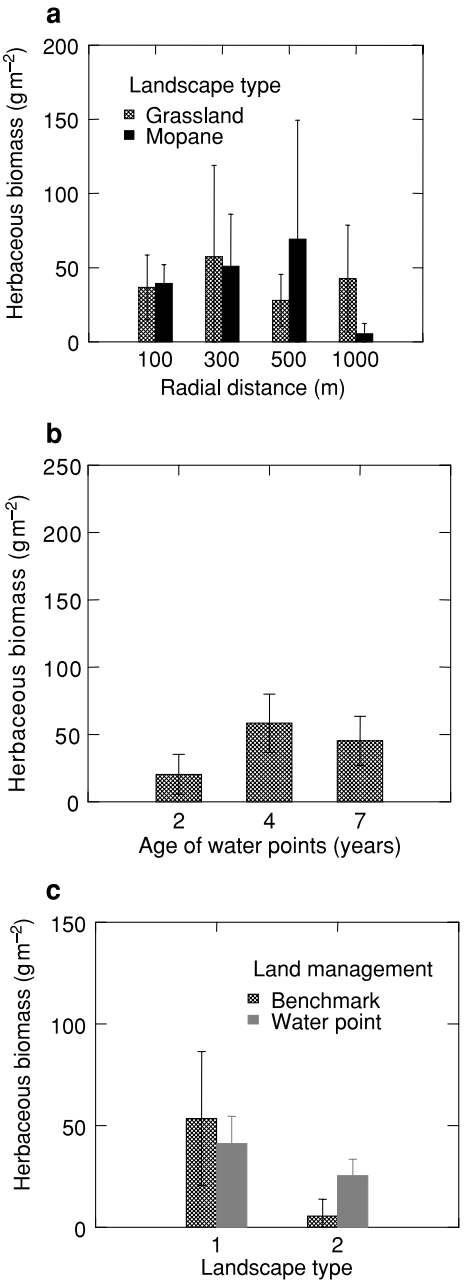


Figure 4 Mean (± SE) herbaceous biomass (g m^{-2}) showing response to (*a*) radial distance, (*b*) age of water points and (*c*) land management (1= saline grassland, 2 = mopane landscape) by landscape type.

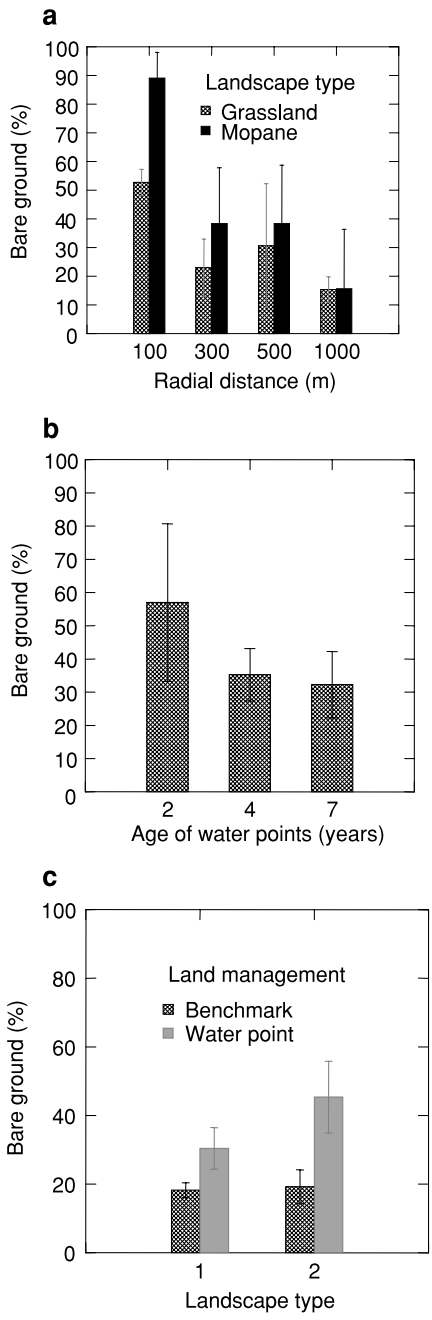


Figure 5 Mean (± SE) bare ground (%) in response to (*a*) radial distance, (*b*) age of water points and (*c*) land management (1= saline grassland, 2 = mopane landscape) by landscape type.

but lack of response to water point age, also implied that while management was influential, the effects were probably mediated through climatic variability (Oba *et al.* 2000*a*, *b*).

When we examined the difference between the benchmark and the water point sites, we deduced that past management had a role in influencing grass cover in the Oshana ecosystem, although landscape types induced most of the differences. However, age of water points had little effect, and this implied that the non-use of water points during the wet season probably overrode the effects of grazing disturbance during the previous dry season. Other researchers have reported different trends. For example, Zeidler (1999) reported the establishment of artificial water points in Northern Namibia resulted in heavy grazing and poor range conditions. Tolsma *et al.* (1987), Pickup *et al.* (1998), Thrash (1998, 2000) and Parker and Witkowski (1999) reported a decline in herbaceous vegetation production around water points serving wildlife in Botswana and South Africa. In the Kalahari ecosystem

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of Botswana, by comparison, Thomas *et al.* (2000) reported that long-term investigation was necessary to make objective observations about land degradation around domestic water points.

Additionally, our findings did not disclose clear patterns of forb and litter cover in response to radial distances or in response to age of water points. The sporadic nature of forb cover suggested that the plant life form was highly seasonal, although greater abundance in the water point sites than the benchmarks suggested that forbs were mostly associated with water points. The litter cover reflected the variability of the herbaceous biomass and herbaceous cover (data not shown) and tended to show greater variability in the grassland than in the mopane landscape.

In the Oshana ecosystem, therefore, if we compare water point with benchmark sites, the response of herbaceous vegetation to radial grazing distance is indirect and cannot be used alone to evaluate factors that create piospheres around artificial water points. The factors that induced bare ground included those related to grazing and trampling, and fluctuations of herbaceous vegetation in response to erratic rainfall. In the South African veld, Thrash (2000) suggested that the previous season's rainfall and stocking rates had an impact. We did not find a significant response to age of water points, which suggests that formation of bare ground (which is usually used as the indicator of desertification) reflected mostly seasonal fluctuations in herbaceous cover. In contrast to our study, Skarpe's (2000) investigations of older water points in the Kalahari region of Botswana showed that radial patterns of grazing pressure caused corresponding changes in plant species. In the south-western Kalahari region, vegetation changes were largely explained by rainfall variability, and not by grazing pressure (Van Rooyen *et al.* 1994; Van Rooyen & Van Rooyen 1998).

In our study, the variability associated with water points could be explained by differences between landscape types. The findings suggest that landscapes might confound the results of radial grazing distances or effects of age of water points. Our findings are interesting because we used more recently established water points than those reported in the literature. Another reason for being cautious in interpreting the results is the special ecological features of the Oshana ecosystem, which fluctuates between seasonal flooding and desiccation. Moreover, a dry season survey could not be used to make general predictions about conditions during the wet season. Nonetheless, the less frequently flooded mopane landscape showed greater vulnerability to water-induced land degradation than the more regularly flooded grassland landscape.

CONCLUSIONS

Our study did not confirm the general expectation that overgrazing around artificial water points promotes annual grass species and reduces perennials. Rather, only one annual grass species showed sensitivity to water point age. As a consequence, in the Oshana rangelands the use of perennial grasses alone as indicators of land degradation might be misleading. The environment is relatively dry, implying that the potential for grass establishment is higher for annuals than perennials. Plant growth cycles were synchronized with the seasonal flooding and desiccation of the Oshana ecosystem and rainfall variability, as opposed to management alone. The response to water point age, especially in terms of reduced herbaceous species richness, might suggest progressive loss of grass species richness, although the effect was bound to be dynamic in response to rainfall and periodic flood inundations. The dynamics of bare ground and herbaceous cover probably reflected rainfall variability and management combined. The non-use of water points during the wet season overrode the effects of grazing during the dry season. Future monitoring should consider the combined effects of grazing and rainfall variability and landscape type in order to provide a better understanding of the effects of artificial water points on the processes associated with desertification. Despite this, the two landscape types responded differently to the impacts of water points. The mopane landscape was more sensitive to water-induced changes than the saline grassland, and development planners should consider spacing water points to avoid probable long-term impacts.

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