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Impact of sheep grazing intensity on vegetation at the Arid Karoo Stocking Rate Trial after 27 years, Carnarvon, South Africa

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ABSTRACT

Sustained heavy grazing is expected to result in degradation and loss of biodiversity in drylands but long-term experiments which assess the impact of management practises on biodiversity are necessary. The effects of stocking rate (SR) on vegetation composition, abundance of different plant functional groups (PFGs), abundance of dominant species, and plant diversity were investigated after 27 years at a long-term SR trial. Vegetation composition was investigated using Canonical Correspondence Analysis and General Linear Models. Stocking rate and time had significant effects on species composition. Increases over time were apparent for total plant cover, palatable shrub cover, and perennial grass cover, annual grass cover decreased over time, whereas other PFGs and rangeland condition showed no trend over time. Greater stocking rates resulted in lower total plant cover, palatable and unpalatable shrub cover, perennial grasses, and annual herbaceous species. Higher annual rainfall resulted in higher total plant cover, while greater preceding three-month rainfall benefitted annual grasses and annual herbaceous species. Plant diversity seemed unaffected by SR. Vegetation structure did not seem to be influenced by SR after 27 years. Our study confirms the slow rate at which vegetation change occurs in drylands and highlights the importance of long-term monitoring trials.

1. Introduction

Drylands (hyperarid, arid, semi-arid and dry sub-humid zones) cover 47% of the world's surface (Le Houerou, 1996). Within southern Africa, the Nama Karoo Biome is the second largest biome covering an area of 607 235 km^2 (23%) within South Africa, Namibia and Botswana (Rutherford, 1997). This vast area is used almost exclusively as rangeland for livestock production (Dean et al., 1995), a land use that contributes indirectly to biodiversity conservation through maintaining natural vegetation (O'Connor and Kuyler, 2009). Management for livestock production faces the challenge of climatic cycles about 18 years in period (Tyson and Preston-Whyte, 2000), with drought years a common experience (Snyman, 1998) and even years of occasional floods. Variable rainfall supports relatively stable long-lived dwarf shrubs and perennial grasses as well as a more variable short-lived grass and seasonal above-ground ephemeral component consisting of herbaceous annuals and long-lived geophytic species. Annual species are often only successful during years with specific rainfall conditions and may otherwise be absent (Dreber et al., 2011). This host of growth forms each respond to inter-annual rainfall variability in a unique way and collectively determine species richness for the Nama Karoo (Cowling et al., 1994). Despite new threats to the biodiversity of the Nama Karoo including alien invasive species, open-cast mining, and renewable energy installations, rangeland mismanagement remains the most important influence because > 80% of the Nama Karoo is used as commercial farming rangeland.

Heavy grazing is one of the main causes of degradation and loss of biodiversity in arid and semi-arid rangelands (Milton, 1994; Milton and Hoffman, 1994; Haarmeyer et al., 2009). Appropriate grazing practices are necessary to ensure the sustainability of the current land use of this vast region. Management practices that can have a pronounced influence on the vegetation dynamics of semi-arid shrublands include stocking rate, grazing systems (including the season of grazing), and animal type, of which stocking rate is widely considered to be the most important (O'Reagain and Turner, 1992). In order to understand the long-term effects of grazing, long-term studies are necessary on account of the pronounced inter-annual variability of rainfall, hence long-term experiments are of exceptional value.

Grazing behaviour reflects the relationship between the animal and rangeland vegetation upon which animals depend (Kasshun et al.,

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Nomenclature

SANBI (South African National Biodiversity Institute) http://newposa.sanbi.org./ National species list (last updated 6 June 2016); Germishuizen and Meyer, 2003

2008). Thus, rangeland condition is an important consideration for decision making in improving grazing and rangeland management systems under arid and semi-arid conditions (Kasshun et al., 2008). At a paddock scale, injudicious grazing management in the Karoo can alter vegetation composition and soil properties (Du Toit et al., 2011). Expected changes of sustained heavy grazing are a change in plant species composition, changes in dominant species, life-forms and growth forms as well as changes in net primary productivity (Milchunas and Lauenroth, 1993). In addition, unpredictability of the seasonal climate can easily result in the deterioration of vegetation if stocking rates are not managed accordingly (Dreber et al., 2011) with the local extinction of vulnerable plant species more readily expected owing to the combination of droughts and sustained grazing (O'Connor, 1991). Vegetation composition, especially the palatable and unpalatable components thereof, is thus central to decision making in arid and semi-arid environments justifying study of vegetation compositional change. In addition, the positive relationship found between climatic heterogeneity and growth form diversity (Cowling et al., 1994) justifies the study of growth form composition and change.

Maintaining biodiversity is a challenge of global concern (Bélair et al., 2010). This challenge cannot be realistically met through the creation of additional protected areas but it is most likely to be met through mainstreaming of biodiversity conservation within the production sector (Pierce et al., 2002). Livestock ranching is one of the best options available for accomplishing this because it relies primarily on the use of natural vegetation (O'Connor et al., 2011) and the same concerns about the effect of grazing management variables on sustainability of production apply to the maintenance of biodiversity. Earlier work on land degradation in the arid shrublands of South Africa reviewed by Dean et al. (1995) emphasised the links between land degradation and less productive rangeland, but gave little attention to the implications of degradation for biodiversity. However, livestock production, not biodiversity, was the overriding interest in degradation during the period of their review (Rutherford and Powrie, 2010), but a foundation for managing rangelands for maintaining biodiversity is now required as a matter of priority. Vegetation compositional change is expected in response to grazing, with species lost or gained over time, as well as the increased threat of alien species, however, the effects on plant diversity are unknown. Formal field experiments provide an opportunity to gain a relatively precise assessment of the impact of specific management variables. An initial focus on plant diversity is critical because it underpins the trophic structure of a food web.

The slow nature of rangeland degradation makes the observation of vegetation change difficult without prior monitoring (Van Rooyen, 1998) reinforcing the importance of long-term trials. The Arid Karoo Stocking Rate Trial, near Carnarvon, is an example of a long-term grazing trial in the Nama Karoo Biome of South Africa. This experiment was initiated in 1988 in order to investigate the influence of stocking rate (number of animals allocated to an area of land) on the Nama Karoo vegetation. The range of stocking rate treatments and length of study period (27 years) offers an opportunity to examine the effect of stocking rate over a longer period than that of a climatic cycle.

The aim of the study was to investigate the effect of stocking rate on vegetation composition, abundance of different PFGs, abundance of dominant species, and plant diversity. The following key questions were investigated: (1) What is the effect of stocking rate on vegetation composition? (2) Does, as expected, an increase in stocking rate depress total plant cover? (3) Does an increase in stocking rate result in a decrease of palatable perennial species and an increase of unpalatable perennial and of annual species? (4) Are annual species successful only under a restricted range of seasonal rainfall, and is their success further dependent on stocking rate? (5) Is the response of the five most dominant perennial species the same as the response of their respective PFGs? (6) Does stocking rate decrease species richness and diversity?

2. Study area

Carnarvon Experimental Station is situated approximately 20 km west of Carnarvon in the Northern Cape, South Africa, at 30°58′S and 21°58′E at an altitude of about 1300 m above sea level. This area is considered representative of the north-western Karoo which has been used for mainly sheep farming for more than a century (Meyer, 1992). Mean annual temperature is 15.2 °C (Mucina et al., 2006) and mean annual rainfall 215 mm, with rain falling mostly in autumn (March) in the form of thunderstorms. Inter-annual variation is high (CV 39.4%). The period from 1931 to 1971 was drier (average 195.8 mm p/a) than after 1972 (average 245.0 mm p/a), with a trend of an increasing concentration of rainfall during the summer months. There was evidence of a cycle with an approximate 22-year period (Du Toit et al., 2015).

The trial is located in the Western Upper Karoo (NKu1) vegetation type (Mucina et al., 2006). Vegetation is dominated by the shrub species *Lycium cinereum* and the dwarf shrub species *Chrysocoma ciliata, Eriocephalus ericoides, E. spinescens, Helichrysum luciloides, Osteospermum spinescens, Pentzia spinescens, Pteronia glomerata, Tetragonia arbuscula* and *Ruschia intricata* (Mucina et al., 2006). Grasses common to this vegetation type are *Aristida congesta, Enneapogon desvauxii, Stipagrostis ciliata* and *S. obtusa* (Mucina et al., 2006) but grasses are relatively sparse at the trial site.

The topography of the 324 ha trial area is gentle varying between 1300 and 1320 m above sea level. Most of the experimental station is situated on a shallow soil variant (depth ± 120 mm) of the Mispah soil form, Myhill 1100 family (Meyer, 1992). The Orthic A-horizon has an average clay content of 10–12% and shows a high rate of water absorption. These stable soils have a low erosion potential. Locals consider these soils to be poorly productive (Meyer, 1992). Two small ephemeral water courses, occupying less than 2% of the trial site, traverse the experimental site. These soils belong to the Valsrivier soil form (Helvetia 1221 family) and are slightly deeper with an effective soil depth of 300 mm (Meyer, 1992).

3. Methods

3.1. Grazing trial

The Carnarvon Experimental Station was purchased in 1962 and since 1963 has been managed at moderate stocking rates based on the concept of maximum profit in the short-term while still maintaining rangeland condition in the long-term (Van den Berg and Du Toit, 2014). Four stocking rate treatments (expressed in terms of hectares per small stock unit (SSU)) were investigated at the trial site. Stocking rate treatments, established in 1988, were 4 ha/SSU (Very Heavy), 5.5 ha/SSU (Heavy), 7 ha/SSU (Moderate) and 8 ha/SSU (Light), (Van den Berg and Du Toit, 2014). In order to aid understanding in this paper, stocking rate treatments are henceforth expressed in an unconventional means as stocking rate per 100 ha i.e. 25 SSU/100ha (Very Heavy), 18 SSU/100ha (Heavy), 14 SSU/100ha (Moderate) and 12.5 SSU/100ha (Light). Paddock sizes were varied in order to obtain the desired