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Effect of grazing on vegetation and soil of the *heuweltjieveld* in the Succulent Karoo, South Africa

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ABSTRACT

We asked how historical and recent grazing intensity affect the patchy landscape of the heuweltjieveld in the semi-arid biodiversity hotspot Succulent Karoo. The study was carried out on a communal farmland 80 km south-west of Springbok, in Namaqualand. Heuweltjies are roughly circular earth mounds that are regularly distributed in this landscape. We sampled plant species and life-form composition, diversity measures, habitat and soil variables in 100 m^2 plots, placed in three visually distinguishable heuweltjie zones (centre, fringe, and matrix) and distributed across grazing camps with different recent and historic grazing intensities. Differences between heuweltjie zones were assessed with ANOVAs and multiple linear regressions. The effect of past and recent grazing intensity on soil and plant variables was analysed by Generalized Linear Models for each heuweltjie zone separately. The three zones constituted clearly distinguishable units in terms of vegetation and soil characteristics. Soil pH and cover of annual plants increased from matrix to centres, while total vegetation cover, species richness and perennial plant cover decreased in the same direction. Historic (pre-2000) grazing patterns had the strongest effects on fringes, showing the strongest soil and vegetation-related signs of overutilization with increased stocking density. Centres showed signs of overutilization irrespective of the stocking density. The much shorter exposure to recent grazing pattern (post-2000), which was nearly inverse to the historic grazing pattern, showed increase of vegetation cover (centres) and species richness (matrix) with recent grazing intensity. We interpret these effects as still visible responses of the lower grazing intensity in these camps during the historic period. No recovery under recent grazing was observed at any of the zones. We conclude that irrespective of their conducive growing conditions, once transformed to a disturbed state, heuweltjie centres recover slowly, whereas the less impacted soil and vegetation of fringes are more responsive than centres and matrix.

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1. Introduction

Rangeland farming, i.e. the farming with livestock on natural vegetation, is the dominating land-use type in drylands. Climatic variability, low productivity of the soils and limiting socio-economic conditions in the farming communities make these lands prone to overgrazing, which can lead to hardly reversible degradation. Even though the relative role of the potential drivers for these changes is controversial (Dean et al., 1995; Kiage, 2013), the threat to drylands worldwide for degradation or "desertification" is undisputed (Reynolds et al., 2007). This threat calls for

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monitoring systems of rangeland states and reliable early-warning indicators for overutilization (Reynolds et al., 2011; Winslow et al., 2011). A broad range of soil- and plant-related indicators for rangeland conditions have been suggested such as invertebrates (Hoffmann, 2010; Prieto-Benitez and Mendez, 2011), plant species or functional traits (Diaz et al., 2007; McIntyre and Lavorel, 2001; Wesuls et al., 2013), as well as soil chemical features (Gröngröft et al., 2010; Manley et al., 1995; Smet and Ward, 2006), that show characteristic responses to grazing. However, rangelands are spatially heterogeneous and variable over time with varying responses to grazing (Illius and O'Connor, 1999; Vetter, 2005). Habitat types that are particularly attractive to herbivores can thus provide early information about consequences of disturbances (Stokes et al., 2009).

Heuweltjies in the southern African winter rainfall region (Lovegrove and Siegfried, 1986; Picker et al., 2007) have been shown to be attractive to herbivores (Esler and Cowling, 1995; Knight et al., 1989; Kunz et al., 2012; Midgley and Musil, 1990). Heuweltjies are earth mounds of 3–5 m in height and up to 30 m in diameter (Lovegrove and Siegfried, 1986). They occupy up to 25% of the land surface of the south-western part of southern Africa (Picker et al., 2007). Age and origin of heuweltjies remain a matter of contention (Cramer and Midgley, 2015; Picker et al., 2007), though most authors assume that they are fossil termitaria of the species *Microhodotermes viator* (Petersen, 2008; Picker et al., 2007) and dating back to 20,000 years of age (Midgley et al., 2012). They are recently sustained by rodent burrowing activity.

Like the mima mounds in Argentina (Roig et al., 1988), termite mounds in East African Savannas (Okullo and Moe, 2012) and fairy circles of Africa's summer rainfall region (Jürgens, 2013), heuweltjies contribute heterogeneity to the landscape, are persistent over time, and influence distribution of biomass and diversity. Due to their special habitat conditions, heuweltjies in the Succulent Karoo support distinct vegetation units (Luther-Mosebach et al., 2012), with soil properties following concentric patterns (Petersen, 2008). Their particular species composition is commonly explained by characteristic edaphic features of the heuweltjies, such as element composition, enrichment in organic compounds, pH value, and physical properties (Esler and Cowling, 1995; Midgley and Musil, 1990). In particular, heuweltjie centres are characterised by better water availability (Midgley and Musil, 1990; Turner, 2003), significantly lower stone content (Kunz et al., 2012) and higher silt content (Midgley and Musil, 1990). Heuweltjie vegetation is either denser and higher or sparser than the surrounding vegetation, depending on the climatic conditions and disturbance regime (Turner, 2003). Compared to the surrounding matrix, heuweltjie vegetation contains more deciduous and opportunistic species, which has been ascribed to the better mineral, nutrient, and water supply (Esler and Cowling, 1995; Midgley and Musil, 1990; Rahlao et al., 2008). The latter characteristics may be responsible for the observed attractiveness of the vegetation to herbivores (Milton and Dean, 1990) due to which Stokes et al. (2009) tested heuweltjies in the southern Succulent Karoo vegetation as “indicator patches” for overutilization in camps, that were each subjected to a different grazing intensity, from low to high, for the last 50 years.

Following the same understanding of heuweltjies as azonal habitat types that are subject to grazing and disturbance, we studied rangeland camps that have been subject to different grazing intensity over several decades until 1999. In the year 2000, the tenure changed and brought along changes in land-use patterns, resulting in resting of some of the formerly overutilized camps and more intense use of some of the formerly moderately used camps. We therefore also tested for the effect of this recent grazing intensity. For this study, we distinguished between three heuweltjie zones, i.e. centre, fringe and the surrounding matrix, and compiled information on soil and vegetation variables for each of the heuweltjie zones.

The following key questions were considered:

- Which biotic (vegetation structure, plant diversity) and abiotic environmental parameters (soil chemistry) characterise the three different heuweltjie zones (i.e. heuweltjie centres, fringes and the surrounding matrix vegetation) in the study area?
- How do vegetation and soil of the three heuweltjie zones respond to different levels of long-term historic and short-term recent grazing and which parameter is the most sensitive indicator of grazing intensity?

2. Materials and methods

2.1. Study area

The study was conducted on the communal farm land of the Soebatsfontein community (Fig. 1; between 30°5′58.02″ S, 17°34′12.20″ E and 30°15′13.09″ S, 17°33′15.93″ E), in the Namaqualand lowland, Northern Cape Province of South Africa. For further information on the study area, see description of Observatory S22 Soebatsfontein in Haarmeyer et al. (2010). The climate is subtropical semi-arid with an average of 130 mm annual precipitation, falling mainly in winter from May to September, and additionally as fog. The mean annual temperature is 19.4 °C, but temperatures fall below 10 °C in winter, while frost hardly occurs (Haarmeyer et al., 2010; Mucina et al., 2006). The area is of slightly undulating topography and ranges from about 200 to 392 m above sea level. Geologically, the area is lined by igneous rocks such as gneisses and granites under red and yellow colluvial soils. Dominating soil groups are Leptosols, Durisols, and Cambisols (Haarmeyer et al., 2010).

The major vegetation type forms part of the Namaqualand Heuweltjieveld within the Namaqualand Hardeveld Bioregion, which is part of the Succulent Karoo Biome (Mucina et al., 2006) and has been recognized as a biodiversity hotspot (Myers et al., 2000). Approximately 25% of the flora is endemic to Namaqualand (Desmet, 2007). The vascular flora of the Succulent Karoo with approximately 6300 species on 100,251 km^2 is extraordinarily species-rich, particularly for a semi-arid to arid region. It is predominantly composed of leaf-succulent dwarf shrubs (mainly Aizoaceae), geophytes, and few grasses (Haarmeyer et al., 2010; Luther-Mosebach et al., 2012; Milton et al., 1997).

Until the year 1999, the study area was owned and managed commercially for small livestock production (mainly sheep). Due to the land reforms of the post-Apartheid government of South Africa, approximately 15,000 ha of the farmland were handed over to the local municipality to be used as communal farmland by the adjacent community. It is since managed by a Commonage Committee and the local municipality. The farmland is subdivided into 16 camps of 200–1400 ha in size, which are used by small groups of farmers for livestock farming (sheep and goats).

2.2. Grazing intensity data

The historic (from 1986 until 1999) grazing intensities per camp were calculated based on all known stock movements (the number of sheep multiplied by the number of days they stayed in the camp) over the period of one year (sheep grazing days per year: SGD). An assumed carrying capacity of 9 ha/small-stock units (SSU, i.e. sheep or goats) was used by the former farm manager (Floors Brand, pers. comm.) to calculate “potential sheep grazing days” [SGD_{pot} =

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