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Spatial variations in plant nutrient concentrations in tissue of a grass species as influenced by grazing intensity in a confined savannah rangeland

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ABSTRACT

Grazing can influence spatial variations in grass tissue concentrations of plant nutrients by promoting nutrient recycling through grazer dung. This study demonstrates the acuteness of the spatial variations, in a confined semiarid savannah rangeland where grazer migration has been curtailed. *Eragrostis lehmanniana*, a commonly grazed grass species, was selected for the study due to its abundance. Grass tissue and soil samples were collected at widely distributed sampling sites. The sample concentrations of macronutrients (N, P, K, Ca, Mg) and the micronutrients Fe, Zn, Mn, Cu, Ni, B, Mo were determined in the laboratory. Geostatistical analysis, spatial interpolation, factor analysis and Normalised Difference Vegetation Index values from a satellite image enabled assessment of spatial patterns in relation to grazing intensity. A grazing intensity induced zone of high nutrient concentrations in *E. lehmanniana* tissue was evident, in the vicinity of artificial water holes. Wide zones (1–2.8 km) of spatial autocorrelation in the grass tissue concentrations of all nutrients suggested grazing-induced homogeneity. Since heterogeneity is the more desirable ecosystem attribute on savannah rangelands, proactive rangeland management to promote heterogeneity is recommended. Artificial water holes need to be rotated and be more than 2.6 kilometres apart on the rangeland landscape.

1. Introduction

Savannahs support the largest diversity of ungulate species (Du Toit and Cumming, 1999). The ungulate diversity is threatened by fragmentation of savannah rangelands due to agriculture and urbanization. Due to the fragmentation many savannah rangelands that are still in intact or near intact state are isolated and often fenced as game or livestock ranches, game reserves or national parks. The fencing can protect the savannah rangelands from further degradation and is, therefore, a useful conservation measure. However, confinement results in added pressures on rangelands to sustain the grazer populations (Augustine and McNaughton, 2006), since migration has been curtailed. In such confined savannah rangelands quantifying the spatial variations in plant nutrient concentrations in grass as influenced by grazing intensity is potentially useful both for rangeland management and ecological theory (McNaughton et al., 1997).

The grasses on savannah rangelands, like all plants, require a number of nutrient elements. The macronutrients (N, P, K, Ca, Mg) are required by plants in relatively large quantities (> 0.1% of dry mass; Maathuis, 2009), and the micronutrients (Fe, Zn, Mn, Cu, Ni, B, Mo, Cl) in smaller quantities (Welch and Shuman, 1995). These nutrient elements are essential to the grazers as components of tissue structure (Coleman, 1992; Augustine et al., 2003). The grazers obtain the nutrients through ingesting the grass. The nutrient content of the grass on the savannahs has implications on ungulate diversity (Codron et al., 2007), due to this relationship. The nutrient content has been shown to influence the selection of grazing areas by ungulate species on the savannahs, in addition to the greenness and palatability of the grass (Ben-Shahar and Coe, 1992; Seagle and McNaughton, 1992; Anderson et al., 2010; Treydte et al., 2013). In turn, high concentration of the grazers promotes the recycling of plant nutrients (McNaughton et al., 1997), through deposition of dung and urine on soil (van der Waal et al., 2011) and thence to the grass. Thus, there is potentially a relationship between grazing intensity and nutrient concentrations in grass tissue on savannah rangelands.

Grazing intensity is defined as the cumulative effects grazing animals have on rangelands during a particular time period (Holechek et al., 1998). It can, ideally, be measured quantitatively in terms of percent of forage utilised in the time period, but the drawback with this quantitative indicator of grazing intensity is the difficulty to measure it (Holechek and Galt, 2000). Therefore, determining the effects of grazing intensity cumulatively in the field can be quite problematic without a long-term study. Given this difficulty qualitative characterisation of grazing intensity is an alternative, for example based on the

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grazer visitation frequency on a particular section of rangeland using visible indicators like trails and dung (Holechek and Galt, 2000; Hendricks et al., 2005).

Soils in high grazing intensity savannah rangelands have been shown to have high concentrations of plant available (extractable) P, K, Ca and Mg, as well as inorganic N (Berliner and Kioko, 1999; van der Waal et al., 2011) due to the promotion of plant nutrient recycling by the grazers. The grass in high grazing intensity sites may also have high concentrations of Si as anti-herbivore defence (McNaughton and Tarrants, 1983).

This study aimed at determining spatial variations in the concentrations of plant nutrients in grass as influenced by grazing intensity in a confined savannah rangeland. On the basis of previous studies in the literature the hypothesis was that grass in high grazing intensity sites had higher concentrations of plant nutrients. Although there has been similar previous research, much of the work was in larger savannah rangelands where the grazing pressure was ameliorated by migration. In this work a smaller savannah rangeland is studied, in which the grazers do not migrate due to fencing. The implications of the results for grazing management on savannah rangelands are pointed out.

2. Material and methods

2.1. Study area

The study area was the 4800 ha Mafikeng Game Reserve in north western South Africa (Fig. 1a). The reserve is located on the outskirts of Mafikeng, the provincial capital of South Africa's North West Province. It is an isolated piece of savannah wilderness bordered by highways: with urban land to the west and south and farmland to the north and east (Fig. 1b). The game reserve was established in 1992 as an amalgamation of farmland.

The landscape on which the game reserve is located is generally flat, sloping gently westward (Fig. 1b). There is a uniform type of soil in the whole reserve, classified as petric calcisol in the FAO system. Petric calcisols are generally rich in Ca^{2+}. Long-term records show that on average the total annual rainfall in the Mafikeng area is 500–600 mm, most of which is received in a distinct rain season commencing in October and ending in April the following year.

Located in a transition zone between savannah and grassland, Mafikeng Game Reserve has very scattered woody cover interspersed with grass. The woody vegetation predominantly consists of short (< 10 m) trees and shrubs. Field measurements of woody canopy cover in 2016 established that most of Mafikeng Game Reserve has less than 20% woody cover, notable tree cover (20–40%) being restricted to river fringes. The vegetation is in the Mafikeng bushveld class (Mucina and Rutherford, 2006), which is characterised by woody shrubs and a well-developed grass layer. The woody species include *Acacia karroo*, *A. hebeclada*, *A. mellifera*, *Dichrostachys cinerea*, *Grewia flava*, *G. retinervis*, *Rhus tenuinervis* and *Ziziphus mucronata*. The prominent graminoid (grass) genera in the Mafikeng bushveld class are *Aristida* (species: *A. congesta*, *A. meridionalis*, *A. mollissima* subsp. *argentea*, *A. stipitata* subsp. *stipitata*), *Eragrostis* (species: *E. lehmanniana*, *E. pallens*, *E. superba*, *E. trichophora*), *Digitaria* (species: *D. eriantha* subsp. *eriantha*, *D. argyrograpta*), and *Brachiaria* (species: *B. nigropedata, B. serrata*). Other grass species include *Anthephora pubescens*, *Cymbopogon pospischilii* and *Urochloa panicoides*. Studies of savannah ungulate diets (e.g. Grunow, 1980; Ben-Shahar and Coe, 1992; Treydte et al., 2013) have shown that these grass species are consumed by ungulates and, therefore, that they are palatable. *Aristida congesta* and *Cymbopogon pospischilii* are unpalatable (Snyman, 2015).

The majority of the ungulate species in Mafikeng Game Reserve are grazers. On the basis of the vegetation consumption capacity attributes of large stock unit (LSU), grazing unit (GU) and browser units (BU) (defined as in Dekker, 1997) some of the ungulate species are large-bodied, with capacity to consume large amounts of vegetation (Table 1). A fence on the perimeter of the game reserve keeps the animals within the confines of the reserve. An additional internal fence (Fig. 1b) keeps the animals out of the western section that is closest to the town's central business district (CBD). The additional fence reduces the available habitat to about 3910 ha (39.1 km^2), resulting in a grazer

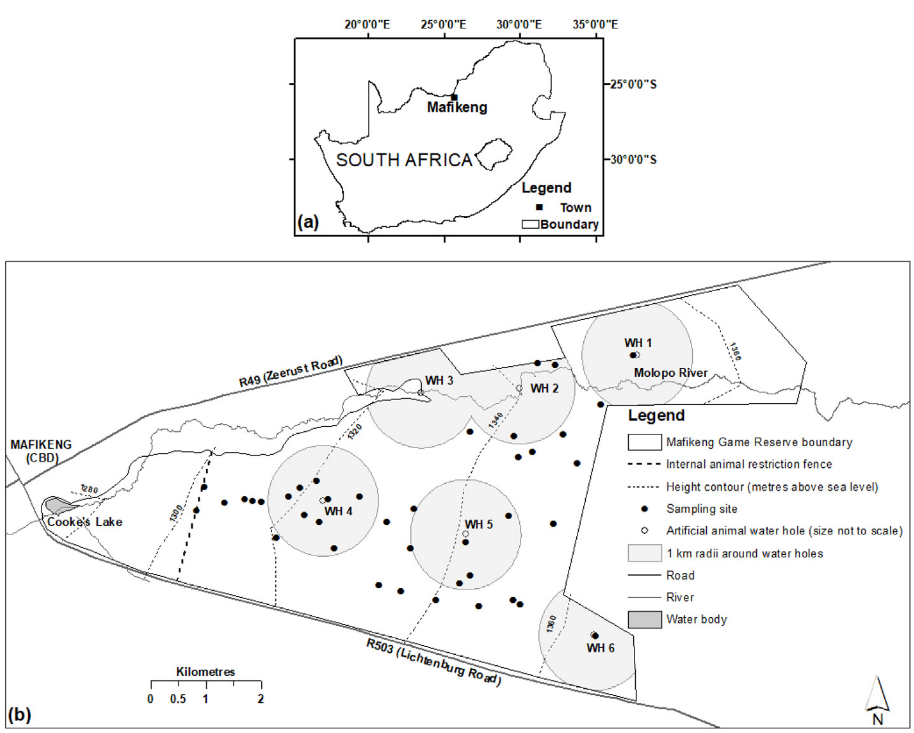

Fig. 1. Location of the study area in South Africa (a), and (b) location context detail of the study area and sampling sites. Sampling sites within a 1 km radius of a water hole were considered to be under high grazing intensity, and those near the boundary as under low grazing intensity.