Influence of Grazing Intensity on Nutrient Concentrations in Grass Tissue: Evidence from Two Savannah Grass Species

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Abstract
High grazing intensity can accelerate the recycling of animal nutrients on savannah rangelands through the deposition of dung and, subsequently, nutrient mineralisation, uptake and concentration in grass tissue. The actual magnitude of this influence can vary depending on the grazing system. This study derived grazing system-dependent magnitudes of the influence of grazing intensity on concentrations of major (N, P, K, Ca, Mg, Na) and trace (B, Co, Cu, Cr, Fe, Mn, Mo, Ni, Se, Zn) animal nutrients in above ground grass tissue. Two grass species were examined: *Brachiaria nigropedata*, a decreaser, and *Eragrostis lehmanniana*, an increaser. For the species, leaf, stem and flower samples were collected in close proximity from respective sampling points in wildlife and livestock grazing sites, and a no-grazing control site. Sampling was conducted at the end of the rainy season in the semi-arid savannah rangelands of north-western South Africa. The concentrations of the nutrients were determined in the laboratory using standard methods. *B. nigropedata* had higher nutrient concentrations than *E. lehmanniana*. Samples from high grazing intensity sites had higher nutrient concentrations than the control site, an effect more pronounced in *B. nigropedata*. Such sites also had low grass cover, a characteristic of grazing lawns. They included the open access communal rangelands and the vicinity of artificial water holes. The two species manifested inter-site covariance in nutrient concentrations, indicating that sites under high grazing intensity generally had high nutrient concentrations in grass tissue, and vice versa. The short, nutrient-rich grass in grazing lawns is attractive to grazers, which can widen the lawns by perpetuating high grazing intensity and low grass biomass. However, not all grazers are adapted to grazing short lawn grass, which can have implications on grazer diversity. The study concludes that grazing-induced increase in nutrient concentrations in grass tissue manifests more in inherently high-nutrient species.

Introduction
Savannah rangelands support a high diversity of both domestic and wild grazers (Baumgartner et al. 2015; Sitters et al. 2009). This diversity of grazers exerts pressure on the grass to provide sufficient nutrients. For purposes of providing data that can inform grazing management interventions, it is important to study the relationship between grazing intensity and the concentration of the animal nutrients in grass tissue.

Grazers require a number of major and trace elements, as components of tissue structure and for various physiological functions (Robbins 1992). The major nutrients are required in large quantities. They are (Robbins 1992): nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), chlorine (Cl), sodium (Na) and Sulphur (S). Trace elements are required by animals in smaller amounts, and they include (Suttle 2010): boron (B), chromium (Cr), cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn).

The grazers on savannah rangelands promote recycling of the nutrients (McNaughton et al. 1997), through deposition of dung and urine on the soil (van der Waal et al. 2011). Although for some nutrients there is some uncertainty as to whether or not there subsequently are high rates of mineralisation (Schrama et al. 2013), the decomposition process then releases the nutrients from the dung and urine, to be taken up by the grass (Rumpel et al. 2015). Thus, high grazing intensity can result in high concentrations of the nutrients in grass tissue. High grazing intensity can also affect the physical attributes of the grass. It can keep the grass in a young, highly nutritious phenological stage (Moe and Wegge 2008). As an indicator of high grazing intensity, grass biomass is low and forb biomass high (Craine et al. 2009). High grazing pressure can, thus, result in grazing lawns. Coetsee et al. (2011) define a grazing lawn as an expanse of short grasses in an immature state, with higher leaf to stem ratios and higher bulk density than that of an expanse of tall or bunch grasses.

Although there is general recognition of the potential effects of grazing intensity on nutrient concentrations in grass tissue, the effects may vary depending on the grazing system and grass species. This study aimed at evaluating the influence of the grazing system and grass species on the concentration of animal nutrients in grass tissue in relation to grazing intensity.

Methods and Study Site

The study was conducted in savannah rangelands near the towns of Mafikeng and Zeerust (Figure 1a), in the North West province of South Africa. The area is semi-arid, receiving 500 mm – 600 mm of rainfall annually. Most of the rain is received in the rainy season between October/November in one year and March/April in the next.

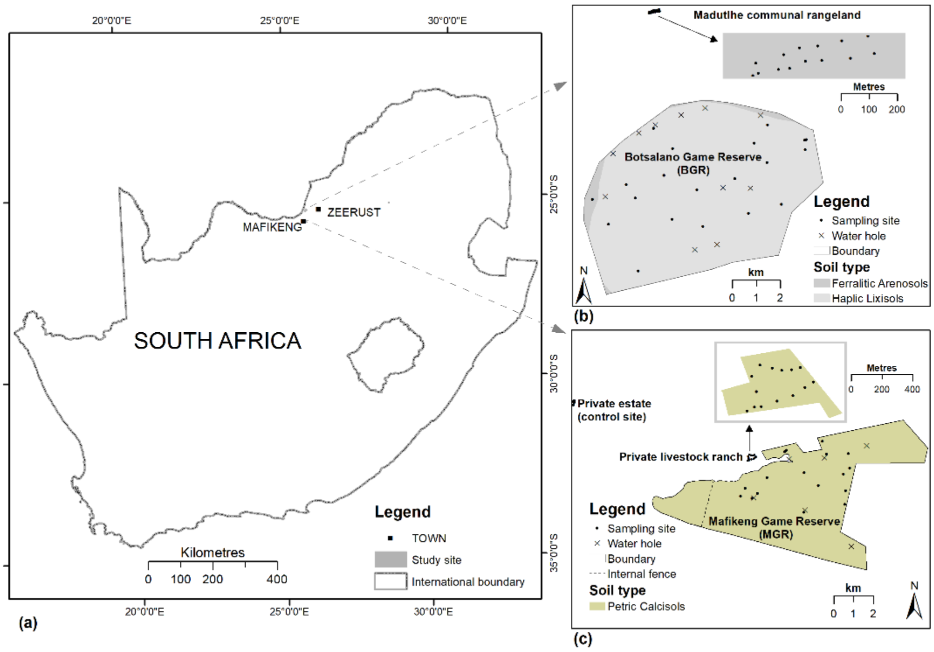


Figure 1. Location of the study sites in South Africa (a), and (b, c) soil types and distribution of sampling in the sites. Soils data: Agricultural Research Council, Pretoria, South Africa.

It was important to examine the effects of both domestic and wild grazers on nutrient concentrations in grasses. Therefore, wildlife grazing areas that were adjacent to livestock grazing areas were sought. Livestock grazing in the study area occurs both as open access communal grazing and restricted grazing (private) ranches, which needed to be represented in the study. Since these required grazing systems did not occur in close proximity in one location, rangelands in and adjacent to two wildlife grazing areas were used: Botsalano Game Reserve (BGR) and the nearby Madutlhe communal rangeland (Figure 1b), and Mafikeng Game Reserve (MGR) with a neighbouring livestock ranch (Figure 1c). A private estate near MGR on which there was no grazing was included as a control study site.

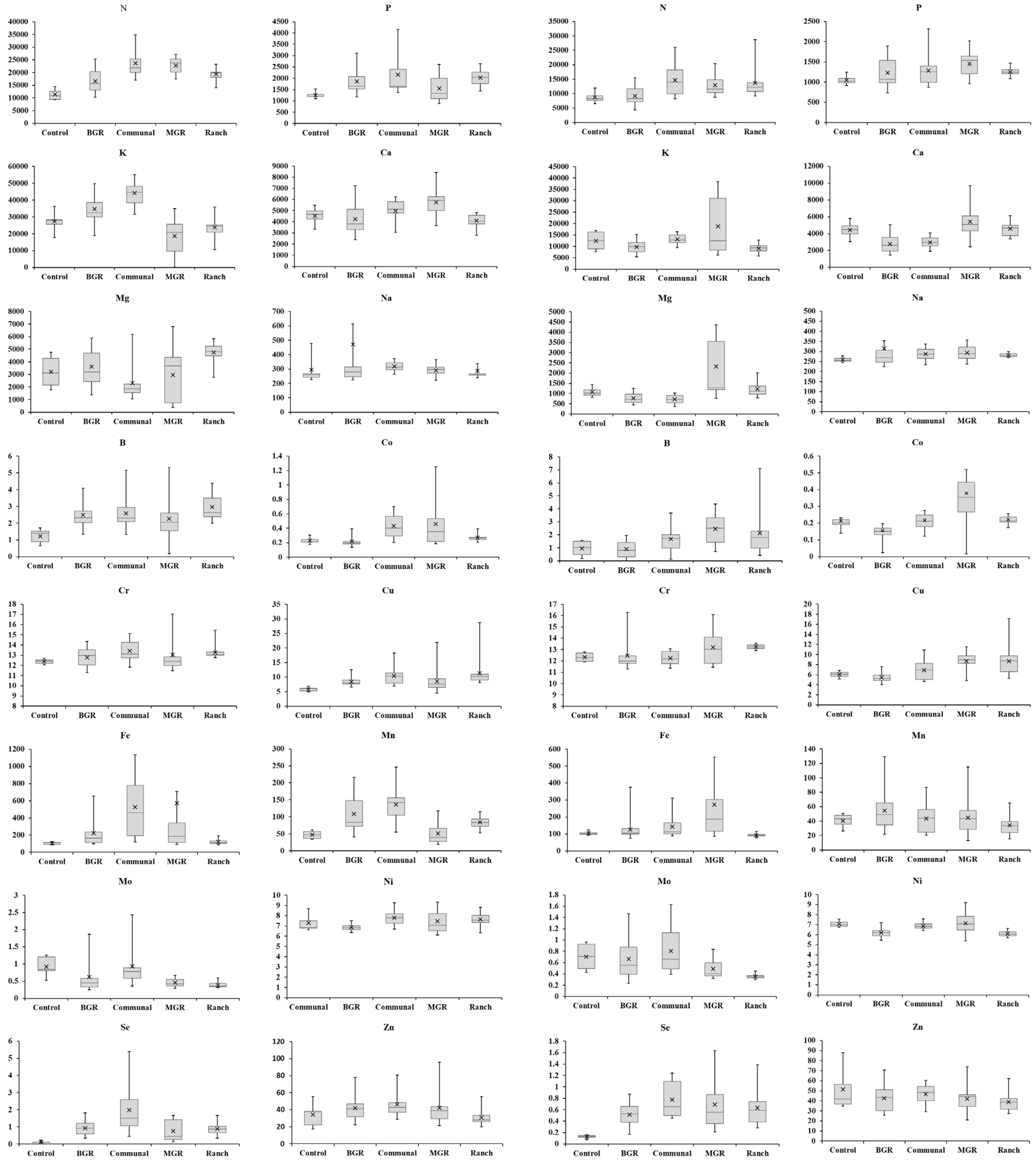
Two grass species which were common in all study sites were selected for sampling: *Brachiaria nigropedata* and *Eragrostis lehmanniana*. Both livestock and wildlife grazers consume the two grasses (Grunow 1980). They were selected to represent grass species of high and low nutrition value, respectively. *B. nigropedata* is a climax, decreaser species of high nutrition value. *E. lehmanniana* is a sub-climax increaser of average nutrition value (Smet and Ward 2005). *B. nigropedata* is among the most important grass species in antelope diet throughout the year, while *Eragrostis* spp. are important antelope diet grass in the dry season (Owen-Smith et al. 2013). Sampling was conducted in April 2018, at the end of the rainy season when the grass was fully grown. During sampling, specimens of the two grass species which were in close proximity (within 50 m) were sought. In the livestock grazing sites, the sampling was conducted in linear transects, at intervals of approximately 100 m. Since the two game reserves were too large for interval sampling in transects, the sampling strategy there was to distribute the sampling points widely across the landscape. The number of sampling points (n) in the study sites were: BGR, $n = 20$; MGR, $n = 17$; control site, $n = 5$; livestock ranch, $n = 14$; communal rangeland, $n = 14$. Leaves, stems and flowers (i.e. above ground tissue) are largely the grass tissue that is consumed by grazers. Therefore, at each sampling site leaf, stem and flower material was clipped from each grass specimen. Grass cover was visually estimated in 90 cm quadrats at each site. The grass tissue samples were then sent to the laboratory, where the concentrations of the animal nutrients were determined.

In the laboratory the tissue samples were air-dried for a week, then ground and microwave acid-digested using the EPA Method 3051A (USEPA 2007). The concentrations (in mg/kg dry matter) of the major (except N, Cl, S) and trace (except I) animal nutrients were then obtained using an Agilent Inductively Coupled Plasma Mass Spectrometer (ICP MS). N concentrations were determined by thermal conductivity using a TruSpec® CN Micro, in units of weight percentage (%) which were then converted to mg/kg.

Results

Comparative Nutrient Concentrations

Nutrient concentrations were higher in the high nutrition value *B. nigropedata* than in *E. lehmanniana*. The concentrations of the nutrients in above ground grass tissue tended to be highest in the open access and high grazing intensity communal rangeland, and lowest in the no grazing control site for most nutrients (Figure 2). This manifestation was more pronounced in *B. nigropedata*, and was evident in the two potentially productivity-limiting nutrients in savannah grass, N and P. Between the two species there was covariance in the concentrations of the nutrients since respective nutrients tended to manifest matching patterns of increase and decrease, respectively, between the study sites (Figure 2).



(a) *Brachiaria nigropedata* (b) *Eragrostis lehmanniana*

Figure 2. Box and whisker diagrams showing concentrations (in mg/kg, Y axes) of the major and trace animal nutrients in above ground tissue samples of the two grass species from the study sites in Figure 1 (X axes). Where × = mean.

Abundance of Grass in Relation to Grazing Intensity

Grass cover was low in highly grazed sites, such as the open access communal rangeland and the vicinity of artificial water supply points (water holes) in the game reserves. In the high grazing intensity sites the grass was relatively short, a characteristic of grazing lawns. Being a decreaser, *B. nigropedata* was relatively infrequent in such sites. Nutrient levels in grass samples from the grazing lawns were much higher than in tall grass dominated sampling sites.

Discussion and Conclusions

Enhanced recycling of nutrients by grazers through deposition of dung and urine explains the high nutrient levels in the grass tissue of high grazing intensity sites. The effect was evident in both wildlife and livestock grazing sites (Figure 2). Although the results confirmed the expectation on the basis of previous studies (McNaughton et al. 1997; van der Waal et al. 2011), this study shows that the magnitude of the grazing intensity-induced increase in nutrient levels can vary among grass species. For the two grasses studied the changes in concentrations of N, the main constituent of protein, can illustrate this species-dependent effect. The mean concentration of N in *B. nigropedata* samples from the high grazing intensity communal rangeland was 2.1 times higher than in the control site, but only 1.7 times higher in *E. lehmanniana*. Low grass biomass as an indicator of high grazing pressure (Craine et al. 2009) was confirmed in this study by the low grass cover in the grazing lawns. Despite the low grass biomass, grazing lawns are attractive to grazers due to the high nutrient levels in the grass, which could widen their sizes. Large grazing lawns would have implications on grazer diversity of savannah rangelands since some grazers are not adapted to grazing short grass. Grazing rotation is recommended to reduce the potential impacts on grazer nutrition and diversity. The main conclusion from this study is that grass species which inherently accumulate high amounts of animal nutrients in their tissue manifest grazing-induced variations in tissue nutrient levels more than low nutrition grasses.

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