Utilizing Perennial Grass Species' Population Patterns to Detect Looming Desertification Tipping Points in Semi-Arid Regions

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Utilizing perennial grass species' population patterns to detect looming desertification tipping points in semi-arid regions

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Key words: Perennial grass; desertification; grazing; management type

Abstract

Namibia is one of the global dryland regions facing desertification threats due to overgrazing and recurrent drought. This has disastrous effects on forage provision and consequently on local livelihoods. Unfortunately, the mechanisms underlying sudden shifts of rangeland ecosystems towards a desertified state are still poorly understood. The ability to predict desertification tipping points with the aid of suitable ecological indicators is critical to ensure sustainable management of rangeland resources, which are a backbone of rural livelihood in drylands worldwide. Accordingly, we aimed to identify key perennial grass species that can be used as early-warning indicators for desertification tipping points; and to assess their dynamics and response to grazing pressure. The study was conducted in the eastern region (Otjozondjupa) of Namibia where 4 communal areas and 4 freehold farms (commercial) were selected in order to compare perennial grass population responses within differently management land-use systems. A space-for-time approach was used for this purpose, where plots were laid out along local grazing gradients. Data on species occurrence, size structure and recruitment were collected. Preliminary findings show that a sudden decrease or disappearance of some sensitive native perennial grass species along grazing gradients and lack of seedling recruitment could be a useful hint to an approaching desertification tipping point.

Introduction

Ecosystem shifts from one stable state to another can occur in response to various environmental drivers (Eslami-Andergoli *et al.* 2015). Such system shifts may have dramatic effects on biodiversity and on ecosystem service supply. While it is well-known that natural or human-induced factors may change an ecosystem from a healthy to a degraded state, the mechanisms underlying these sudden shifts towards a degraded state are still poorly understood. Hence, a better understanding of ecological processes in temporal vicinity to an ecological tipping point is urgently needed (Eslami-Andergoli *et al.* 2015). A prominent example of tipping point behaviour in terrestrial ecosystems is the sudden shift of dryland rangelands from a healthy state – where the grass layer is dominated by perennial grasses – to a desertified, non-vegetated state. Namibia is one of the dryland regions where ecosystems primarily support livestock rearing (Adeel *et al.* 2005). According to Mendelsohn and Obeid (2002), the communal areas are generally over-utilized and show serious problems of overgrazing. While these desertified areas are often dominated by annual grasses, particularly close to waterpoints (Strohbach 2014), commercial farms are often in a more healthy state, with the grass layer dominated by perennial grasses. Here, the crossing of a so-called 'desertification tipping point' (DTP) is thought to be triggered by combined effects of overgrazing and recurrent drought, with catastrophic consequences for rangeland productivity and local livelihoods.

The ability to predict DTPs with the aid of suitable ecological indicators is critical to ensure sustainable management of rangeland resources, which are a backbone of rural livelihood in drylands worldwide. One of the early-warning indicators of desertification that has been proposed is the use of spatial vegetation patterns (Lin *et al.* 2010). O'Connor (1994) proposed the use of changes in population structure and dynamics in perennial grass species, as these may be precursors of ecosystem shifts due to their fundamental role in ecosystem processes such as preventing soil erosion (Sala and Paruelo 1997). Therefore, this paper seeks to identify key perennial grass species that can be used as indicator species; and to assess their dynamics and response to grazing pressure. It specifically focuses on the size structure, densities and recruitment patterns within a semi-arid ecosystem situated in Namibia.

Material and Methods

Study area

The study was conducted in the Greater Waterberg Landscape. This semi-arid region has an average annual rainfall ranging from about 325 mm to 350 mm, with rainfall displaying pronounced intra-annual and inter-annual variation (Strohbach 2014).The region regularly experiences prolonged drought periods, causing significant losses of livestock to local farmers (Shikangalah 2020).The study area is characterized by a mixture of different land management types, including communal areas and commercial farms.

Species selection

Four perennial grass species were selected during a reconnaissance survey in October 2019 as the commonly occurring species in the study area. These are *Stipagrostis uniplumis* (Licht. ex Roem. &Schult) and *Eragrostis rigidior* (Pilg.), two palatable grasses in dryland regions, and *Aristida congesta* (Roem. & Schult) and *Aristida stipitata* (Hack.) which have generally poor forage value (Muller 2007).

Research design

Using a space-for-time substitution, a total of eight study sites was selected distributed over four communal areas (Ohamuheke-TK, Ombooronde- TM, Ovitatu-TV, Ozongarangombe-TZ) and four commercial farms (Hamakari-TH, Hassenpflug-TP, LaPaloma-TL, Ouparakane-TR). At each site, two transects (T) were randomly demarcated along local grazing gradients leading away from a water point. In total, 16 transects were set up. Along each transect, nine permanently marked plots (10m x 10m) were set up, with a higher plot density near the water points. Each plot was subdivided into four quadratic subplots.

Sampling

Data were collected at the end of the growing season (May) 2020 when perennial grass species had reached their peak growth stage and prior to the subsequent wet season October (2020). As the Covid-19 pandemic restricted the duration of the growing season field trip, only density and recruitment studies could be completed in five out of the nine plots per transect whilst population health data could be collected at the end of the dry season (October). A minimum of 25 individual tufts per plot and species was recorded either on the whole plot area or on subplots, obtaining measurements of their basal area. Seedling abundances were recorded within four 1m x 1m quadrats nested within plots.

Data analysis

For each species, we calculated the cumulative basal area on a plot to capture population health. Cumulative basal area is influenced both by the number of individuals on a plot, and by their size (individual basal area). Population densities were derived from plant counts on a known number of subplots per plot.We used ANOVA to test for differences in cumulative basal areas.

Results

Population health

We found distance from water points in both management types to have no significant influence on the average cumulative basal area of *S. uniplumis* ($F(4, 42) = 2.31$, $p = 0.060$) and *A. stipitata* ($F(4, 10) = 0.55$, $p = 0.707$); see Figure 1. *Stipagrostis uniplumis* was found to generally be in a better state (with more and/or larger individuals) compared to *A. stipitata* (Fig. 1).

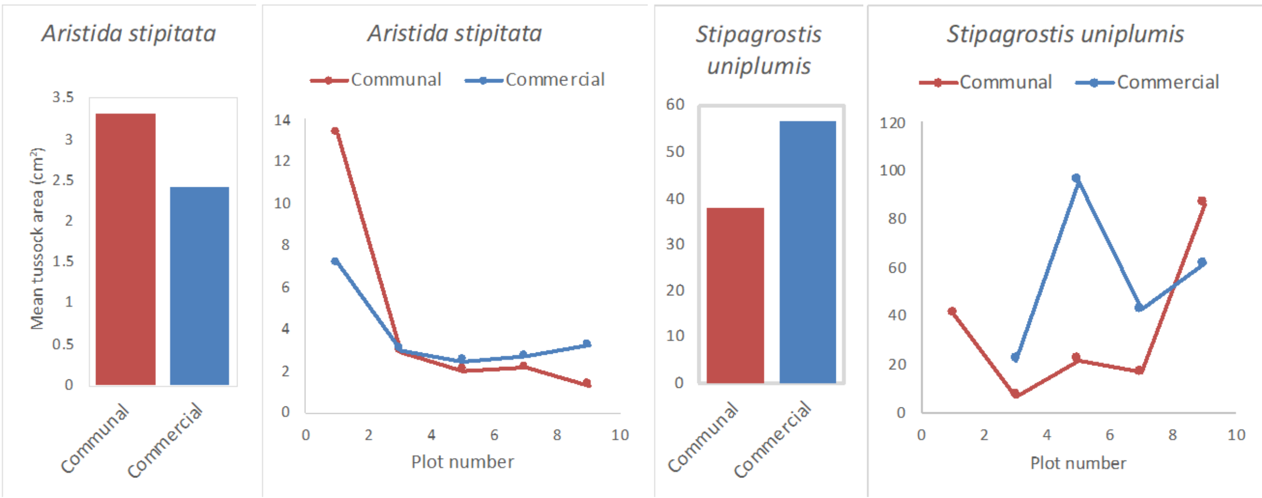

Figure 1: The basal size structure of two grass species (*Aristida stipitata* and *Stipagrostis uniplumis)* in different management types (Communal areas or Commercial farms) and across the grazing gradients. Plot 1 being closest to the water points and thus experiences higher grazing intensity.

Grass density and seedling recruitment

Both on communal areas and commercial farms, grass densities and recruitment generally decreased with increasing grazing pressure (Figure 2), with very low to no grass tufts and seedlings in plots closer to water points. These effects were more pronounced on commercial farms.

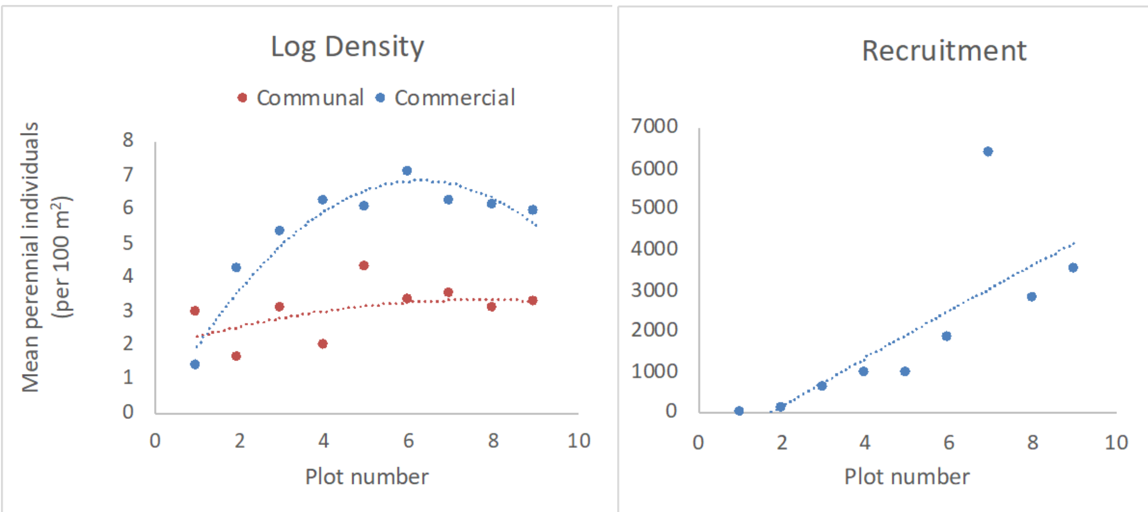

Figure 2: A comparison of total overall densities and recruitment of the 4 grass species across 16 transects with different management types N.B. Density is displayed on a log scale (i.e. 3 = 19; and 6 = 402 individuals).

Discussion

Grazing effects on population health

We found no influence of distance from water point on population health, which could possibly be explained by a high spatial heterogeneity of soil conditions and grazing pressure. *Stipagrostis uniplumis* is a densely tufted large sized grass compared to *A. stipitata* (Fig. 1). In general *A. stipitata* performed poorly under grazing pressure, decreasing in size in either the assumed highly grazed communal areas compared to commercial farms, as well as across the grazing gradients, Conversely, *S. uniplumis* had larger tufts on commercial farms compared to communal areas, which peaked in size earlier than *E. rigidior* (data not shown). The rarity of *E. rigidior* in communal areas is a possible explanation of the effects of continuous grazing in those areas. *S. uniplumis* dominated in commercial farms compared to communal areas where the species was even absent in some transects which is a possible indication of a system approaching desertification tipping points whereby such sensitive species such as *E. rigidior* and *S. uniplumis* tend to vanish with continuous grazing. Contrarily, species such as *A. congesta* and *A. stipitata* tend to be more common in the communal areas. These subclimax grass species are known as indicators of overgrazing with *A. stipitata* having a tendency of occupying disturbed open spaces hence displacing the more desirable native grass species (Muller 2007). Such species have the ability to tolerate high grazing intensity and harsh environmental conditions.

Grazing effects on population density and recruitment

The higher grass densities and recruitment in commercial farms could be explained by the controlled grazing system that is being implemented in those farms whereby species such as *E. rigidior* and *S. uniplumis* still form a major component of the veld (Muller 2007). In general, grass densities and recruitment tended to be affected by grazing pressure across management types. This is possibly due to high trampling effects and grazing intensity as livestock gather around watering points as well as seed bank depletion which will require further inference. A sharp decline in grass density away from grazing pressure could be possibly due to edge effects as most commercial farms have different fenced off units/paddocks. However, a sharp increase in seedling recruitment in those areas is likely a result of elimination of competition from established vegetation (Zimmermann et al. 2008). Our findings match the results from previous studies on perennial grasses (e.g. Aguilera and Lauenroth 1993, Zimmermann *et al.* 2008) where the presence of established competitors severely suppressed seedling recruitment.

The effects of high grazing intensity tend to favour less palatable increaser grass species whilst long lived species that have high or average grazing value tend to disappear. Additionally, a suppression of seedling recruitment was another possible effect of high grazing intensity. We conclude that perennial grass species that are more responsive to grazing impact than to other environmental factors are probably useful early warning indicators of change. Further study and analyses of the system and data will continue to explore this possibility, to further determine the perennial grass dynamics, in order to better understand and predict desertification tipping points. In this way, suitable strategies will then be identified to manage and avoid irreversible effects of desertification.

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