Long-term impacts of stocking rate on soil carbon sequestration in arid areas of South Africa

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Introduction

Overstocking is one of the most important factors which results in changes of carbon stocks (Reeder and Schuman, 2002) and soil degradation, particularly in sandy soil, vulnerable to degradation through physical erosion. South African (RSA) topsoil is characterized by the low level of organic matter (Du Preez *et al.* 2011). Like most other African countries, little is known about the level of C sequestration under various grazing strategies in the vast dry grassland areas of RSA. It is well known that long-term studies with various stocking rate would be able to shed light on the level of C sequestration in varying soil types (Peneiro *et al.* 2010). Although studies have been undertaken concerning impacts of grazing on vegetation dynamics in RSA (Du Toit 2000), only few have focused on soil carbon stocks. Hence, this study was designed to assess impacts of long-term grazing at different stocking rate on carbon sequestration in Grootfontein, South Africa.

Materials and methods

Long-term continuous grazing paddocks at high (CGH) and low (CGL) stocking rate and Exclosure (Excl), which has not been grazed for more than 60 years, were used in this study. The paddocks were laid out in the form of parallel rectangular strips (width: length ratio of approximately 1:10) of 25 ha (at a stocking rate of one sheep to 0.85 ha for CGH and at stocking rate of one sheep at 1.28 ha for CGL) or 3.4 ha (exclosure) along the slope on gently sloping mixed Karoo apron veld. Merino wethers were introduced to the grazing treatment sites at the "two-tooth" stage and replaced after three to four years. The soil of the area is sandy clay, Shigalo series with calciferous layers (Donaldson, 2012). Each plot was grouped into five homogenous transacts located every 100 m along the slope. Each transact was considered as a replicate for each treatment. Soil samples were collected every 20 m along transect with 15 m left as border on either side of each transect. The samples were collected using auger from the 0-0.10, 0.10-0.20, 0.20-0.30, 0.30-0.40, and 0.40-0.60 m layers. The samples from each layer of a sampling point in each transact were combined and mixed to make a single homogeneous soil sample per layer. The samples were air dried and pulverized to pass through a 150-µm screen and analyzed for total C and N using a Carlo Erba NA1500 C/N analyzer (Carlo Erba Strumentazione, Milan, Italy). The data were analyzed using the GLM procedures in the statistical package of SAS, with grazing treatment (fixed effects) and error (random effect). Post hoc mean comparisons were done on all significant treatment means using Tukey's method ($P<0.05$; <0.01; <0.001).

Results and Discussion

This study showed that grazing significantly reduced soil organic carbon (SOC) levels ($P<0.05$; $P<0.01$) (Table 1). Exclosures possessed significantly higher SOC at all depths except at 20-30 cm. The C:N ratio of the exclosure was higher compared to continuous grazing at 30-60 ($P<0.01$) and 0-60 cm ($P<0.05$) (Table 2). The higher SOC content in exclosure trial paddock is mainly due to the accumulation of organic matter (OM) as grazing influences the amount and composition of the OM. This is in agreement with the results of Du Preez *et al.* (2011) and Liu *et al.* (2012) who reported lower SOC when vegetation has been removed as a result of grazing and /or burning in uncontrolled grazing conditions in sandy soil. Excluding grazing livestock in erosion-prone sandy soils has a great potential to restore soil fertility, sequester SOC and improve biological activity (Yong-Zhong *et al.* 2005), and land rehabilitation and biodiversity (Witt *et al.* 2011).

Conclusion

Higher SOC in the exclosure treatment is an indication of organic matter accumulation. The results also imply that continuous grazing under the described grazing conditions

Table 1. Soil organic carbon content (%) in different grassland management systems (mean ± s.e) in Grootfontein.

Soil depth (cm)	CGH	CGL	Excl	F value	Sign.
0-10	0.49±0.02b	0.53±0.03b	0.66±0.02a	6.48	0.003**
10-20	0.51±0.02b	0.52±0.05b	0.66±0.04a	4.21	0.019*
20-30	0.48±0.02	0.50±0.03	0.58±0.04	3.00	0.057NS
30-60	0.36±0.02b	0.40±0.04b	0.59±0.05a	4.72	0.013*

Means with different letters (a, b) in a row are different at indicated P value, NS non-significant, *$P<0.01$, ** $P<0.01$

Table 2. C: N ratio in different grazing management systems (mean + s.e) of Grootfontein.

Soil depth (cm)	CGH	CGL	Exclo	F value	Sign.
0-10	9.46+0.12	9.60+0.18	10.41+0.60	2.718	0.074NS
10-20	9.49+0.22	9.36+0.36	10.14+0.51	1.184	0.313NS
20-30	8.78+0.18	8.65+0.11	8.44+0.76	0.341	0.713NS
30-60	7.91+0.19b	7.95+0.48b	10.68+1.24a	5.335	0.008**
0-60	9.31+0.10b	8.98+0.22b	10.05+0.55a	3.982	0.024*

Means with different letters (a, b) in a row are different at indicated P value, NS non-significant, *P<0.01, ** P<0.01

is not a viable management option in sandy soils for grasslands aimed at reducing soil degradation & C losses through improving land and biodiversity rehabilitation. Periodical soil re-sampling is required to detect the dynamics of C stocks and other soil properties.

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References

Donaldson CH (2012) An important milestone in the development of pasture research at Grootfontein College of Agriculture http://gadi.agric.za/printarticle.php?page (accessed on June, 2012) pp 1-5.

Du Toit PCV (2000) Estimating grazing index values for plants from arid regions. *Journal of Range Management* **53**, 529-536.

Du Preez Christ C, Cornie W, Van Huyssteen Pearson, Mnkeni NS (2011) Land use and soil organic matter in South Africa: A review on spatial variability and the influence of rangeland stock production. *South African Journal of Science* **107**, 5-6.

Liu N, Zhang Y, Chang S, Kan H, Lin L (2012) Impact of Grazing on Soil Carbon and Microbial Biomass in Typical Steppe and Desert Steppe of Inner Mongolia. *PLoS ONE* **7(5)**, e36434. doi:10.1371/journal.pone.0036434

Pineiro G, Paruelo JM, Oesterheld M, Jobbay EG (2010) Pathways of grazing effects on soil organic carbon and nitrogen. *Rangeland Ecology and Management* **63**, 109-119

Reeder JD, Schuman GE (2002) Influence of livestock grazing on C sequestration in semi-arid mixed-grass and short-grass rangelands. *Environmental Pollution* **116**, 457–463.

Yong-Zhong Su, Li Yu-Lin, Jian-Yuan Cui, Wen-Zhi Zhao (2005) Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. *Catena* **59**, 267–278.

Witt G Bradd, Michelle V Noël, Michael I Bird, Beeton, Menzies RJS, Neal W (2011) Carbon sequestration and biodiversity restoration potential of semi-arid mulga lands of Australia interpreted from long-term grazing exclosures. *Agriculture, Ecosystems and Environment* **141**, 108–118.