Rangeland Management in a Changing World – Active and Passive Restoration Case Studies from Ethiopia, Tanzania, and South Africa

A. C. Treydte
Nelson Mandela African Institution of Science Technology, Tanzania

S. A. Baumgartner
University of Hohenheim, Germany

S. K. Tuffa
Oromia Agricultural Research Centre, Ethiopia

A. A. Abdeta
Oromia Agricultural Research Centre, Ethiopia

The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress

Published by the Kenya Agricultural and Livestock Research Organization

Rangeland management in a changing world – active and passive restoration case studies from Ethiopia, Tanzania, and South Africa

Treydte, A.C.[*] [†]; Baumgartner, S.A. [†], Tuffa, S.K.[††], Abdeta, A. A. [†††]

* School of Life Sciences and Bioengineering, Nelson Mandela African Institution of Science Technology, Arusha, Tanzania and

[†]University of Hohenheim, Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute) and

[††] Oromia Agricultural Research Centre, Ethiopia

[†††]Faculty of Natural Resources, Botswana University of Agriculture, Gaborone, Botswana

Key words: exclosures; woody and herbaceous vegetation; livestock species diversification; savannas; soil and grass nutrients

Abstract
Rangelands cover almost 50% of the earth's land surface and are often found in marginal areas that often face climate extremes. The production of herbaceous biomass has strongly declined over the last decades due to overgrazing and adverse climatic conditions such as frequent droughts and flooding. While different rangeland restoration methods are being used, their effect on vegetation quality and quantity over time has rarely been experimentally tested and monitored. Our research comprises experiments of various rangeland restoration tools we have used across eastern and southern Africa. We conducted passive restoration through exclosure experiments and compared vegetation in and outside of exclosures to understand regrowth patterns as well as overall forage quality. The active restoration methods we tested comprised domestic livestock species diversification, i.e., inclusion of browsers in rangeland systems. Further, we investigated how reseeding of nutritious rangeland grass species and subsequent grazing regimes can improve the rangeland health. We found that exclosures strongly improved biomass and productivity but that regular moderate grazing can further enhance those compared to no grazing. Our results further suggest that including browsers might enhance nutrients of herbaceous vegetation and soils of rangeland systems. We also claim that young grass species such as *Chloris gayana* and *Cenchrus ciliaris*, which are commonly used for reseeding of rangelands, show higher nutrient contents and productivity under light or moderate grazing pressure while mature grasses did not show this effect. We conclude that a combination of active and passive restoration methods can greatly enhance quality and quantity of African rangelands and enhance their sustainable use and resilience towards climatic shocks such as increasing drought frequencies.

Introduction
Rangelands cover almost 50% of the earth's land surface and are often found in marginal areas, unsuitable for cropping. The production of herbaceous biomass and woody vegetation is highly seasonal and climate-dependent. Rangelands support over 2.5 billion people (UN 2008) and the global demand for livestock products is increasing (Bouwman 1997). Currently, 96% of the mammal biomass on the earth is composed of humans and livestock alone (Yinon et al. 2018). Recently, the number of domestic herbivores has rapidly increased to fill this demand. The United Nations has announced the Decade on Ecosystem Restoration (2021-2030), highlighting the importance of understanding restoration interventions in African rangelands (UN 2019). Various rangeland restoration methods have been suggested but little has been quantified about their effect on vegetation and soil recovery. One passive restoration method used globally has been exclosures that either fully or selectively exclude livestock herbivory (e.g., Rong et al. 2014). However,

herbaceous biomass as well as productivity and nutrient contents in plants and soil have rarely been quantified and compared between grazing regimes. In addition, little is known on the long-term effects of exclosures on grass biomass and how the rainfall regime impacts grass regrowth.

An active restoration model is to diversify the herbivore species, i.e., including browsers and grazers into a rangeland system rather than a mono-specific herd. It has been shown that livestock, particularly cattle in high numbers, can severely damage the grass layer and soil properties. Few studies have addressed whether different livestock species assemblages will have different effects on both woody and grassy vegetation and whether the inclusion of browsers is beneficial to overall rangeland quality.

Another active method for restoration has been reseeding, which has generally shown positive effects on rangelands and their inhabitants (Davy et al. 2017). Despite the widespread use, few studies have addressed how young plants respond to grazing after their seeding and establishment and what grazing intensity is appropriate for enhancing productivity and nutrient contents for the plants' sustainably.

We tested various active and passive restoration methods and monitor quantify their success over time for eastern and southern African rangeland systems.

Methods and Study Site

Passive restoration. We selected exclosures of different age within the Borana rangeland, Yabello region, of southern Ethiopia. Here, we selected six traditional range enclosures of varying ages (12 to 30 years) and measured the biomass, cover and species richness of the herbaceous vegetation inside and outside the exclosure. We used a linear model to compare herbaceous vegetation characteristics across grazing management and season. We further identified herbaceous species and their grazing value as well as woody vegetation components between inside and outside exclosures.

Active restoration. To assess the importance of livestock species diversification, we selected communal grazing lands of different livestock species composition (cattle only vs cattle, goats and sheep) adjacent to the Kruger National Park, South Africa. At each site, we selected information on grass cover, biomass as well as nutrient contents (Nitrogen and Phosphorus) at systematically distributed sampling points. To address the importance of reseeding in improving rangeland forage quality, we planted *Chloris gayana* and *Cenchrus ciliaris* and exposed young and mature tufts to different grazing pressure (clipping) and rainfall regimes (irrigation). We measured regrowth potential as well as Nitrogen content in these grasses.

Results

Passive restoration

Herbaceous biomass, cover and species richness were about 20% higher in exclosures compared to openly accessible communal grazing lands (F = 145, P < 0.001,F = 140, P <0.001, F = 17.6, P < 0.001). The younger enclosures showed slightly larger differences than the older ones. More desirable grass and forb species were found inside the exclosures than in the outside as well as a lower woody species density.

Active restoration

Our livestock species diversification results showed that grass Nitrogen contents were by about 1/3 higher in sites that included browsers compared to sites with only mono-specific cattle grazing ($F_{1,107}$ = 69.4; P < 0.001). Grass phosphorus contents showed similar but less strong patterns ($F_{1,35}$ = 5.7; P = 0.023). During our reseeding experiment, we found that young grasses of *C. ciliaris* showed about twice as high biomass under light and moderate grazing than under no or frequent grazing ($F_{3,72}$ = 5.4, p = 0.002). Mature *C. ciliaris* showed higher below-ground carbon under frequent and moderate grazing compared to no and light grazing ($F_{2,12}$ = 4.6; P = 0.0146). Low irrigation reduced above-ground carbon of both plant species, irrespective of grazing regime ($F_{2,61}$ = 8.5, P = 0.0006; $F_{2,61}$ = 15.0, P < 0.0001).

Discussion

Passive restoration

Our findings that exclosures provide important grass resources for both livestock and wildlife fit well with studies in eastern and southern Africa, where traditional rotating resting of the rangeland has been practiced for centuries (Alemie and Gebremedhin 2019, Venter et al. 2017). We also highlight that older enclosures will likely succumb to self-thinning of grasses, leading to lower productivity in the long run (Enquist et al. 1998). Hence, regular but moderate grazing is recommended to promote productivity and quality of the herbaceous layer in rangelands.

Active restoration

Further, we found that inclusion of browser species can highly improve the nutrient content of the herbaceous layer. This might be due to the higher nutrient contents in browser dung (see also Sitters and Olde Venterink 2018) as well as the lower impact on the herbaceous layer despite similar stocking densities of domestic herbivores (see also Mohammed et al. 2020). However, goats can also severely hamper tree seedling growth and they might turn to grasses rather than browse if these are nutritious (Ventura-Cordero 2018), which might also have a negative impact on the overall tree-grass balance in the rangeland system. Hence, we recommend enhancing mammalian herbivore species diversification and promoting resting periods and moderate offtake for freshly reseeded grasses in tropical rangeland systems for a sustainable management.

Acknowledgements

We acknowledge the Food Security Centre at the University of Hohenheim, funded through the German Academic Exchange (DAAD), which financed field logistics and research activities. Further, the Foundation Fiat Panis funded parts of this work as well. We thank field assistants and local research centres for support during sampling activities.

References

Alemie, D. K., Gebremedhin, H. H. 2019. Vegetation Diversity and Soil Physico-chemical Properties Under Traditional Management of Rangeland in Eastern Ethiopia. *Journal of Agricultural Science*, *11*(5).

Bar-On, Y. M., Phillips R, Milo, R. 2018. The biomass distribution on Earth. *Proceedings of the National Academy of Sciences* 115.25: 6506-6511.

Bouwman, A.F. 1997. FAO Land and water bulletin 6, National Institute for Public Health and the Environment, The Netherlands (RIVM), Food and Agriculture Organization of the United Nations (FAO) Rome, 1997. http://www.fao.org/3/W5146E/w5146e06.htm

Davy, J., Dykier, K., Turri, T., Gornish, E. 2017. Forage seeding in rangelands increases production and prevents weed invasion. *California Agriculture*, *71*: 239-248.

Enquist, B. J., Brown, J. H., West, G. B. 1998. Allometric scaling of plant energetics and population density. *Nature* 395, 163–165.

Fensham, R. J., Wang, J., Kilgour, C. 2015. The relative impacts of grazing, fire and invasion by buffel grass (*Cenchrus ciliaris*) on the floristic composition of a rangeland savanna ecosystem. *The Rangeland Journal* 37.3: 227-237.

General Assembly resolution 62/195, United Nations Decade for Deserts and the Fight against Desertification (2010-2020), A/RES/62/195 (19 February 2008).

Mohammed, A. S., Animut, G., Urge, M., Assefa, G. 2020. Grazing behavior, dietary value and performance of sheep, goats, cattle and camels co-grazing range with mixed species of grazing and browsing plants. *Veterinary and Animal Science*, *10*, 100154.

Rong, Y., Yuan, F., Ma, L. 2014. Effectiveness of exclosures for restoring soils and vegetation degraded by overgrazing in the Junggar Basin, China. *Grassland science* 60: 118-124.

Sitters, J., Olde Venterink, H. 2018. A stoichiometric perspective of the effect of herbivore dung on ecosystem functioning. *Ecology and evolution*, *8*: 1043-1046.

UN (2019). General Assembly resolution 73/284, United Nations Decade on Restoration (2021-2030), A/RES/73/284 (1 March 2019).

Venter, Z. S., Hawkins, H. J., Cramer, M. D. 2017. Implications of historical interactions between herbivory and fire for rangeland management in African savannas. *Ecosphere*, *8*(10), e01946.

Ventura-Cordero, J., González-Pech, P. G., Sandoval-Castro, C. A., Torres-Acosta, J. F. J., Tun-Garrido, J. 2018. Feed resource selection by Criollo goats browsing a tropical deciduous forest. *Animal Production Science* 58: 2314-2320.