Assessing the relevance of drought duration on dryland rangelands: an experimental and modelling study

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Background

Picture: Kai Behn

Dryland rangelands contribute to the **livelihoods** of numerous people in southern Africa by providing **ecosystem services** such as **forage** for **livestock**.

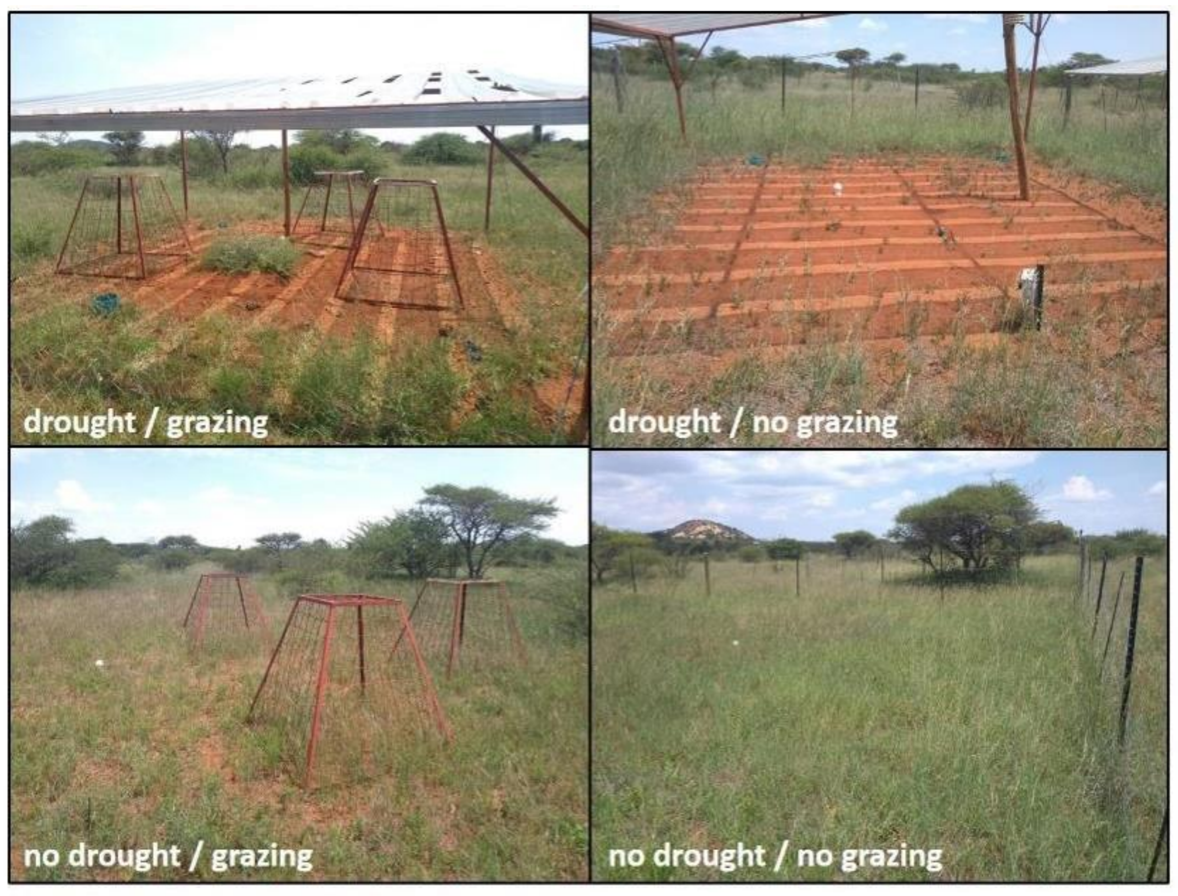
Climate change effects (e.g. less rainfall, more variability, prolonged droughts) and **high demand** for **grazing** land / **forage** pressure these ecosystems.

Research gaps:

- Potentially **interactive effects** of **drought** and **grazing** on savanna ecosystems
- Importance of **drought duration**

Research questions:

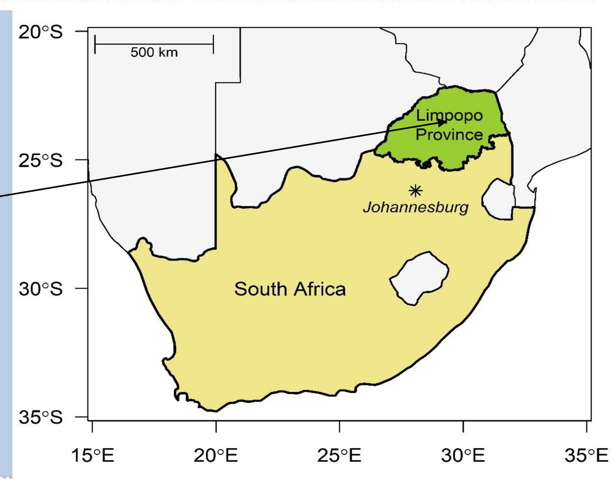
- How **resistant** is herbaceous savanna vegetation to a two- and a six-year **extreme drought** under both **grazed** and **rested** conditions?
- How do the **different drought lengths** influence the **recovery** after drought release?



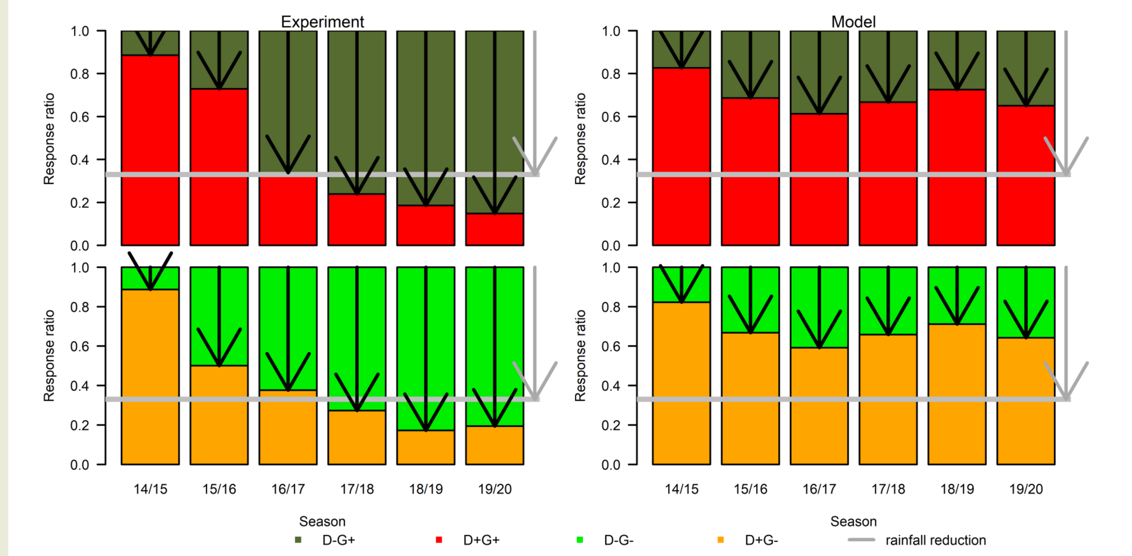
Experimental plots after five treatment years.
Pictures: Vincent Mokoka

Location of the experiment:
Syferkuil experimental farm

Semi-arid savanna
Precipitation: 400-600 mm / year



Drought effects on productivity



Black arrows show the average productivity* reduction under drought conditions (D+) in relation to non-drought (D-) for the experiment (left) and the model (right). The grey line and arrow indicate the rainfall reduction in the drought treatment. Slight effects of grazing (G+) vs resting (G-) in the experiment.

Experiment	Model
Similar drought effects in the first 2 seasons	
Ongoing decline to < 20 % of no-drought control	Stabilization after the second year at around 60 %
Rain use efficiency initially above, then below control	Rain use efficiency always above control

* Productivity is estimated as aboveground net primary production (ANPP) in the experiment and net primary production (NPP) in the model.

DroughtAct-experiment

Large-scale field experiment to study **combined** effects of **drought** and **grazing** on a semi-arid savanna ecosystem established in 2013.

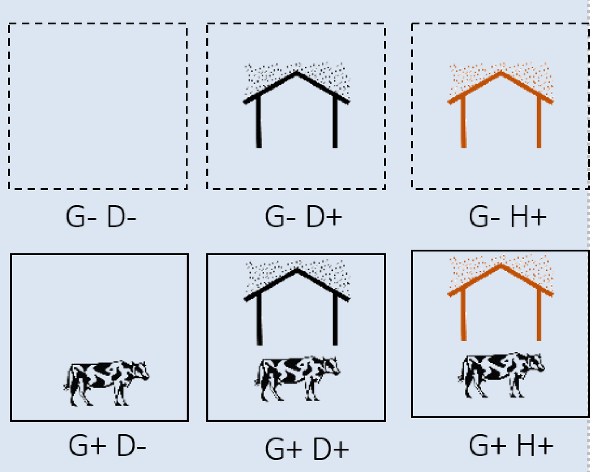
Experimental drought:

- Passive rainout shelters with transparent roofs
- 66%-reduction of ambient rainfall
- Turning a normal year into a year of "exceptional drought"
- Plots trenched to avoid horizontal water flow
- For 2 (H+) and 6 (D+) years

Rainout shelter. Picture: Kai Behn

Grazing Management:

- Rotational grazing (G+)
- Cattle, moderate pressure
- Fences to exclude grazing in rested plots (G-)



Treatment combinations, repeated in 4 blocks

Conclusions

Drought impact increases with duration of drought!

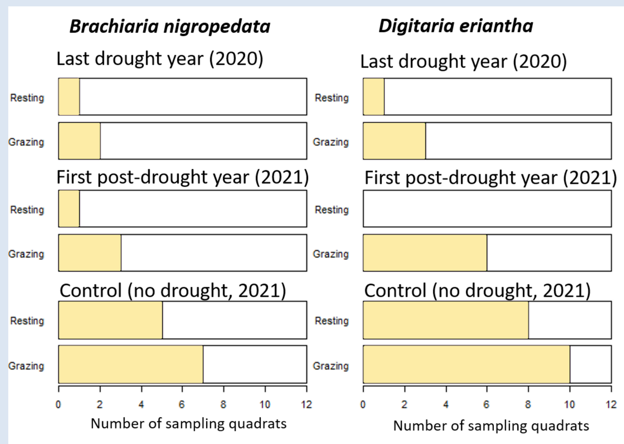
- Little impact in first drought years
- Devastating effect of ongoing drought
- Changes in species compositon
- Loss of ground cover and valuable forage grasses
- Fast recovery after 2-years drought
- Vegetation model indicates a lengthy recovery process after drought

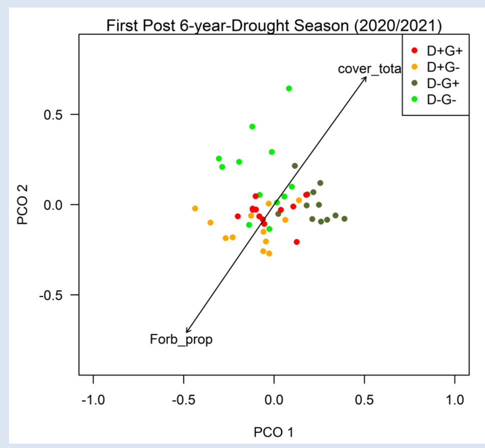
Role of grazing ambivalent:

- Can stimulate recovery
- Can accelerate degradation
- Depends on drought impact, duration (and grazing intensity)

Drought effect on species

- **Drought** changes **species composition** beyond drought event
- Reduction of perennial grass cover
- The longer the drought the more severe
- Availability of diaspores may be crucial for recovery
- Resting strongly changes species composition





Left: Occurrence (yellow = present, white = absent) of two important perennial forage grasses during and after drought in experimental plots.

Right: Principal coordinates analysis of species composition in the first post-drought season after 6 drought years.
Each dot represents a sampling quadrat; the color indicates the treatment; the arrows the proportion of forbs in the quadrat and the total cover.

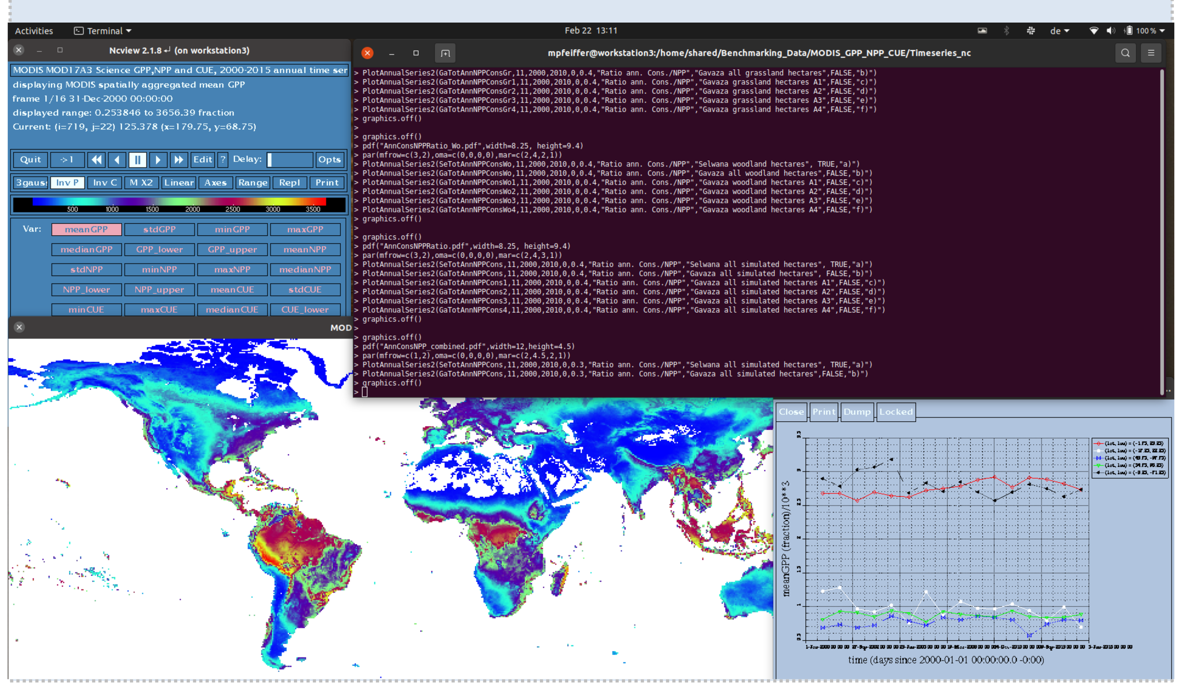
Vegetation model

Adaptive Dynamic Global Vegetation Model (aDGVM)

- Functional trait-based vegetation model developed for tropical vegetation
- aDGVM2: Further improved by including e.g. different plant functional types and grazing impacts

Simulation of DroughtAct-treatments with aDGVM2

- to extrapolate the experiment on a temporal scale
- estimating the recovery periods in the future



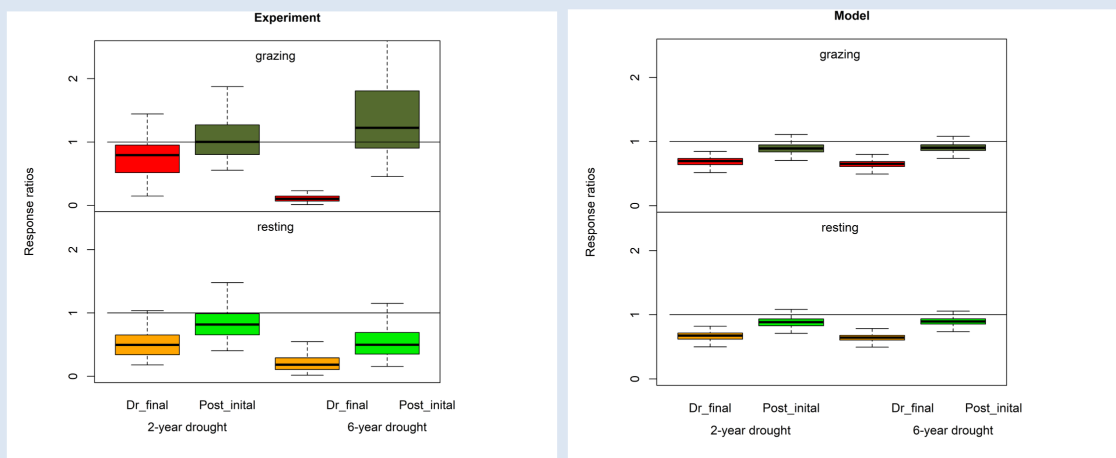
Recommendations

- Moderate grazing also during drought to avoid accumulation of dead biomass
- Reduce grazing with ongoing drought
- Temporal resting after drought release to facilitate recovery
- Grazing exclosures for seed production of perennial grasses
- Regular monitoring of rangeland health using indicators such as perennial grass cover and forb proportion
- Knowledge transfer between farmers, extention service and science

Rangeland at the study site. Picture: Kai Behn

Post-drought recovery

- Experimental plots´ productivity post-drought above (G+) and below (G-) control
- Vegetation model predicts reduced post-drought productivity for > 10 years



Response ratios of productivity*) in the 2nd/6th drought year and the first respective post-drought year.

Key references:

Pfeiffer M, Langan L, Linstädter A, Martens C, Gaillard C, Ruppert JC, Higgins SI, Mudongo EI, Scheiter S (2019) Grazing and aridity reduce perennial grass abundance in semi-arid rangelands – Insights from a trait-based dynamic vegetation model. *Ecological Modelling*, **395**, 11—22.

Scheiter S, Pfeiffer M, Behn K, Ayisi KK, Siebert F, Linstädter A (2023) Managing southern African rangeland systems in the face of drought – a synthesis of observation, experimentation, and modeling for policy and decision support. In: Sustainability of southern African ecosystems under global change: Science for management and policy interventions. Eds: von Maltitz G, Midgley GF, Veitch J, Brümmer C, Rötter R, Viehberg F, Veste M. Springer.

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