Interactive effects of fire and experimental warming on high-altitude grasslands in South Africa

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NRF National Research Foundation | SAEON South African Environmental Observation Network

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Introduction

- **Tropical grassy biomes** (C_4 grasslands and savannas) occupy large parts of the world and **are increasingly under threat** from human population growth, agricultural expansion, alien species invasions, native woody encroachment and climate change (Parr et al. 2014).
- One of the **greatest current threats** to these grassy biomes are CO_2-centric climate-change mitigation programs that promote the wide-scale planting of trees in **afforestation programs** (Veldman et al. 2015).
- A major **cause** of this threat is that grassy biomes are often regarded as degraded forests and that **inherent ecosystem drivers such as fire and herbivory are disregarded** (Veldman et al. 2015).
- **Fire is a major driver** of the functioning of grassy biomes (Bond et al. 2005, Archibald et al. 2005), but we have little understanding of how fire regimes will change due to climate change.
- **Climate change scenarios** for southern Africa predict **higher temperatures and more variable precipitation** against a background of rising levels of atmospheric CO_2 (Midgley and Bond, 2015).
- This will alter vegetation indirectly via **altered fire regimes**, but also directly via elevated levels of atmospheric CO_2 and rising temperatures.
- **Elevated CO_2** favours C_3 plants with their CO_2-limited photosynthetic pathway (Buitenwerf et al. 2012), whereas **higher temperatures** benefits C_4 grasses with their higher water-use efficiency (Morgan et al. 2011). Effects of temperture are predicted to be stronger at higher elevations (Sundqvist et al. 2013).
- We know little about the interactive effects of different fire regimes and increasing temperatures on grassy biomes in southern Africa. This knowledge is essential to adapt to a warmer future with altered fire regimes.

Objective

Develop a long-term temperature-manipulation experiment in Africa, where such experiments are scarce and data are lacking.

Determine how fire regimes and elevated temperature interactively affect high-altitude C_4 grasslands in South Africa

Figure 2. Location and picture of the study site, the uKhahlamba Drakensberg Mountains in South Africa.

Research questions

- How do C_3 and C_4 plants differ in their response to experimental warming under different fire regimes?
- How does experimental warming affect plant productivity and composition under different fire regimes and how does this feed back to altered biophysical climate-vegetation interactions?
- How does experimental warming affect soil respiration and microbial activity under different fire regimes and how does this feed back to altered biogeochemical cycles?

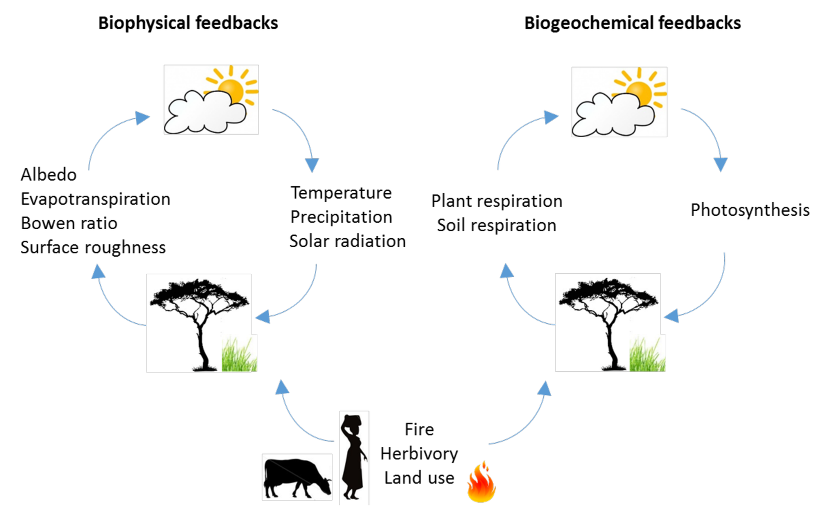


Figure 2. Biophysical and biogeochemical climate-vegetation in grassy biomes.

Methods

- We use a unique long-term fire-manipulation experiment in the uKhahlamba Drakensberg Mountains in South Africa, the Brotherton trial.
- Running since 1980 this fire experiment consists of annual, biennial, quinquennial and no-burn treatments in a full-factorial randomized block design. Each treatment is replicated four times in 25x25m plots.
- In January 2017 we established transparent hexagonal open-top warming chambers with an inside diameter of 1.5 m in each fire treatment, following the ITEX design (Marion et al. 1997). Warmed plots were paired with a 1x1m control. The warming chambers will be removed on the days of the planned experimental fires.
- We monitor air- and soil temperature, soil moisture, plant species composition, biomass, cover and leaf area index, as well as decomposition using the Tea Bag Index, soil respiration and microbial biomass and composition.

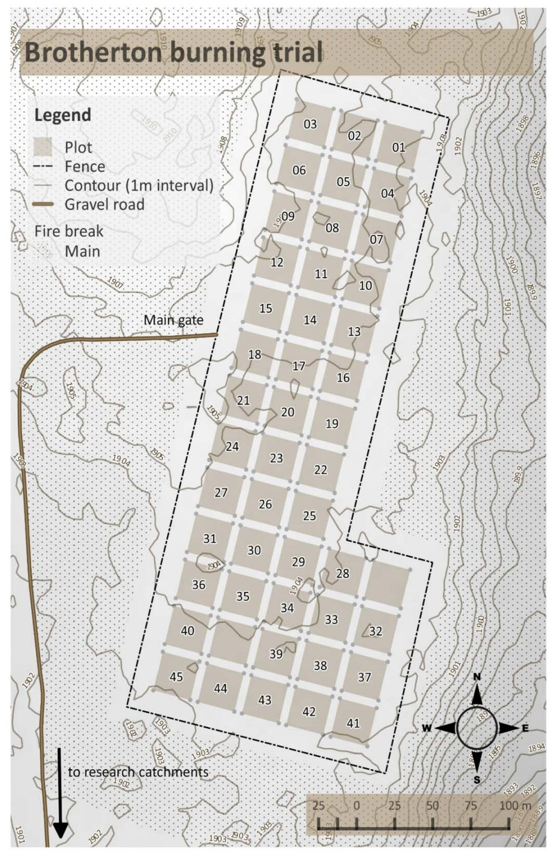
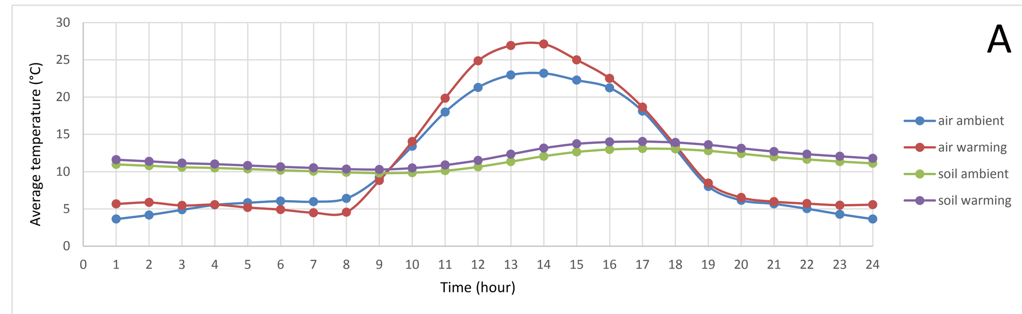


Figure 3. Experimental lay-out of the long-term fire experiment and the hexagonal open-top warming chambers established in the experiment.

Preliminary results



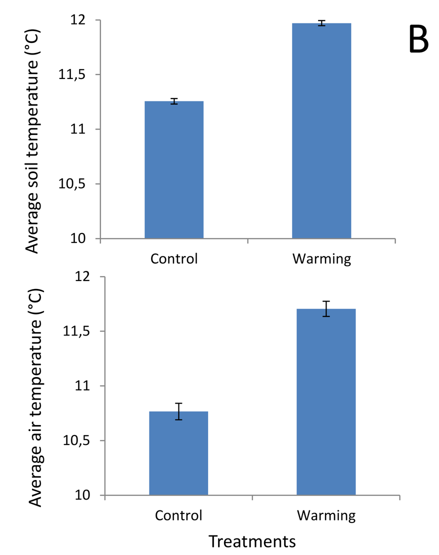


Figure 4. (A) Diurnal temperature pattern of average air and soil temperatures in the open-top chambers (OTC) and the control plots during March-June 2017 . During midday OTCs increased average air temperatures by appr. 4 °C and average soil temperature by appr. 1 °C. **(B)** Average daily soil (top graph) and air (bottom graph) temperatures. OTCs increased average daily air temperatures by 1 °C and soil temperature by 0.7 °C.

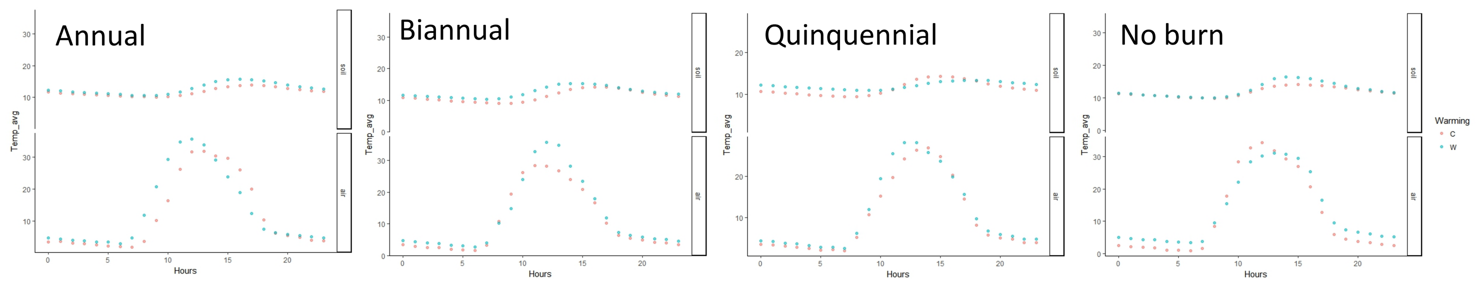


Figure 5. Diurnal temperature patterns in soil (upper lines) and air (lower lines) temperatures for control plots in red and warmed plots in blue. The warming effects of the OTCs differs per fire treatment. On average, the treatments with higher fire frequency show a larger temperature effect.

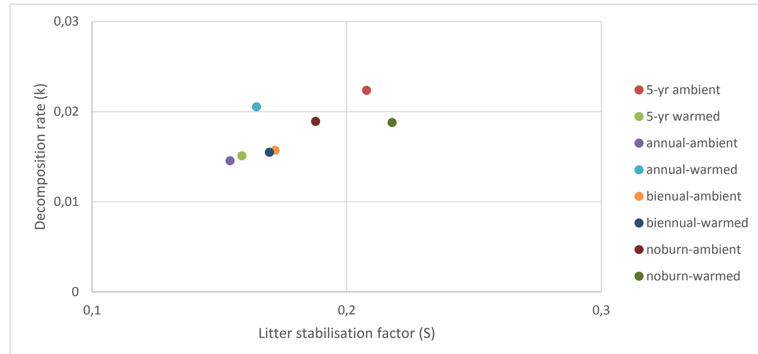


Figure 6. Average decomposition rates (n=4) measured using the Tea Bag Index during January-March 2017. In general treatments with higher fire frequency seem to have lower litter stabilisation factors (S). No clear trend of the warming treatments could be detected yet.

Conclusions

- During the first 6 months the warming treatments increased mid day air temperatures by 4 °C and average daily air temperatures by about 1 °C.
- Open-top chambers increased soil temperatures by about 1 °C.
- The different fire treatments differ in their warming effect, which is most likely due to differences in the density of the grass sward.
- Decomposition rates show differences between fire treatments, but it is too early to pick up any effect of the warming treatment.

Temperature-manipulation experiments in Africa are scarce. We hope this newly established long-term experiment can act as a platform for collaborations.

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