SALLnet 1st Annual Meeting
Stakeholder Day, Sept 11th 2019

How to manage a rangeland during and after drought?

Evidence from a long-term field experiment

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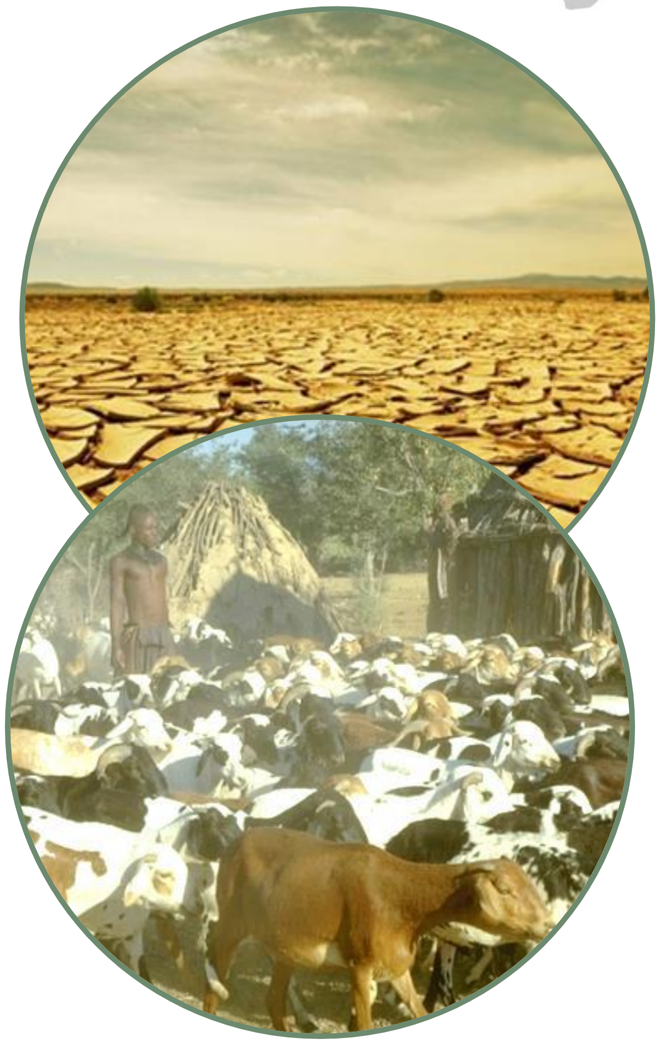
Severe global change effects on dryland rangelands

A. Climate more extreme

- Precipitation amount↓, precipitation variability ↑
- Frequency & intensity of **extreme weather events** ↑ **(drought, floods)**

B. Growing populations

- Demand for ecosystem services ↑
- Frequency & intensity of **human disturbances** ↑ **(livestock grazing)**
- **Combined effects** of **grazing & drought** still **poorly understood**[1]
- Non-linear responses[2]
- Sometimes sudden regime shifts



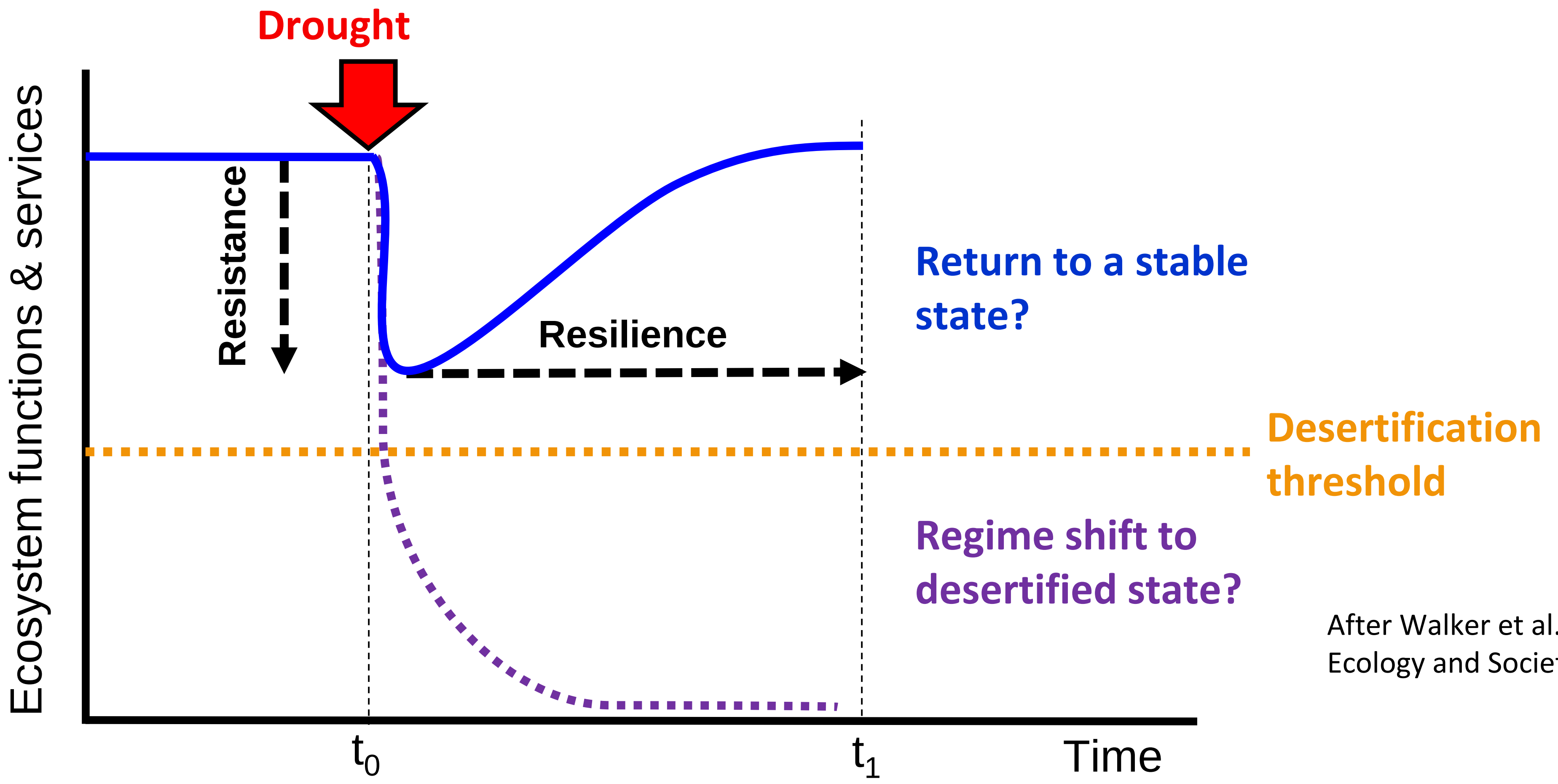
[1] Ruppert et al 2015, Glob Change Biol
[2] Linstädter et al. 2014, PlosOne

Disentangling drought and grazing effects: DroughtAct

- **DroughtAct experiment** combines severe, prolonged **drought** treatments with **grazing** treatments
- **Evaluates**
  1. Ecosystem functions
  2. Ecosystem services

…from **grazed (G+)** and **ungrazed (G-) vegetation** under **drought (D+) and non-drought (D-)** conditions

Assessing ecosystem stability in the face of drought

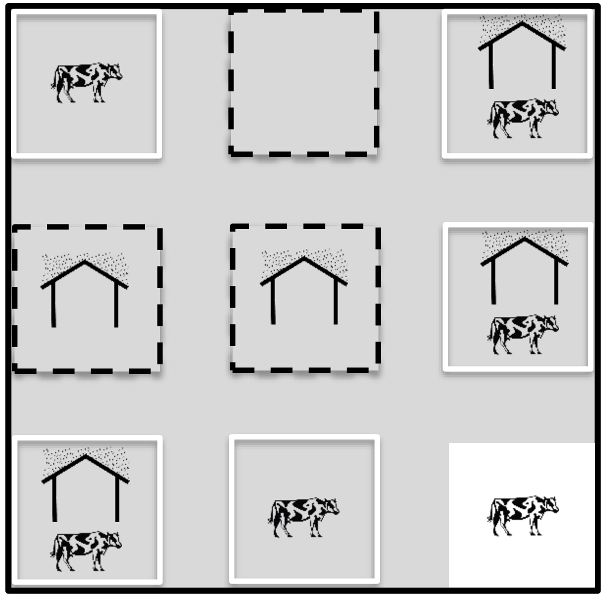


After Walker et al. 2004, Ecology and Society 9(2):5

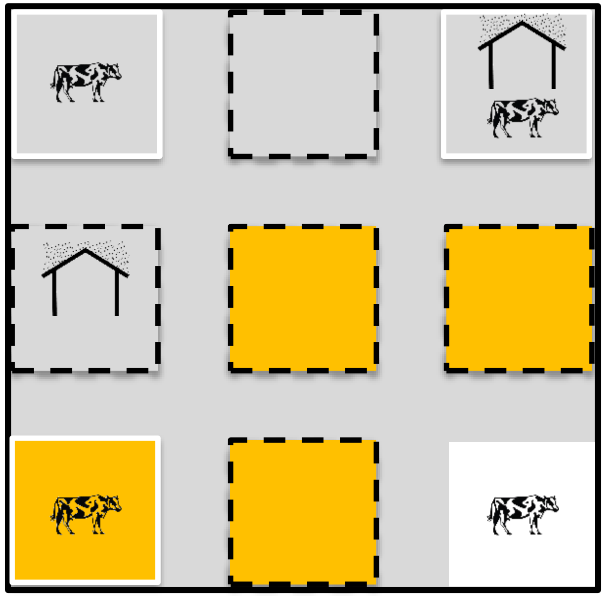
Drought resistance and resilience quantified as changes in ecosystem functions & services

Experimental assessment of ecosystem stability

Years 1 & 2



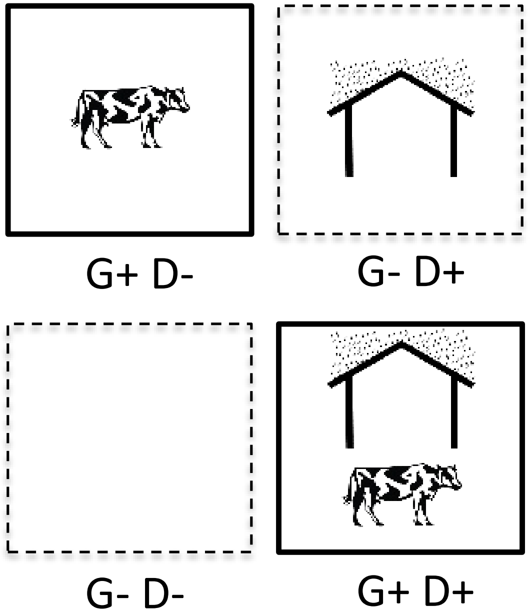
Year 3: Treatment changes



No treatment changes: Resistance to extreme drought

Treatment changes after two years: Resilience to 2-year extreme drought

Grazing treatments: Management effects during/ after drought



Question 1: How **resistant** is the vegetation to a 5-year drought?

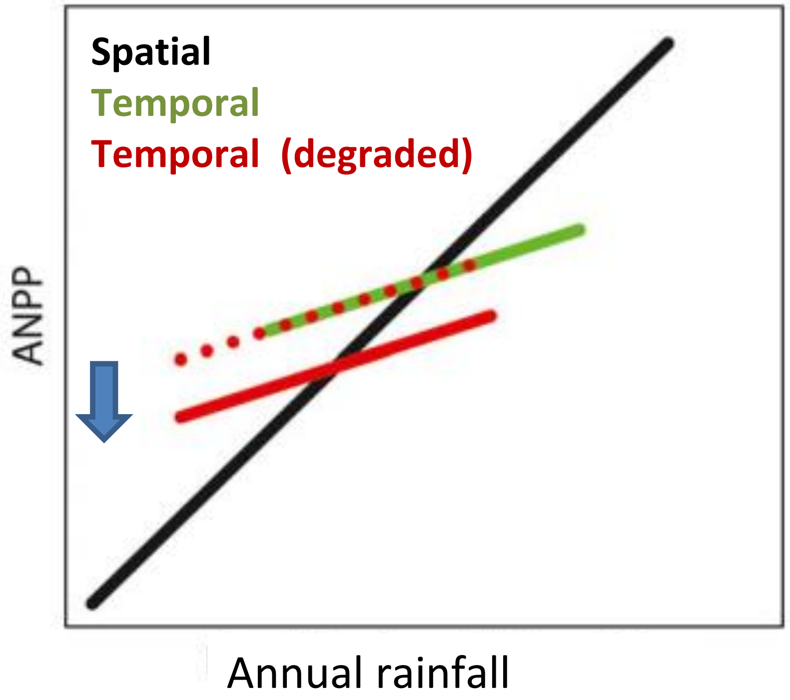
Hypothesis: Breakdown of grass layer production

Question 2: Which effect has **resting on drought resistance**?

Hypothesis: Improved resistance

Figure from Mudongo, Ruppert & Linstädter (in prep.)

Productivity-precipitation relationship captures degradation



1. Linear regression

- **“Temporal fit”:** Relates plant production to corresponding annual rainfall (with long-term data from a site)
- Lower intercept of y-axis hints to degradation[1]

2. Calculating a ratio

“Rain-use efficiency”: Ratio of plant production & rainfall

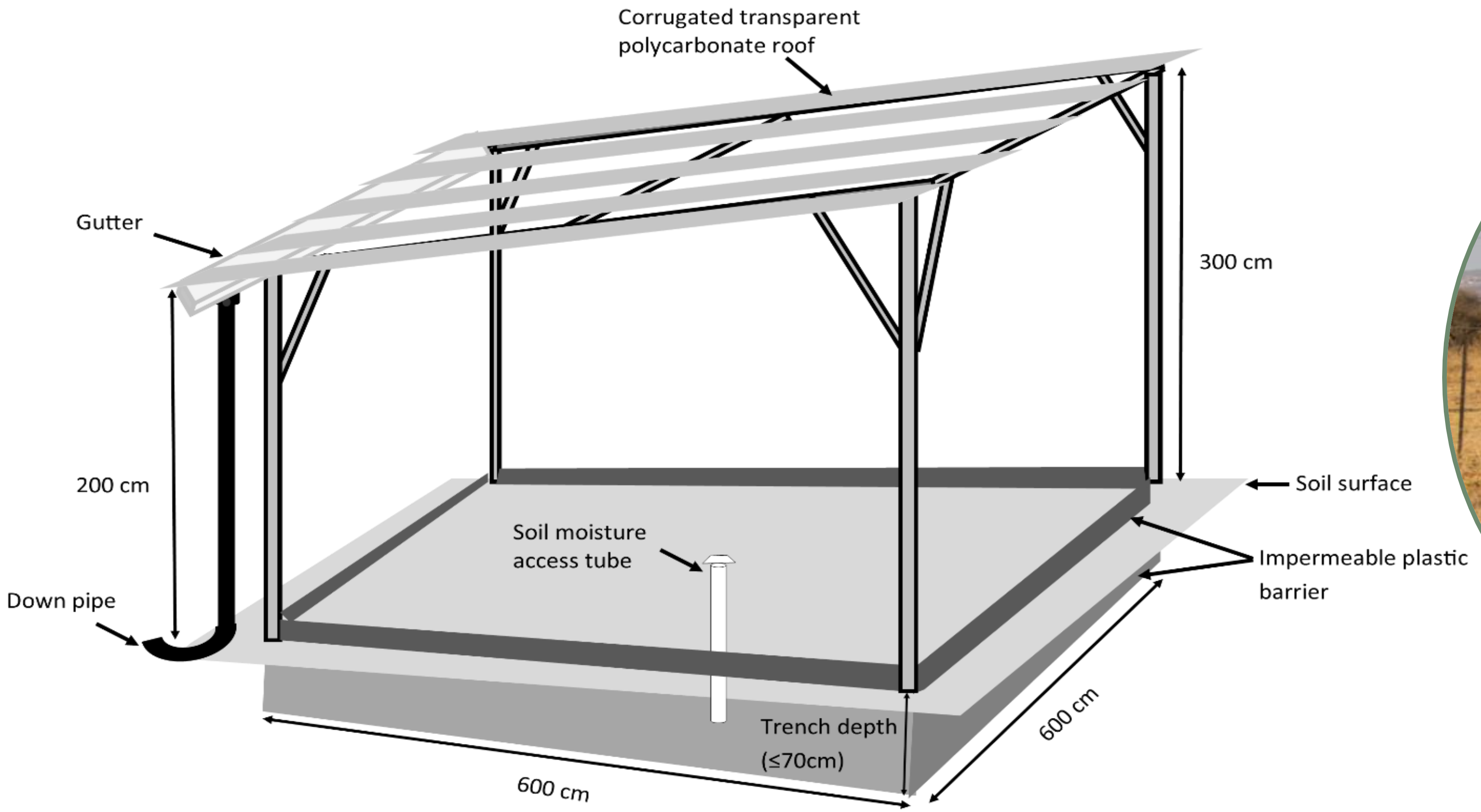
- Lower values may hint to degradation[2]

Question 3: Do **these indicators respond** to experimental drought?

Hypothesis: **Shift towards degraded state** due to structural and/or functional changes

[1] Estiarte et al., Global Change Biol 2016
[2] Ruppert et al., J Veg Sci 2012

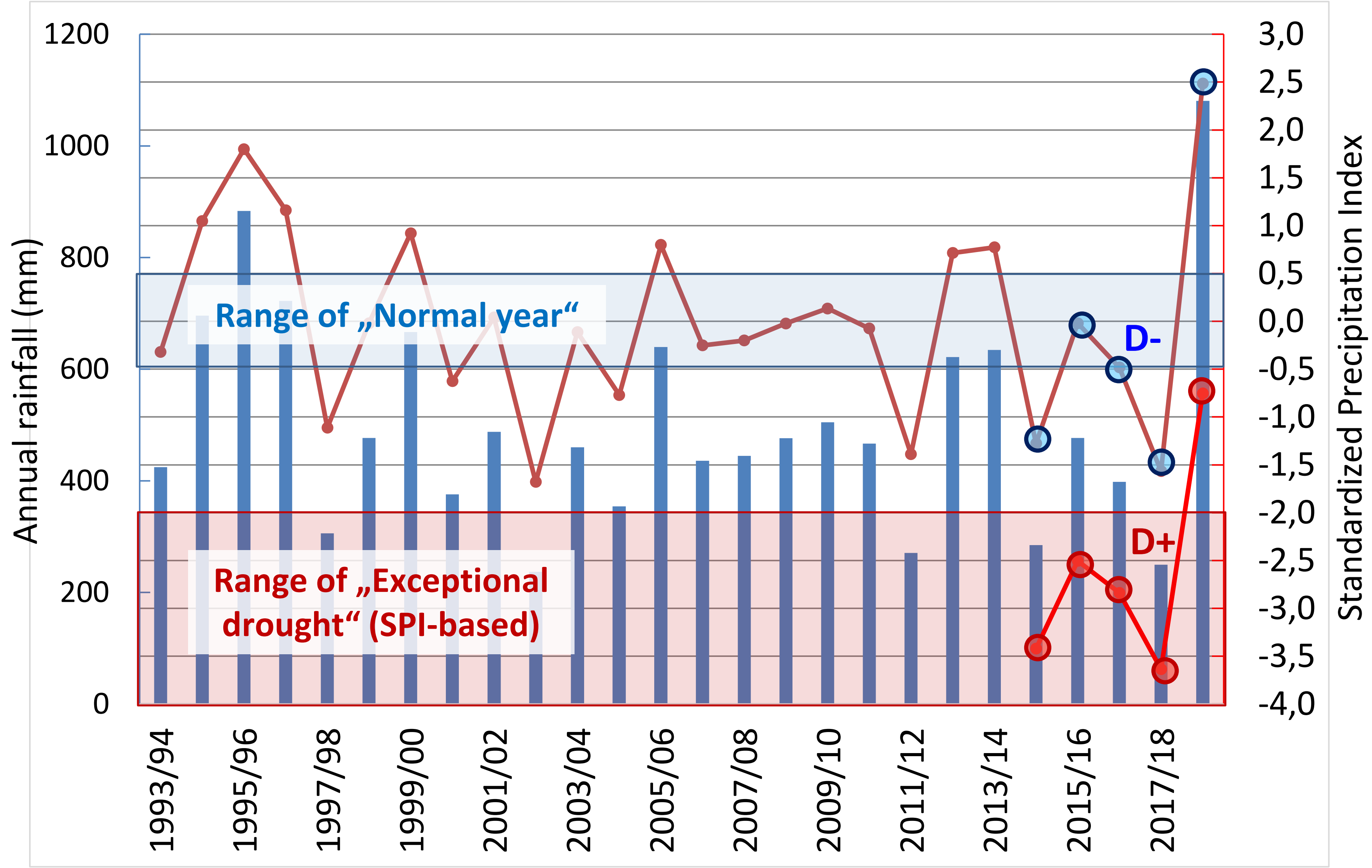
Making a severe drought: Rainout shelter design



- **Large size** (6 x 6 m) to allow cattle grazing underneath
- Reduce ambient rainfall by 66% → **centennial-scale drought**

Figure from Mudongo, Ruppert & Linstädter (in prep.)

Rainout shelter effects on rainfall

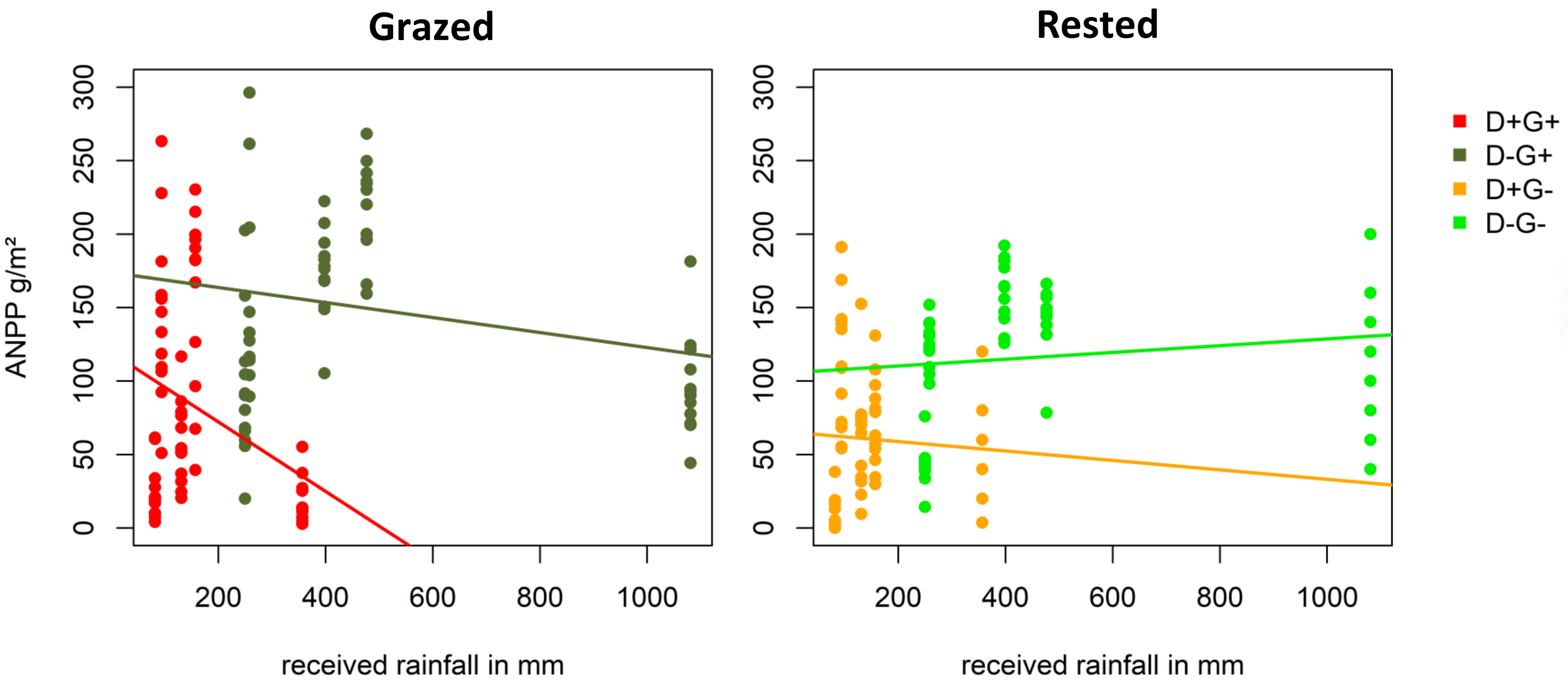


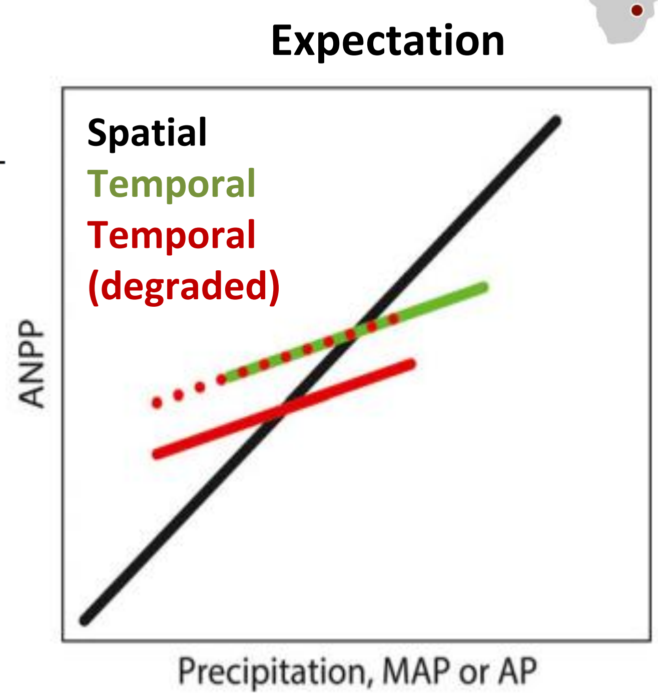
Rainout shelters convert “normal year” into “exceptional drought year”

Exceptionally wet year (2018/19) converted to “abnormally dry” year

→ Drought strength depends on ambient rainfall

Productivity-precipitation relationship: Temporal fit

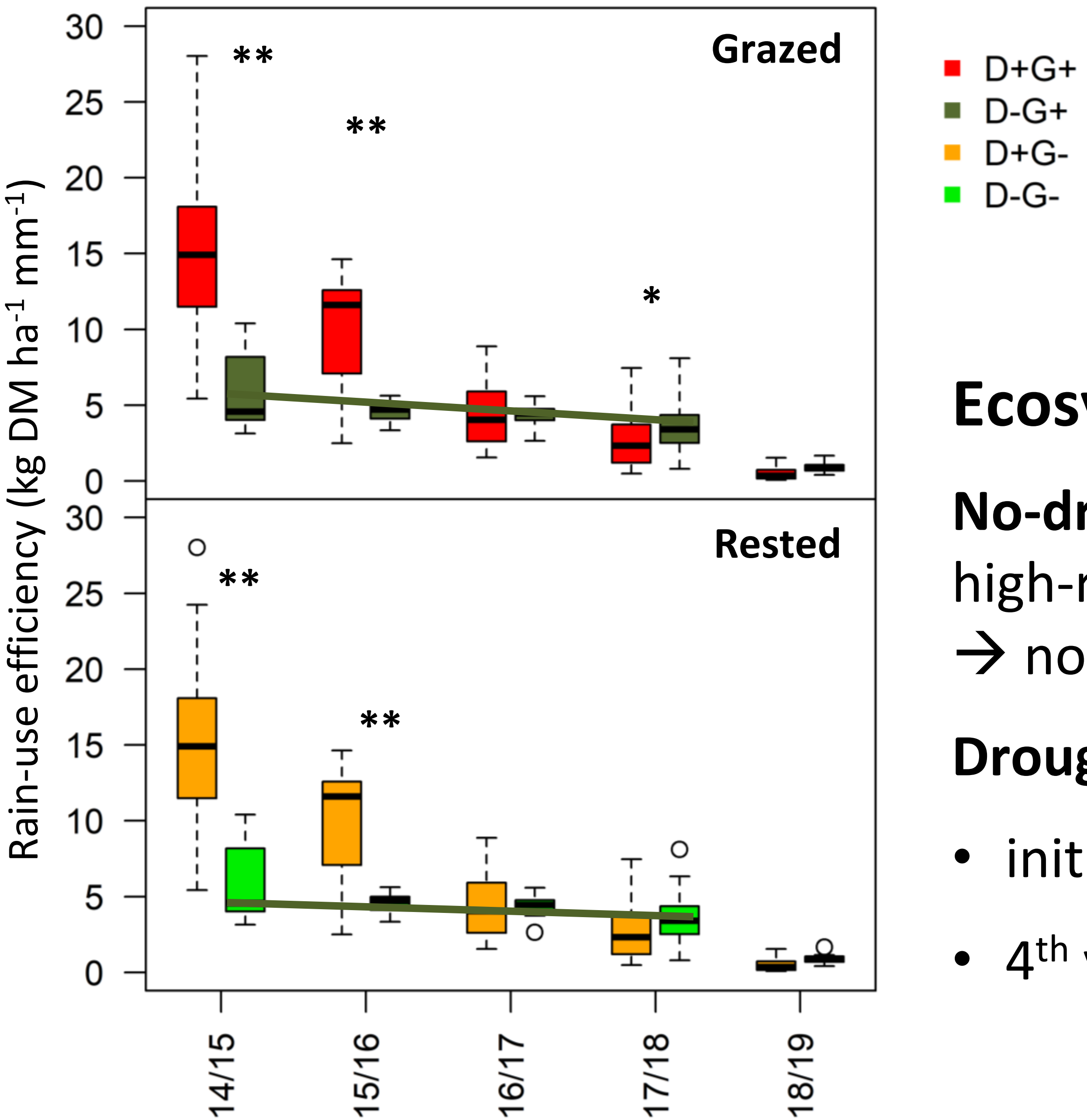




Temporal fit (Year 1-5)

- Altered ecosystem state (lower intercept) both under grazed and rested conditions → clear signal of degradation; in line with expectation
- Clear signal due to the broad range of annual rainfall covered

Productivity-precipitation relationship: Rain-use efficiency



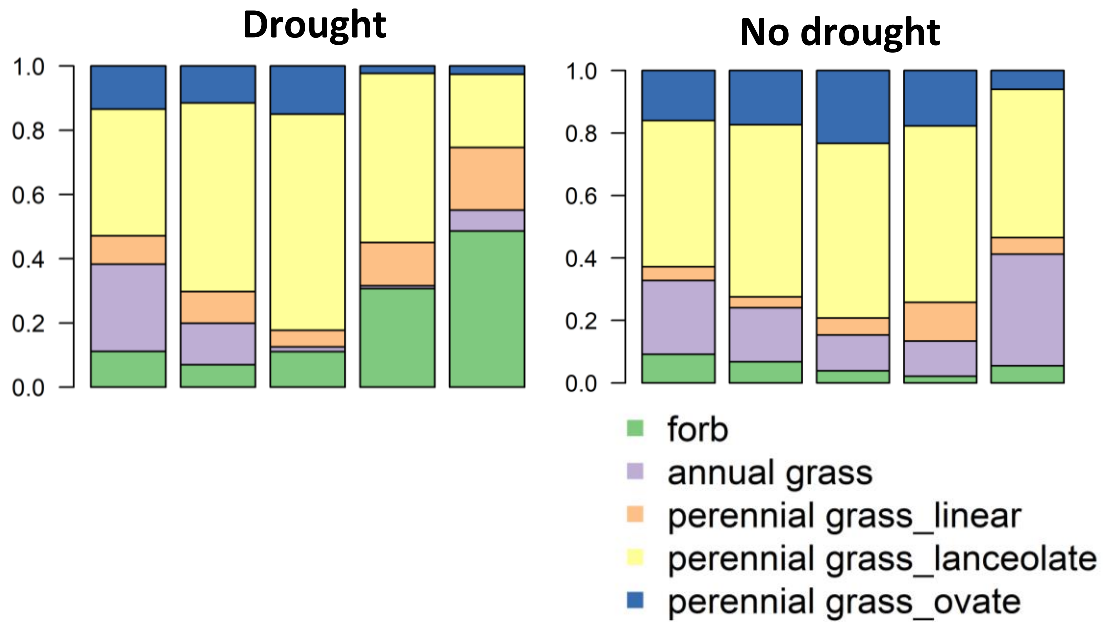
Ecosystem resistance

No-drought plots: little change in RUE, except for high-rainfall year 2018/19
→ no degradation

Drought plots:

- initially higher RUE (legacy effect?)
- 4th year with lower RUE → hints to degradation

A plant functional trait perspective on drought effects



Plant Functional Types (PFTs)

PFTs defined based on 1-3 functional traits[1]:

- Growth form (forb, grass)
- Life duration (annual, perennial)
- Leaf width (linear, lanceolate, ovate); correlated with stress tolerance[1,2])

Losers

- Palatable, broad-leaved perennial grasses

Winners

- Narrow-leaved perennial grasses (stress-tolerant)
- Forbs (stress-tolerant/pioneer plants)

→ Functional shifts towards undesired rangeland state

[1] Linstädter et al., PLOS One 2014
[2] Pierce et al., Funct Ecol 2017

How to manage a rangeland during and after drought?

1.) “Avoid losing your perennials”

Our findings: Loss of perennials may be triggered by overgrazing during drought and by too early grazing after drought[1,2]

Management implications: Rest rangelands during drought and in the post-drought year to avoid degradation

Policy implications: Current drought mitigation by governments/ NGOs (fodder subsidies during drought) may be unsustainable

→ Support local livestock breeders by providing /subsidizing supplementary feed during AND after droughts[1]

[1] Müller et al., Agric Syst 2015
[2] Pfeiffer et al. , Ecol Modelling 2019

How to manage a rangeland during and after drought?

2.) “Be aware of overresting”

Moribund biomass

Build-up of old (“moribund”) biomass after two years of resting[1]

→ Self-shading, reduces plant fitness (= individual biomass production)[2]

[1] Mudongo et al. in prep.
[2] Zimmermann et al., Oecologica 2015

How to avoid overresting

Management implications:

- Attune resting periods to the condition of your rangeland[1]
- Use moribund plant biomass as indicator for overresting[1,2]

Ideas for extension services:

- Provide capacity building on the role of overresting
- Support local communities in maintaining ≥ 3 water points to facilitate rotational grazing & avoid underutilization
- Support local communities in developing own enforcement strategies

[1] Mudongo et al. in preparation
[2] Zimmermann et al., Oecologica 2015

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Thank you!

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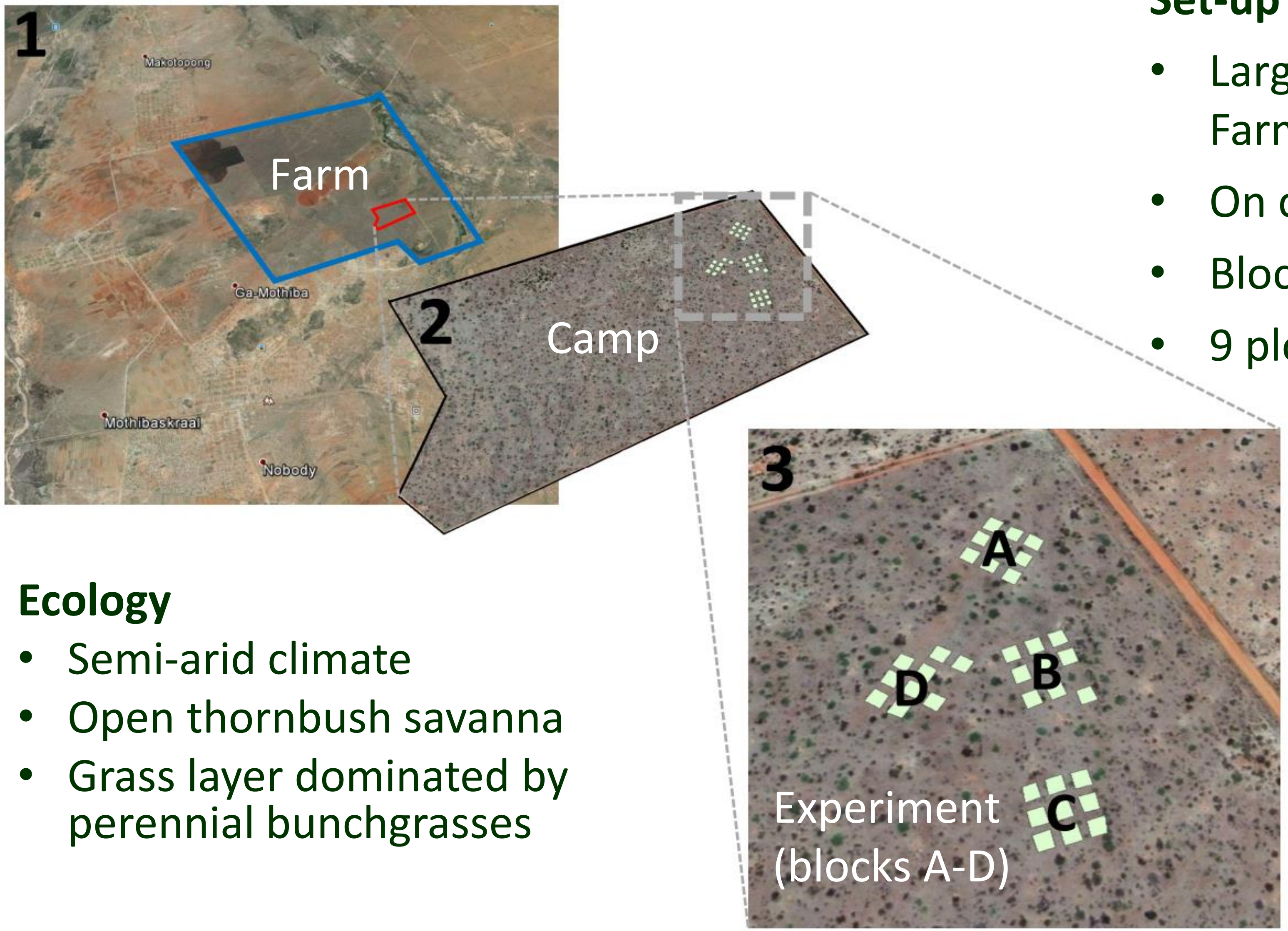
DroughtAct experiment: Set-up and ecology



Set-up

- Large field experiment (Experimental Farm, University of Limpopo)
- On camp with moderate cattle grazing
- Block design (4 blocks)
- 9 plots (100 m^2) per block

Ecology

- Semi-arid climate
- Open thornbush savanna
- Grass layer dominated by perennial bunchgrasses

Assessing changes in ecosystem functions & services

1. Ecosystem functions

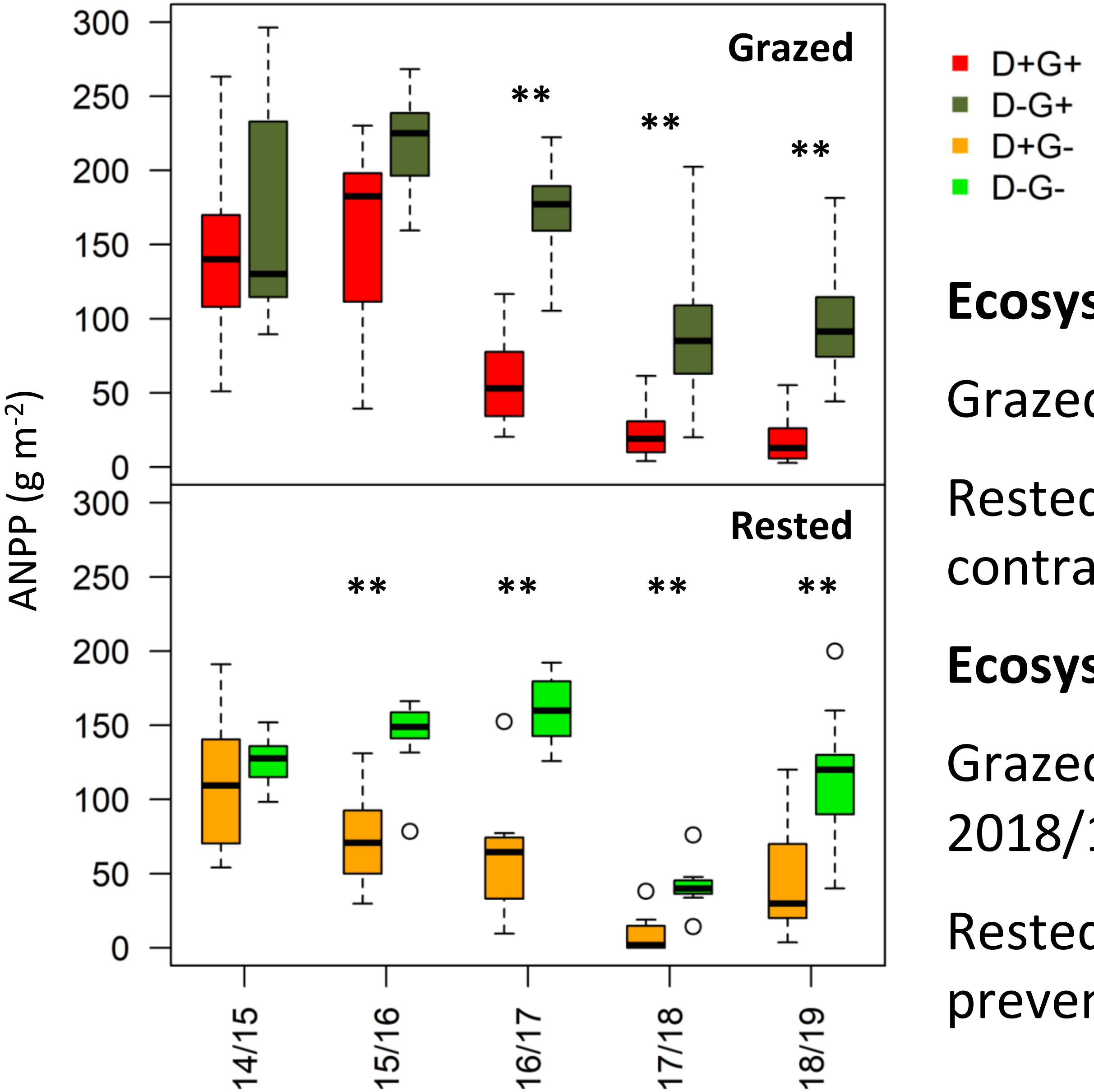
- Grass layer productivity (ANPP)
- Rain-use efficiency (RUE)
- Composition & diversity of plant communities
- Composition & diversity of ant and spider communities*
- Litter decomposition rates

2. Ecosystem services

- Forage quantity
- Forage quality, cattle diet composition*
- Soil fertility*
- Carbon storage

* In collaboration with South African partners from SALLnet

Responses of aboveground net primary production (ANPP)



Ecosystem resistance (Years 1-4)

Grazed plots: Breakdown in 3rd drought year

Rested plots: Breakdown in 2nd drought year → contrary to H2

Ecosystem resilience (Year 5)

Grazed plots: No recovery in exceptionally wet year 2018/19 → regime shift to desertified state?

Rested plots: Better recovery → resting might have prevented regime shift