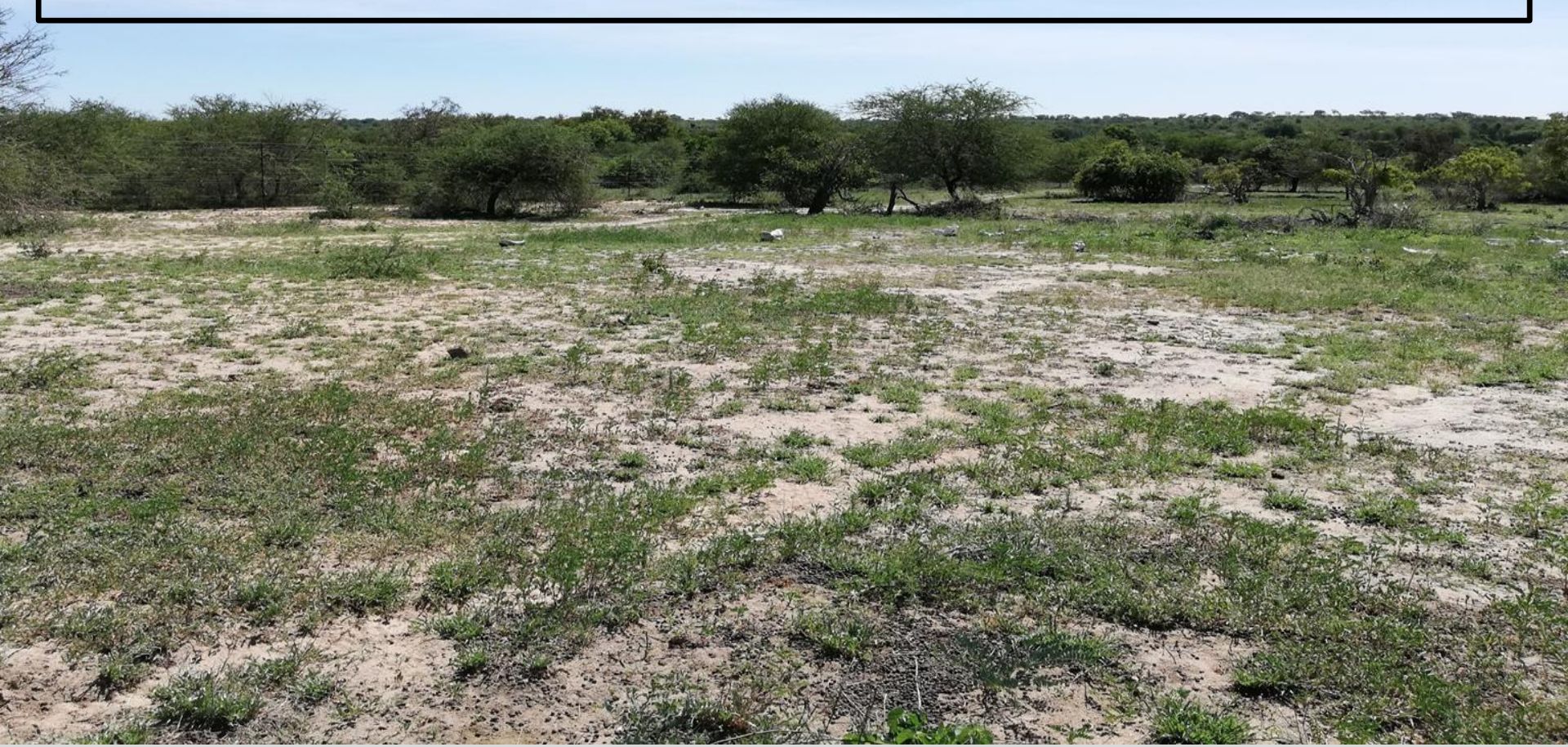
Large mammals mediate soil characteristics in a nutrient-rich sodic savanna



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Introduction

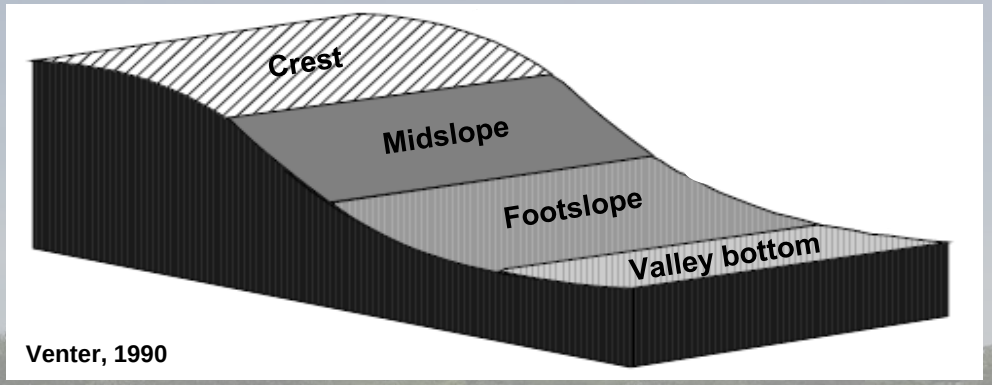
- **Aboveground responses to top-down controls such as fire and large mammalian herbivores (LMH)**
- **LMH biodiversity loss – focus almost exclusively on these aboveground responses** (Forbes *et al*., 2019)
- **Feedbacks between producer, consumer and decomposer subsystems**
  - Combined above-and belowground approach (Bardgett & Wardle, 2003)
- **Savanna ecosystem dynamics**
  - Water availability, soil nutrients, fire and herbivory (Augustine, 2003; Sankaran *et al*., 2008; Yu & D'Odorico, 2015)
- **Altered by anthropogenic activities**
  - Loss of large-bodied wildlife, particularly taxa of large mammalian herbivores (LMH)
  - Impact the functioning of savanna ecosystems worldwide (Fuhlendorf & Engle, 2001; Koerner *et al*., 2014; Daskin *et al*., 2016; Smith *et al*., 2018; Forbes *et al*., 2019)

Introduction

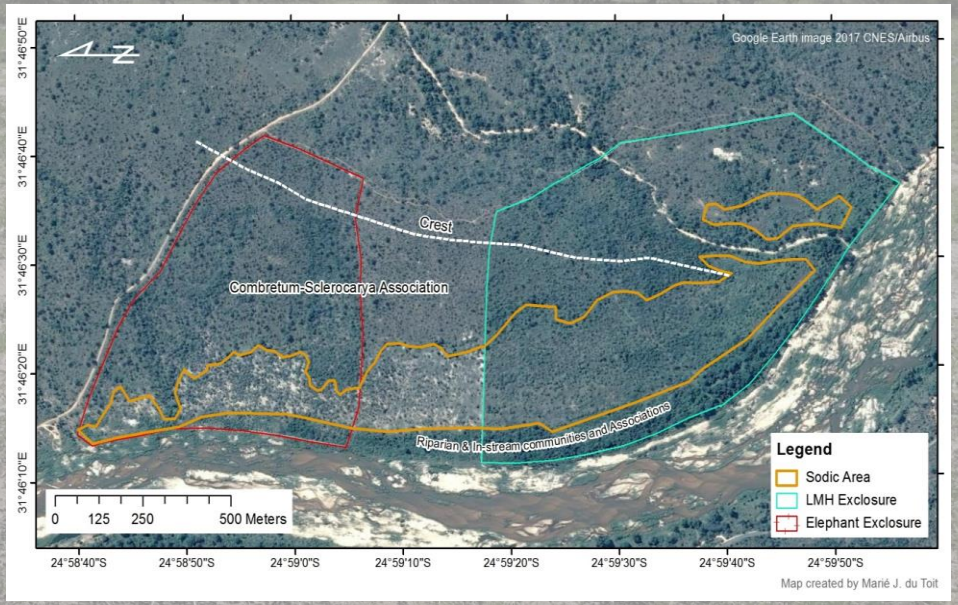
- **Reduced grazing pressure**
  - Restore and improve natural resources such as soil nutrients and vegetation biomass of degraded semi-arid ecosystems (Descheemaker *et al*., 2006; Mekuria *et al*., 2007; O'Connor, 2015)
- **However,** extensive exclosure experiments – little consensus on wild large herbivore effects on ecosystem function (Forbes *et al*., 2019)
- **Furthermore,** there is limited information available on whether long-term herbivore exclusion positively affects bottom-up controls such as soil chemical properties (Mekuria *et al*., 2007)
- **Poor physical soil conditions impede plant growth** (Bailey & Scholes, 1997; Khomo & Rogers, 2005; Davis *et al*., 2012)
- **Nevertheless,** nutrient-rich vegetation growing on sodic soil favoured and intensely utilised (Tarasoff *et al*., 2007; Levick & Rogers, 2008)
- **Semi-arid sodic patches expected to change over short time scales aboveground** (Khomo & Rogers, 2005)

Sodic patches

- **Represent 518 million hectares globally** (Eskandari *et al*., 2018)
- **Landscapes derived from sodium-releasing parent material such as granite** (Dye & Walker, 1980; Khomo & Rogers, 2005)
- **Associated with footslopes of catenas in semi-arid southern Africa** (Dye & Walker, 1980; Venter, 1990; Bailey & Scholes, 1997; Khomo & Rogers, 2005)
- **Duplex soil with a high clay content and proportion of Na to Ca, Mg and K** (Fensham *et al*., 2007)
- **pH >8.5 and EC <4 dS/m** (Ogle, 2010)



Venter, 1990

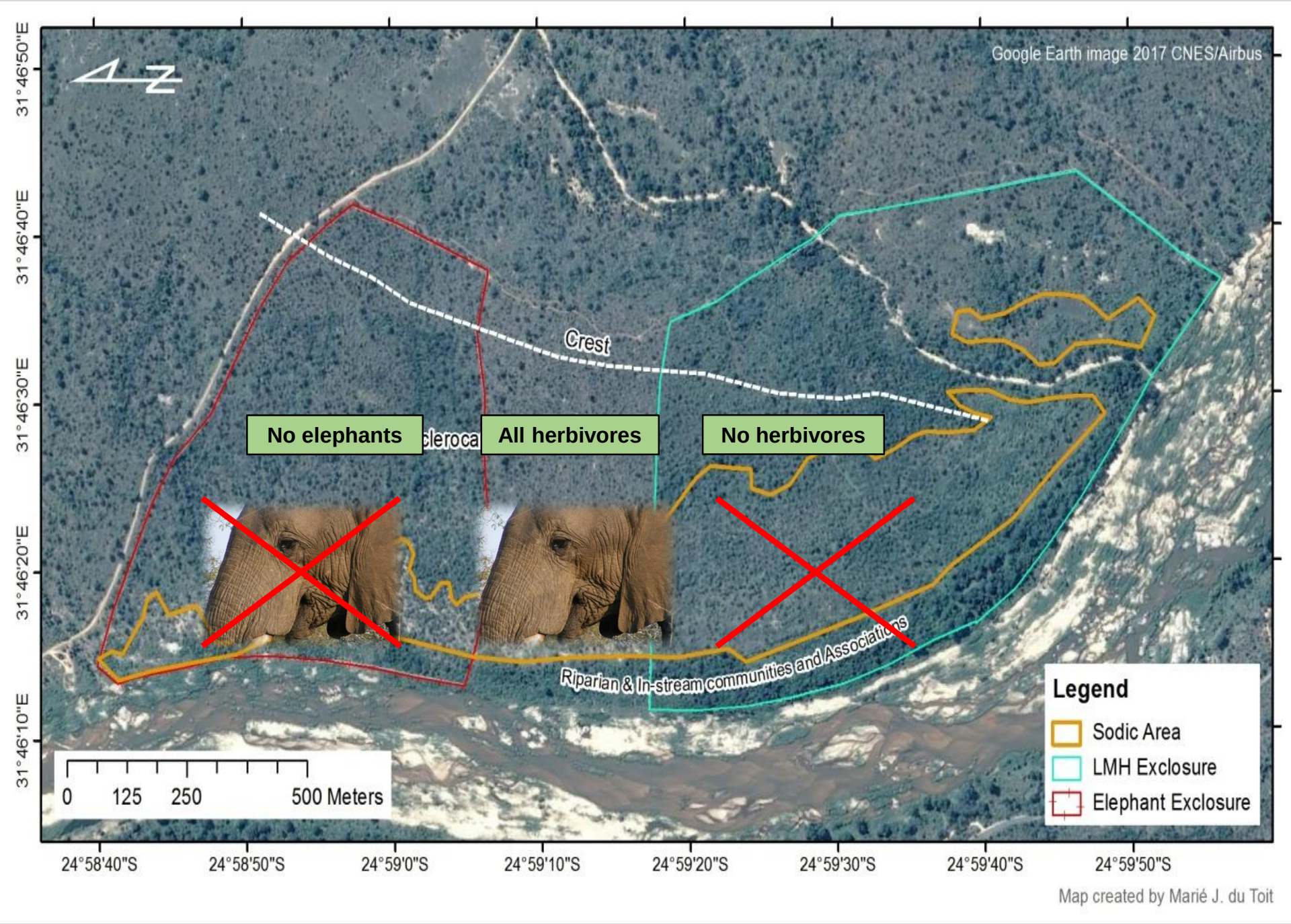


Sodic patches

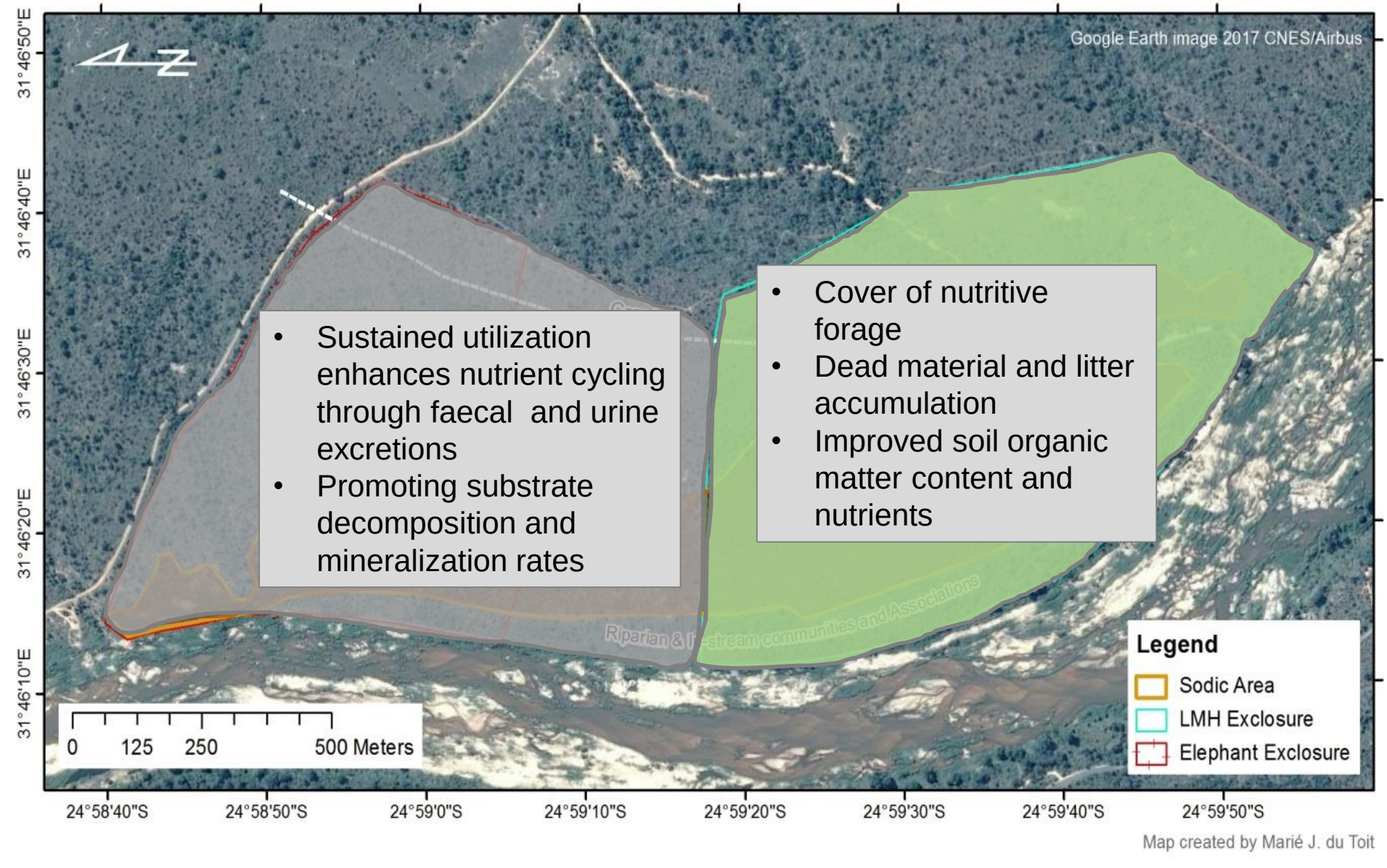
- **Reduced grazing pressure**
  - Significant increases in standing biomass and dead moribund grass material (Jacobs & Naiman, 2008; Van Coller *et al*., 2013)
  - Cover of tall, perennial palatable grasses (Guo, 2004; Sasaki *et al*., 2009; Teague *et al*., 2011; Van Coller & Siebert, 2019)

- **Moderate grazing pressure**
  - Herbivores congregate for dietary salts and increased predator vigilance (Venter, 1990; Bailey & Scholes, 1997; Khomo & Rogers, 2005; Grant & Scholes, 2006)
  - Maintain herbaceous layer in open, palatable grazing lawn state

- **Sodic plant community shows distinct aboverground species and structural differences in response to herbivore treatments, mainly driven by herbivore exclusion** (Siebert & Eckhardt, 2008)


Google Earth image 2017 CNES/Airbus
Crest
No elephants
All herbivores
No herbivores
Riparian & In-stream communities and Associations
Legend
Sodic Area
LMH Exclosure
Elephant Exclosure
0 125 250 500 Meters
31°46'50"E
31°46'40"E
31°46'30"E
31°46'20"E
31°46'10"E
24°58'40"S
24°58'50"S
24°59'0"S
24°59'10"S
24°59'20"S
24°59'30"S
24°59'40"S
24°59'50"S
Map created by Marié J. du Toit

Research question and hypothesis



Methods

Soil samples (belowground):

- Composite soil samples (x3) were collected at each plot (*n* = 35)
- In the laboratory:
  - Samples were air-dried and sieved (2 mm mesh)
  - Soil chemical properties (e.g. pH, EC, soil organic matter (SOM), plant available cations and anions) were determined using the Handbook of standard soil testing methods for advisory purposes

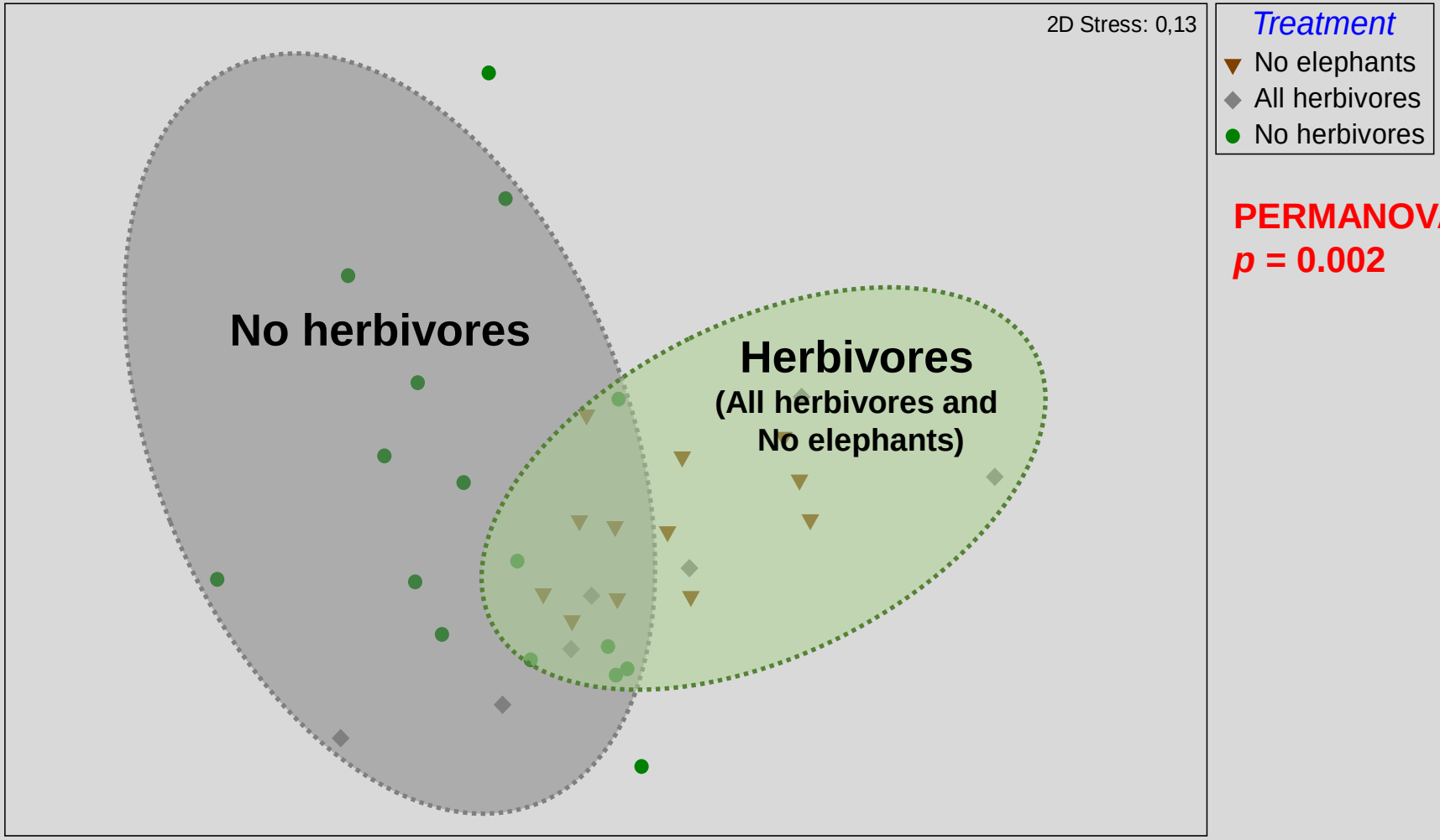
Biomass and debris (aboveground):

- Biomass was estimated by clipping 0.25 m^2 plots (*n* = 53)
- Debris/leaf litter was collected within the same plots
- In the laboratory:
  - Biomass was sorted according to life form (i.e. forbs and grasses)
  - Biomass and debris were dried, weighed and the weight was converted to kg/ha

Results

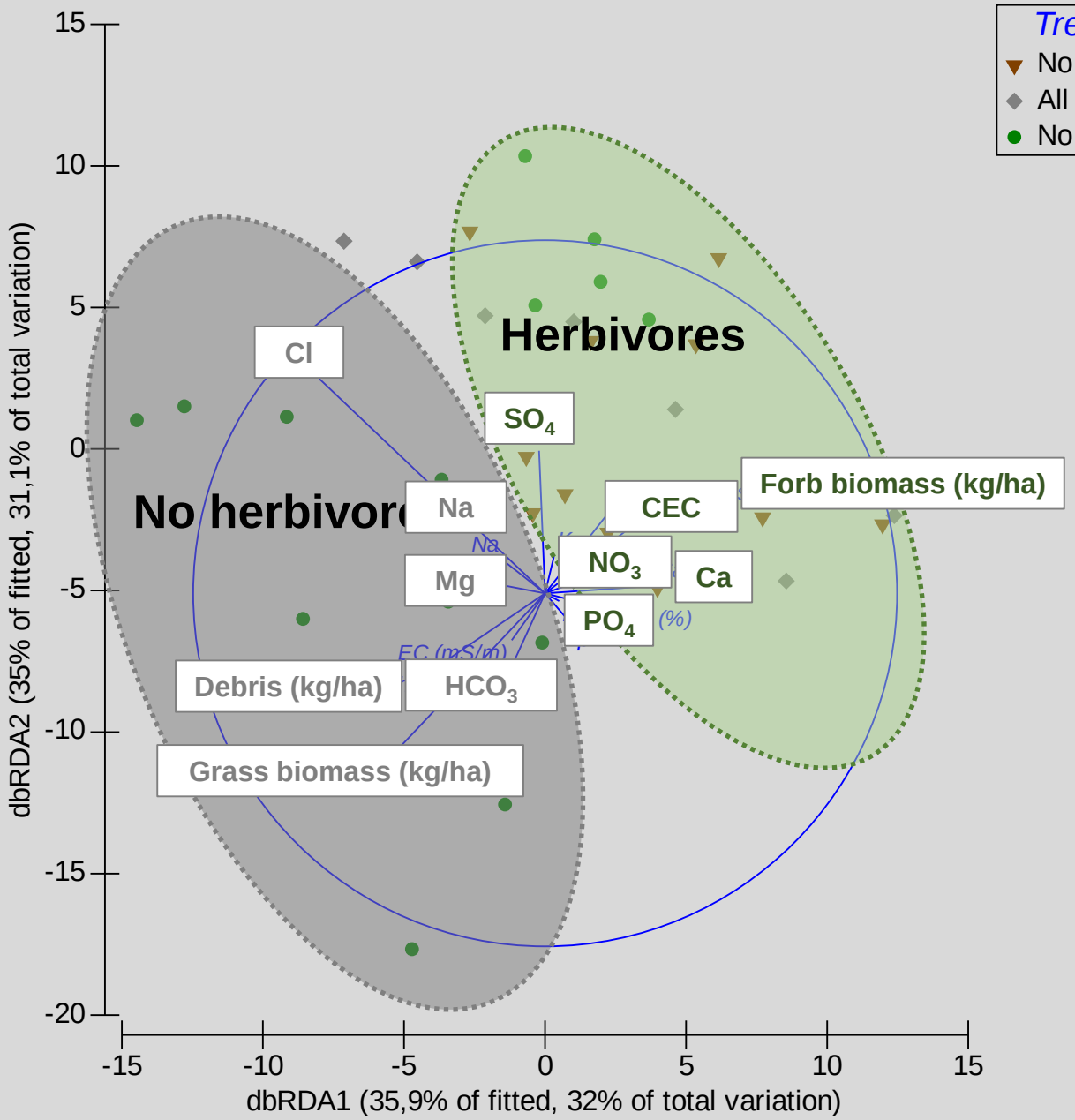
PAIR-WISE TESTS:

No elephants, All herbivores	$p = 0.141$
No elephants, No herbivores	$p = 0.001$
All herbivores, No herbivores	$p = 0.034$



PERMANOVA:
$p = 0.002$

Results



Distance-based linear models (DistLM): $p < 0.05$

Results

Results of one-way ANOVA	
Response variable	***p*-value**
Debris	< 0.001
NO_3	0.007
PO_4	0.152
Na	0.148
Mg	0.107
HCO_3	0.281
Cl	0.203
Grass biomass	0.063
SO_4	0.319
Forb biomass	0.135
Ca	0.085

Results

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Results

One-way ANOVA: $p < 0.001$

***Post-Hoc* Tukey test**:
All herbivores vs No elephants: $p = 0.019$

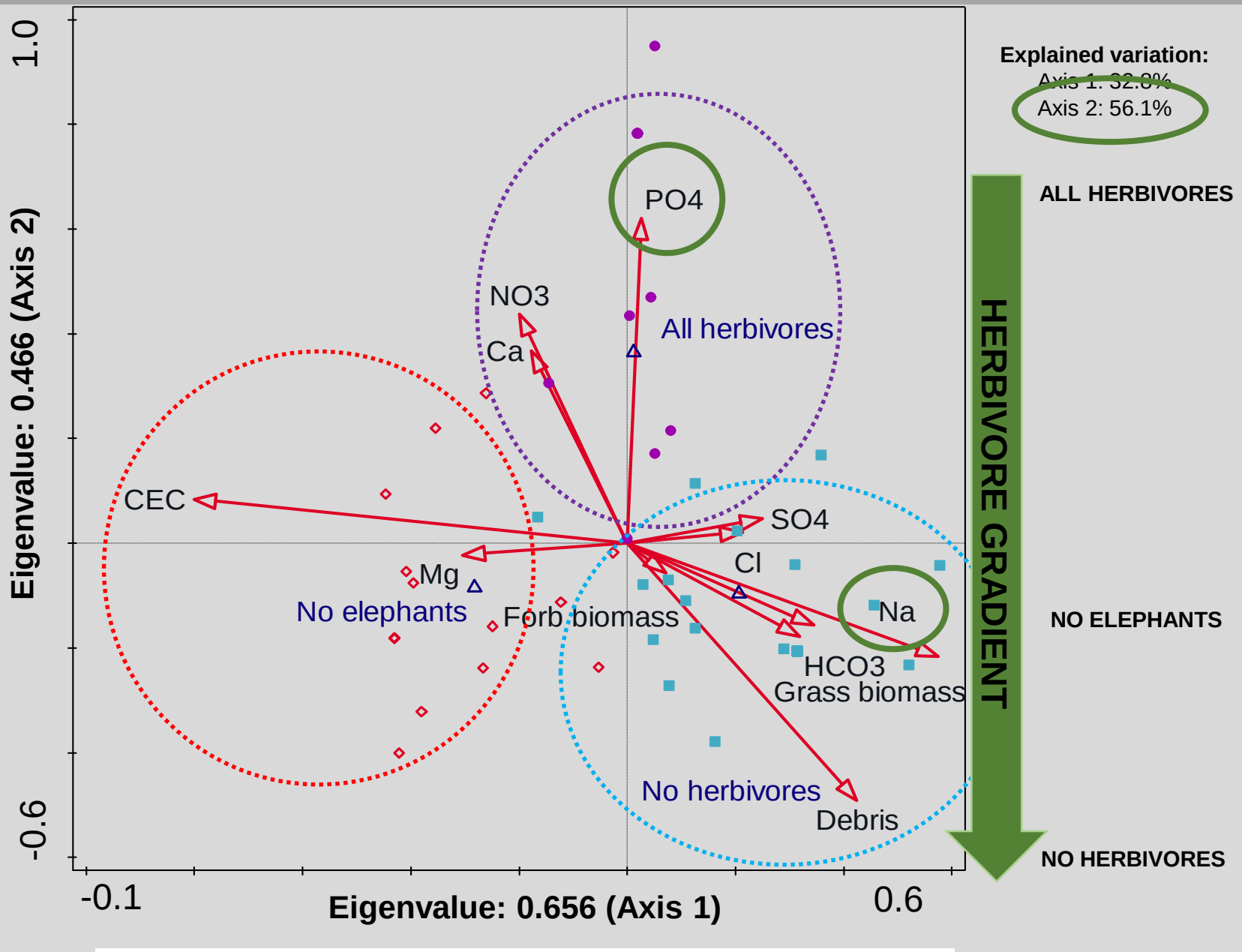
All herbivores vs No herbivores: $p < 0.001$

No elephants vs No herbivores: $p = 0.059$

Results

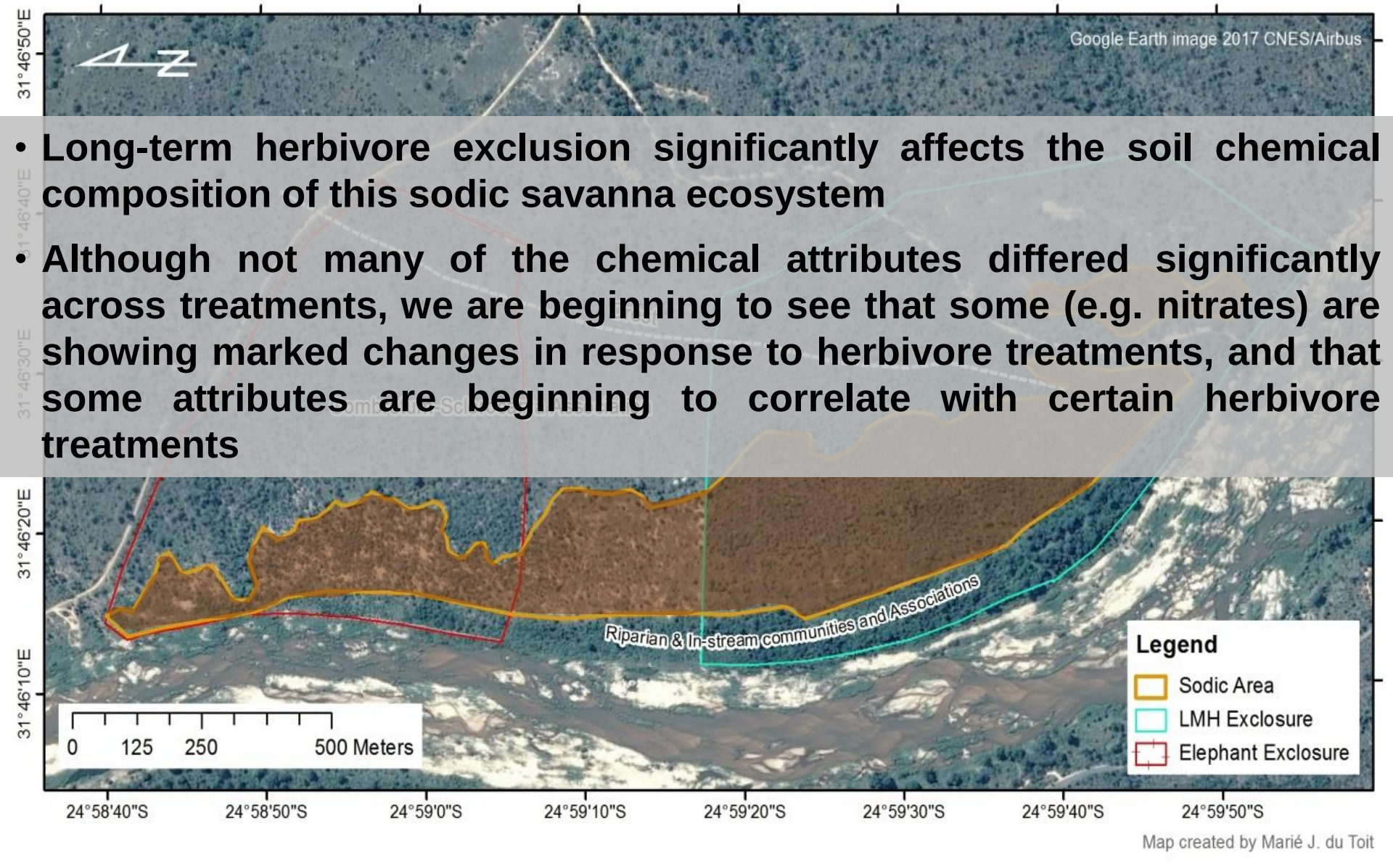
- **LMH shift plant allocation of nutrients to roots leading to increased microbial activity and soil nitrogen mineralization**
(Ruess & McNaughton, 1987)

Results


Explained variation:
Axis 1: 32.8%
Axis 2: 56.1%
ALL HERBIVORES
NO ELEPHANTS
NO HERBIVORES
HERBIVORE GRADIENT
PO4
NO3
Ca
All herbivores
CEC
SO4
Cl
Mg
No elephants
Forb biomass
Na
HCO3
Grass biomass
No herbivores
Debris
1.0
-0.6
Eigenvalue: 0.466 (Axis 2)
-0.1
0.6
Eigenvalue: 0.656 (Axis 1)
No elephants
All herbivores
No herbivores

Conclusions

- **Long-term herbivore exclusion significantly affects the soil chemical composition of this sodic savanna ecosystem**
- **Although not many of the chemical attributes differed significantly across treatments, we are beginning to see that some (e.g. nitrates) are showing marked changes in response to herbivore treatments, and that some attributes are beginning to correlate with certain herbivore treatments**

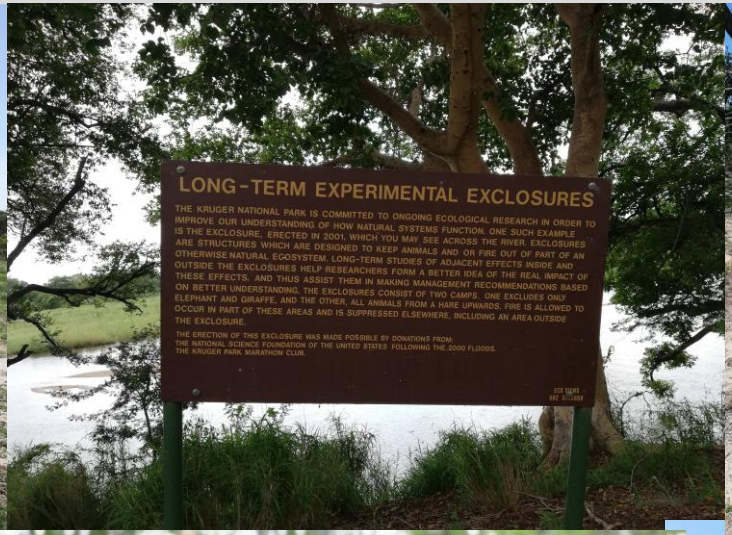


Implications for conservation

- **Findings from this study may enable decision makers to be prepared for and better understand the anticipated increasing changes in top-down savanna drivers such as LMH, and how these changes could affect the bottom-up controls of semi-arid savanna ecosystems**

Thank you

Botany 2020
100 YEARS



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