Perennial forage species and soil microbial nitrogen transformations in East Africa: implications for climate-smart agriculture

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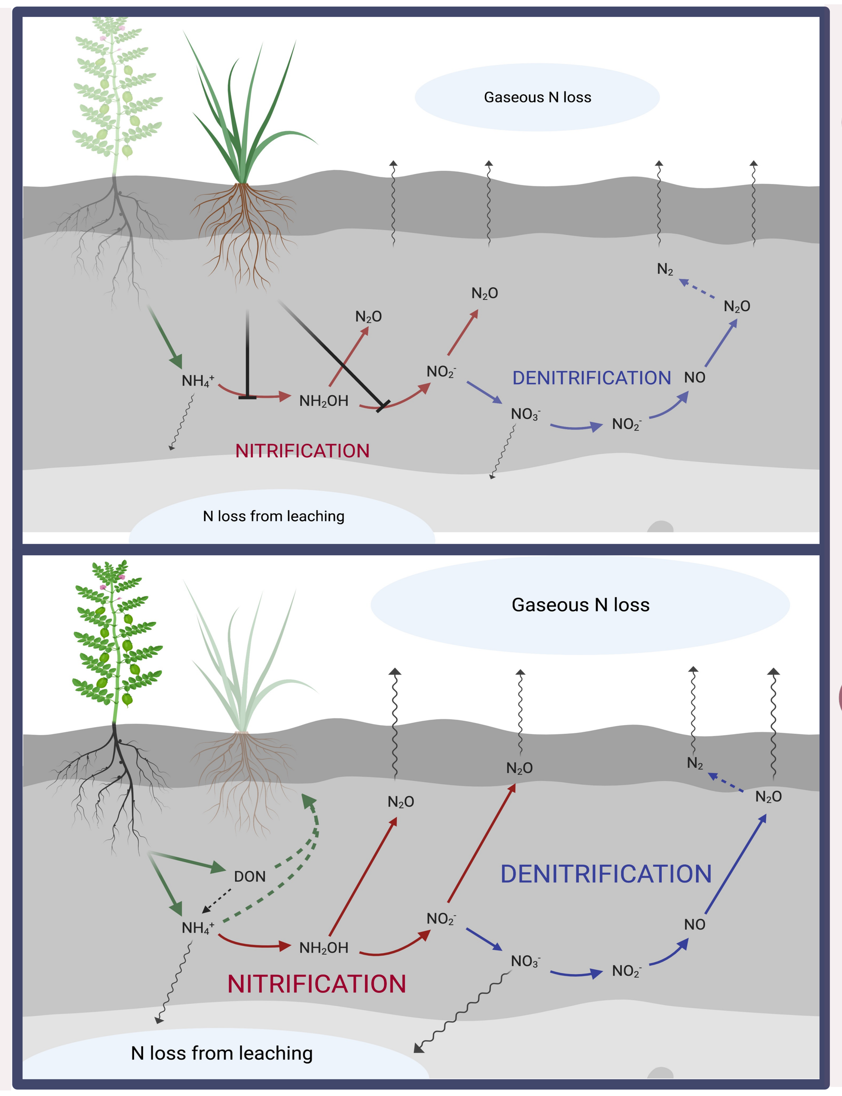
Introduction

- Shifting to low-nitrifying cropping systems can reduce nitrous oxide (N_2O) emissions and prevent the loss of leachable mineral nitrogen (N) in low-fertility soils.
- **Climate-smart forages are thought to retain soil-N, yet this has not been verified in field conditions that include seasonal variations in soil moisture and frequent defoliation.**

Brachiaria prevents potential **N loss** through **biological nitrification inhibition (BNI).** Intensive harvesting can result in yield declines in unfertilized pastures.

Perennial forage **legumes (*Desmodium distortum*)** may promote soil fertility as an intercrop. However, legumes are known to affect nitrifying and denitrifying microbial communities with a potential to increase N_2O emissions[1].



Expected Results

1. ***Brachiaria*** will limit potential sources of N-loss by lowering nitrifier and denitrifier enzyme activity relative to the baseline (*C. purpureus*). Perennial crops will also exhibit lower NP and DEA relative to farmer-preferred annual maize.
2. **A legume intercrop** will increase NP and DEA compared to monocrop treatments. DEA will increase in the rainy season and NP activity will be greatest in the dry season.

Research Questions

1. **Does the climate-smart forage *Brachiaria* reduce potential N loss** from microbial pathways compared to preferentially grown non-BNI forage crops such as Napier grass (*Cenchrus purpureus*) or annual maize *(Zea mays)*? To what extent is this effect mediated by season?
2. **Are nitrification and denitrification stimulated** by the presence of a perennial forage legume (*Desmodium*) intercrop?

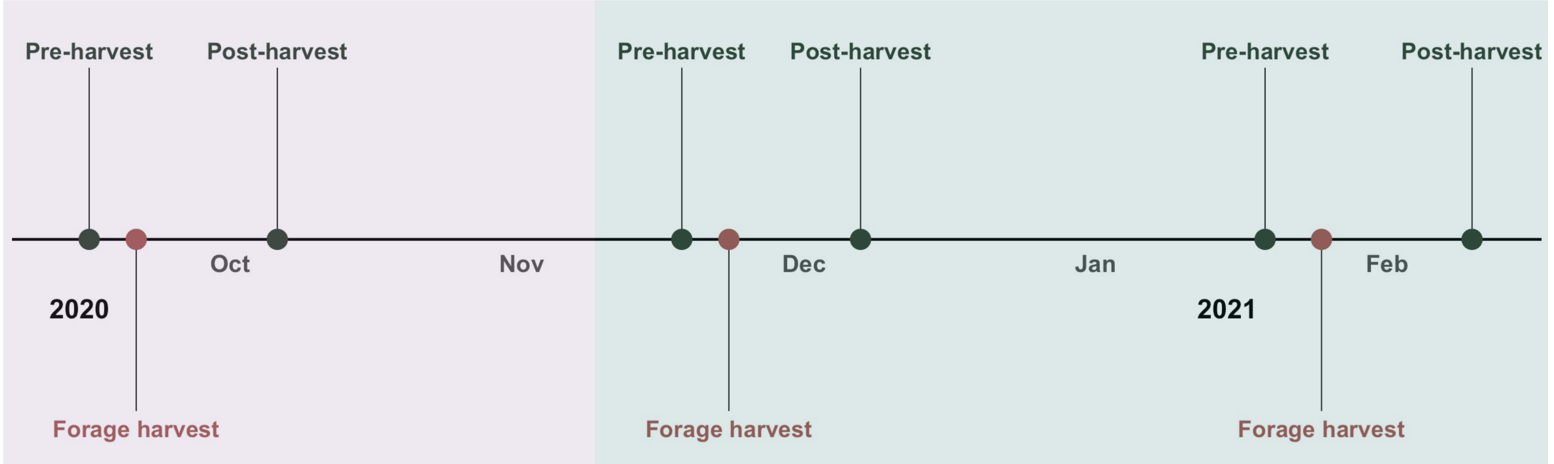
Methods

Forage Treatments

Study Locations

Forage trials were planted in October 2019 and harvested every ~8 weeks since establishment. Maize was not harvested during the course of data collection.

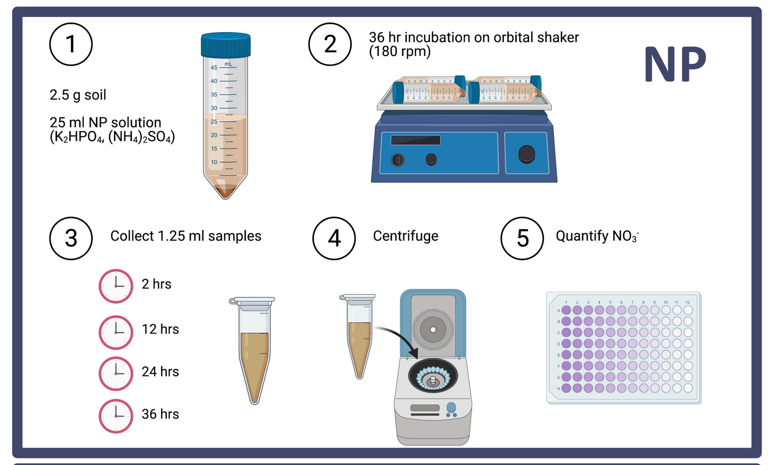
Soil Sampling

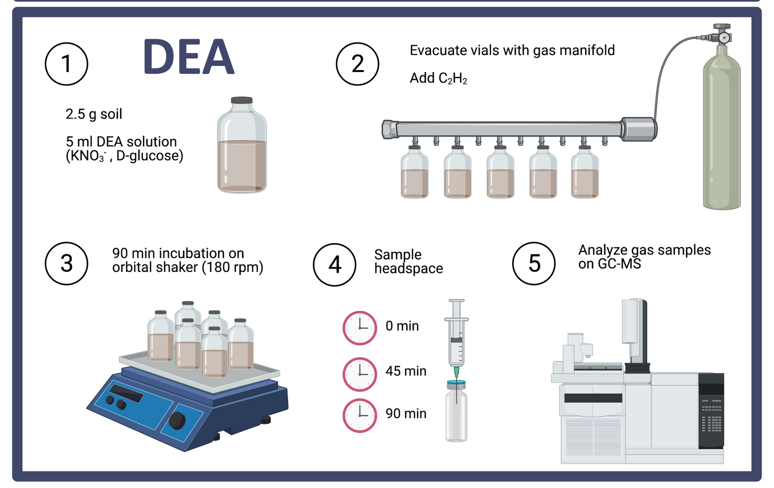


Bulk soil was collected to a depth of 12cm after removing the top layer of leaf litter. Soil was collected six times at each location between September 2020 and March 2021. These sampling events spanned both dry and rainy seasons, occurring immediately before and two weeks following forage harvest to account for contrasting periods of crop N demand.

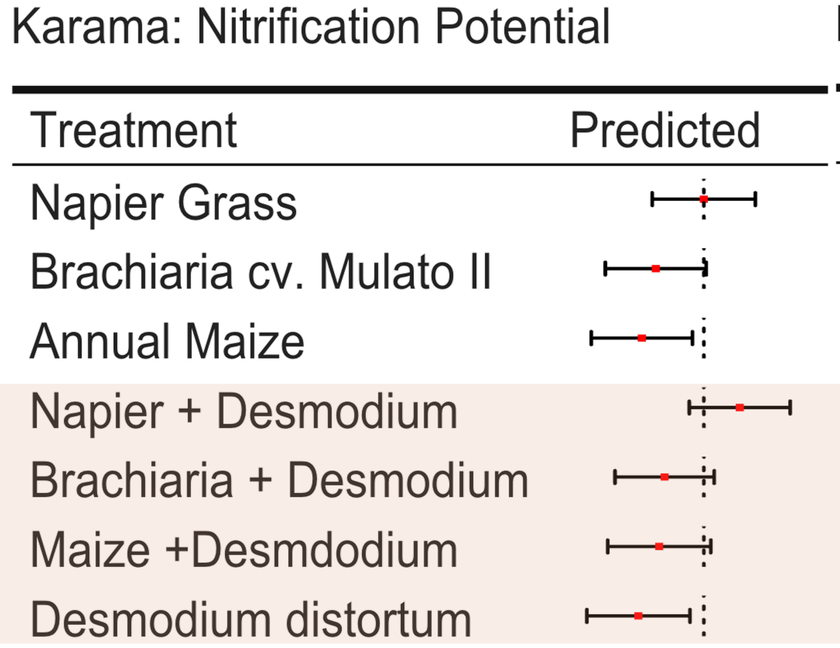
Soil Analyses

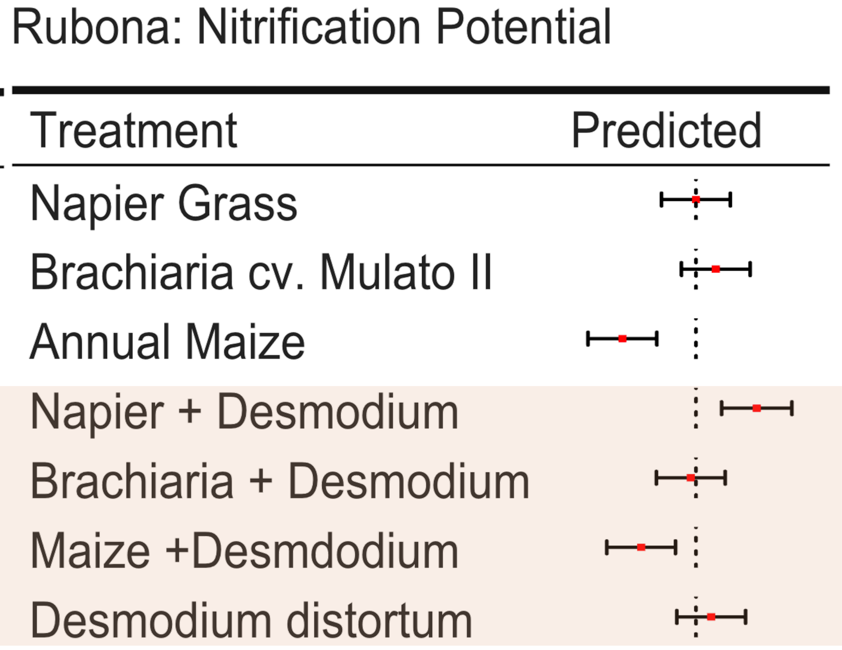
- NH_4^+-N, NO_3^--N
- Potentially mineralizable Nitrogen
- Permanganate - Oxidizable Carbon
- Nitrification Potential
- Denitrification Enzyme Activity





Results

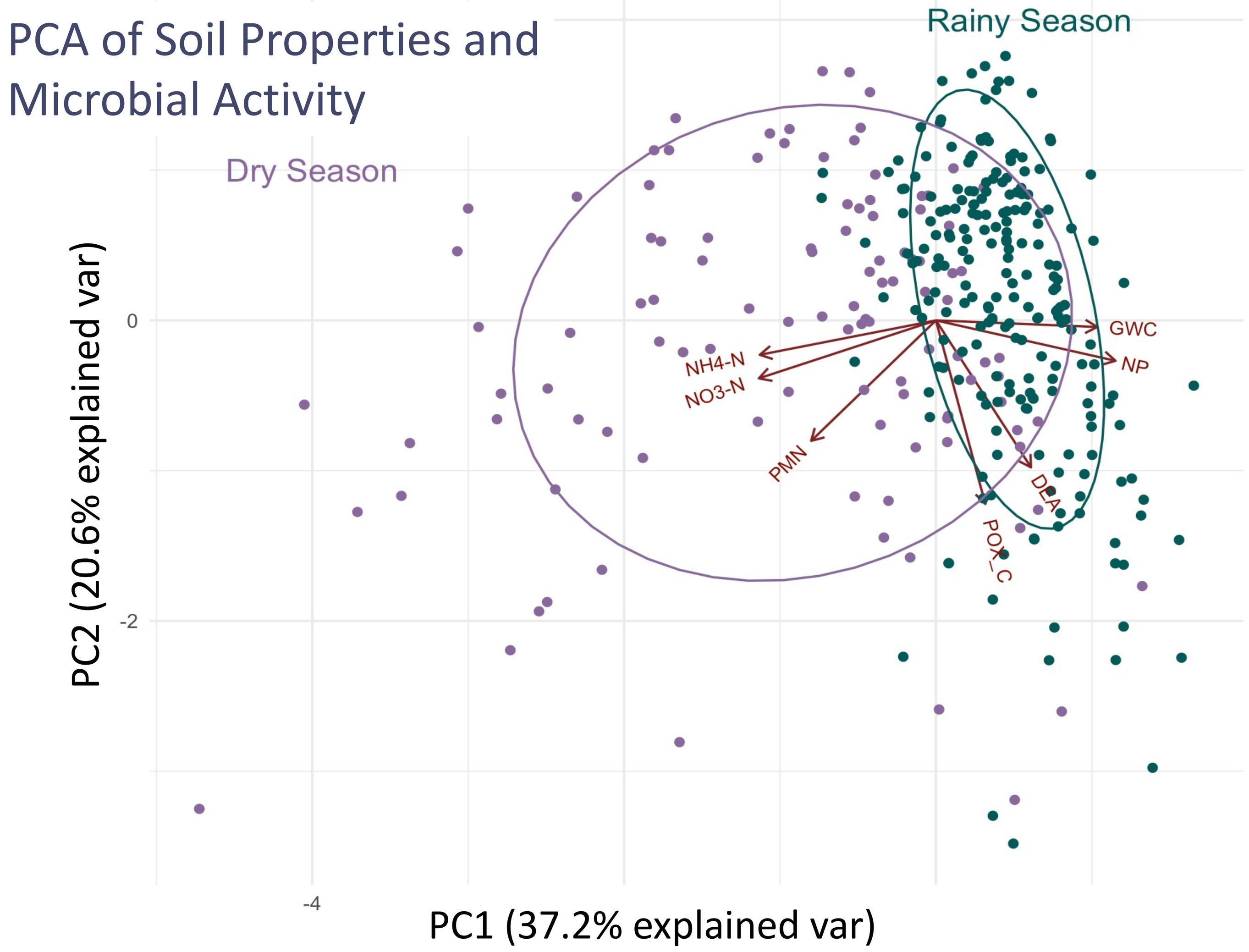




Predicted value is defined as the estimated marginal means of treatment effects from a mixed effects linear model. Treatment and collection timepoint were both treated as fixed effects, with block and timepoint as random effects. **Dashed vertical line: marginal mean effect of the Napier grass (*C. purpureus*) monocrop treatment, which as treated as the control group.**

- *Brachiaria* did not significantly decrease NP in either location compared to Napier (*C. purpureus*).
- Maize tended to have lower nitrification (NP) (Rubona: $p<.05$; Karama: ns) and denitrification (DEA) potential activity compared to Napier (Rubona: $p<.05$; Karama: ns).
- Legume intercropping did not increase NP or DEA relative to monocrop treatments.
- Forage growth stage had a significant effect on NP in the rainy season (Rubona & Karama: $p<.001$) but not the dry season (Rubona & Karama: ns).

PCA of Soil Properties and Microbial Activity



- Soil moisture was a strong driver of N dynamics and microbial activity, regardless of location or planting treatment
- NP and DEA increased with soil gravimetric water content ($r=0.32$, $p<.001$; $r=0.2$, $p<.001$), even as putative leaching in the rainy season decreased min-N availability

Conclusion

Maize plots had low nitrification and denitrification activity compared to *Brachiaria* and Napier plots; this may be due to root-mediated effects on microbial activity from intensive forage harvesting[2]. **Legume intercrops did not stimulate NP or DEA compared to monocrops**, suggesting that they can provide N inputs without contributing to N loss. Intercropping BNI forage grasses with perennial legumes is a novel strategy to provide both N-retention and N-provision services in tropical agriculture. However, additional strategies beyond BNI crops may be necessary to conserve N during the rainy season in highly weathered soils.

Acknowledgements

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References

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