Diversity, structure, and function across global dry forests and savannas

Dr. John L. Godlee

THE UNIVERSITY of EDINBURGH
School of GeoSciences

Background

- Applied functional ecologist
  - Ecosystem productivity, biogeography, structure
  - Tropical savannas, dry forests, temperate woodlands

Open savanna, southwest Angola

- PhD (2021) at the University of Edinburgh
  - Biodiversity and ecosystem function in African savannas

- Currently a post-doc at the University of Edinburgh
  - SECO: Carbon dynamics and biogeography of the dry tropics

Ancient woodland, North Yorkshire

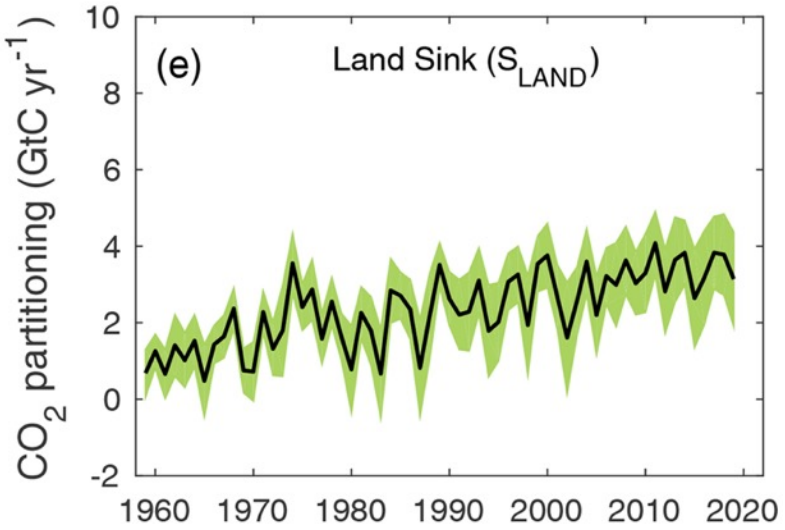
Motivations and approach

Grand challenges:

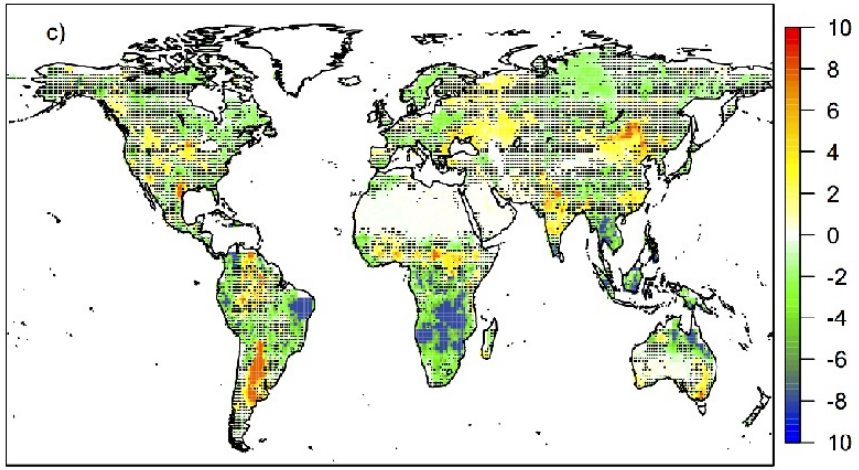
1. What is the role of terrestrial vegetation in global biogeochemical cycles?

- Long term demographic data.
- Environmental and geographic variation in carbon dynamics.

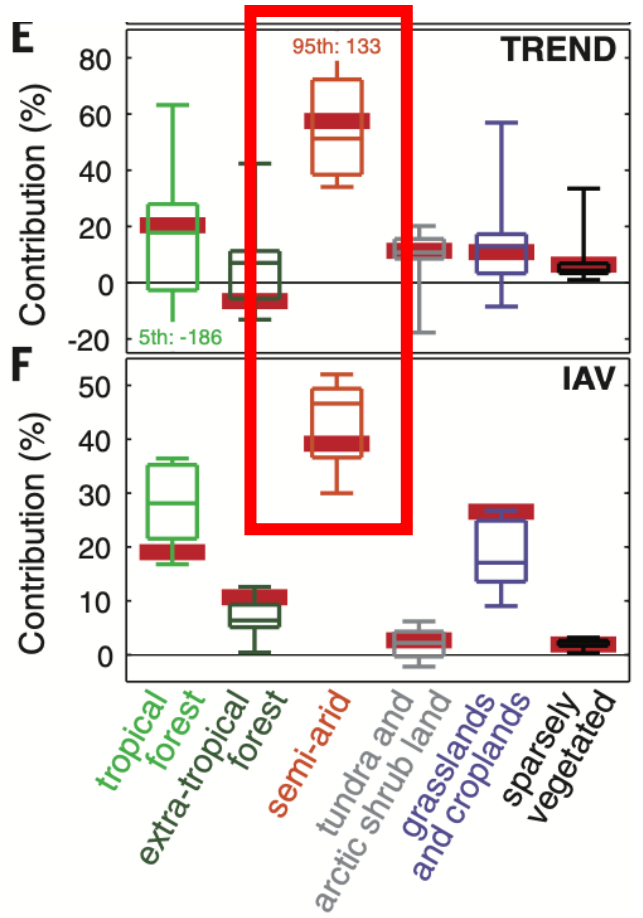
Models: increasing terrestrial carbon sink



Spatial variability in carbon flux trend



Uncertainty in trend and inter-annual variability of carbon sink



Ahlstrom et al. (2015), Sitch et al. (2015), La Quere et al. (2020)

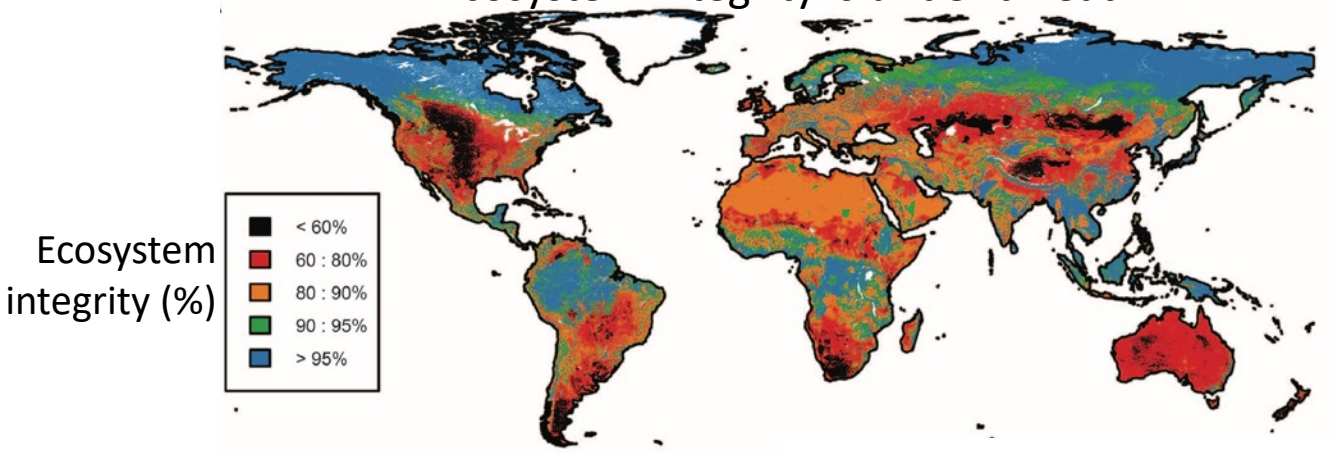
Motivations and approach

Grand challenges:

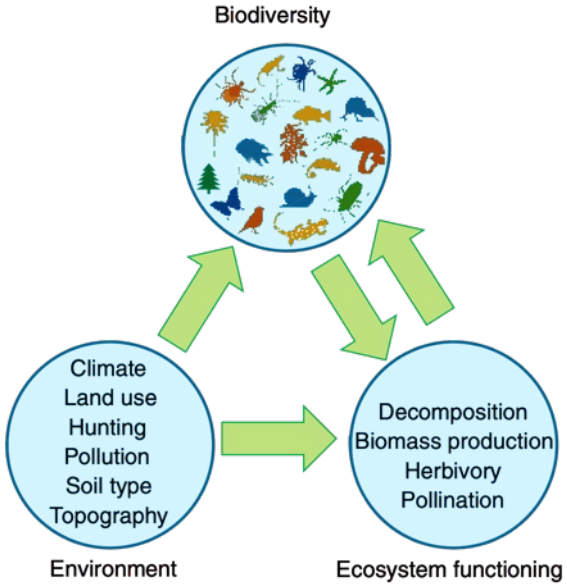
2. How do biodiversity, biogeography and environment jointly affect ecosystem structure and function?

- Remote sensing
- Global plot networks
- Modern field techniques

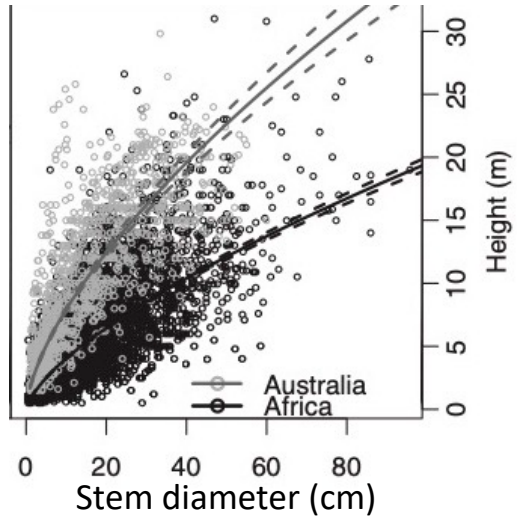
Ecosystem integrity is under threat

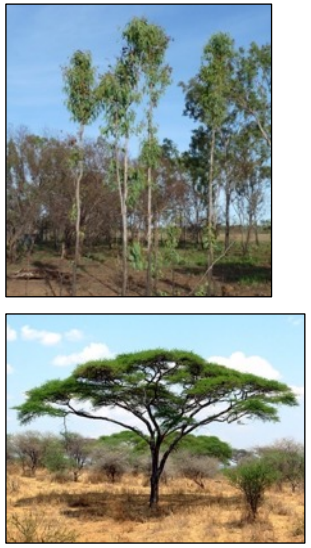


Complex biodiversity-function feedbacks



Biogeographic mediation of structure and function





Newbold et al. (2016), van der Plas (2019), Moncreiff et al. (2014)

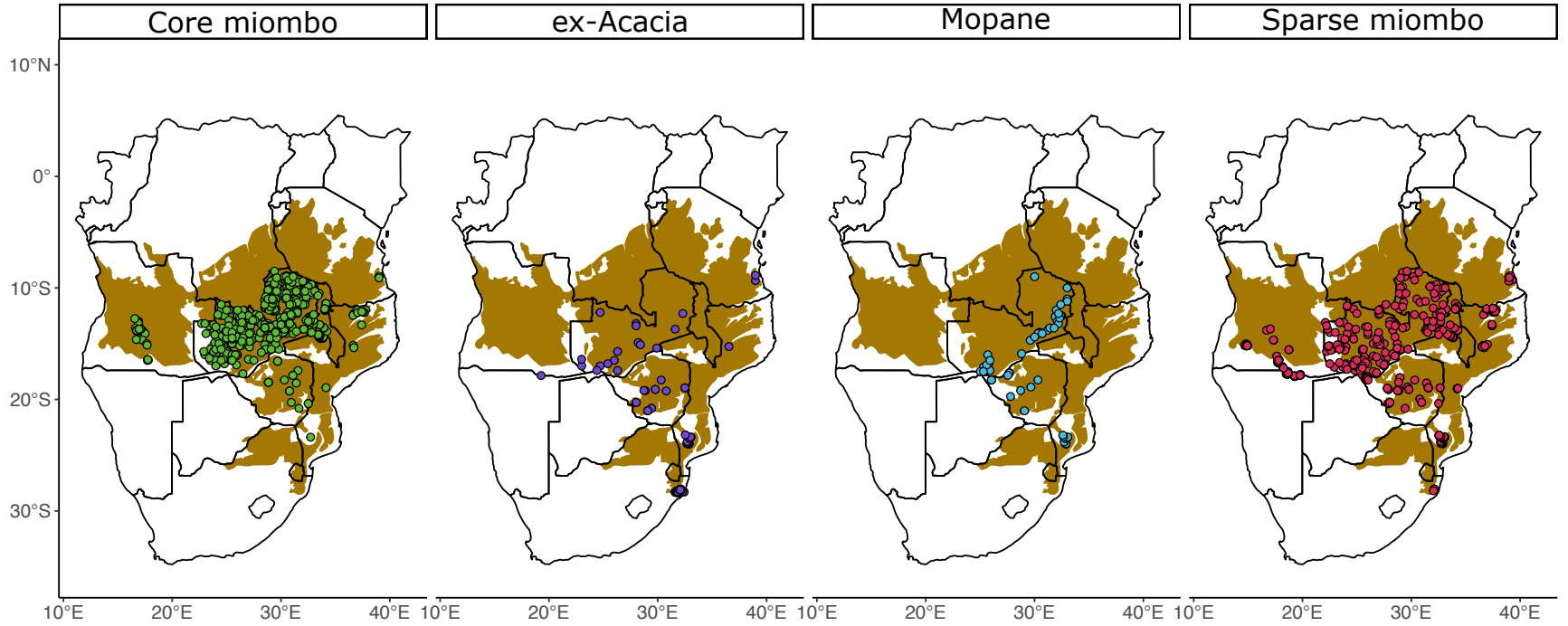
Previous and ongoing research:

Research strengths and impact

Determinants of woody biomass in African savannas

How do biodiversity and environment jointly affect woody biomass in African savannas?

SEOSAW



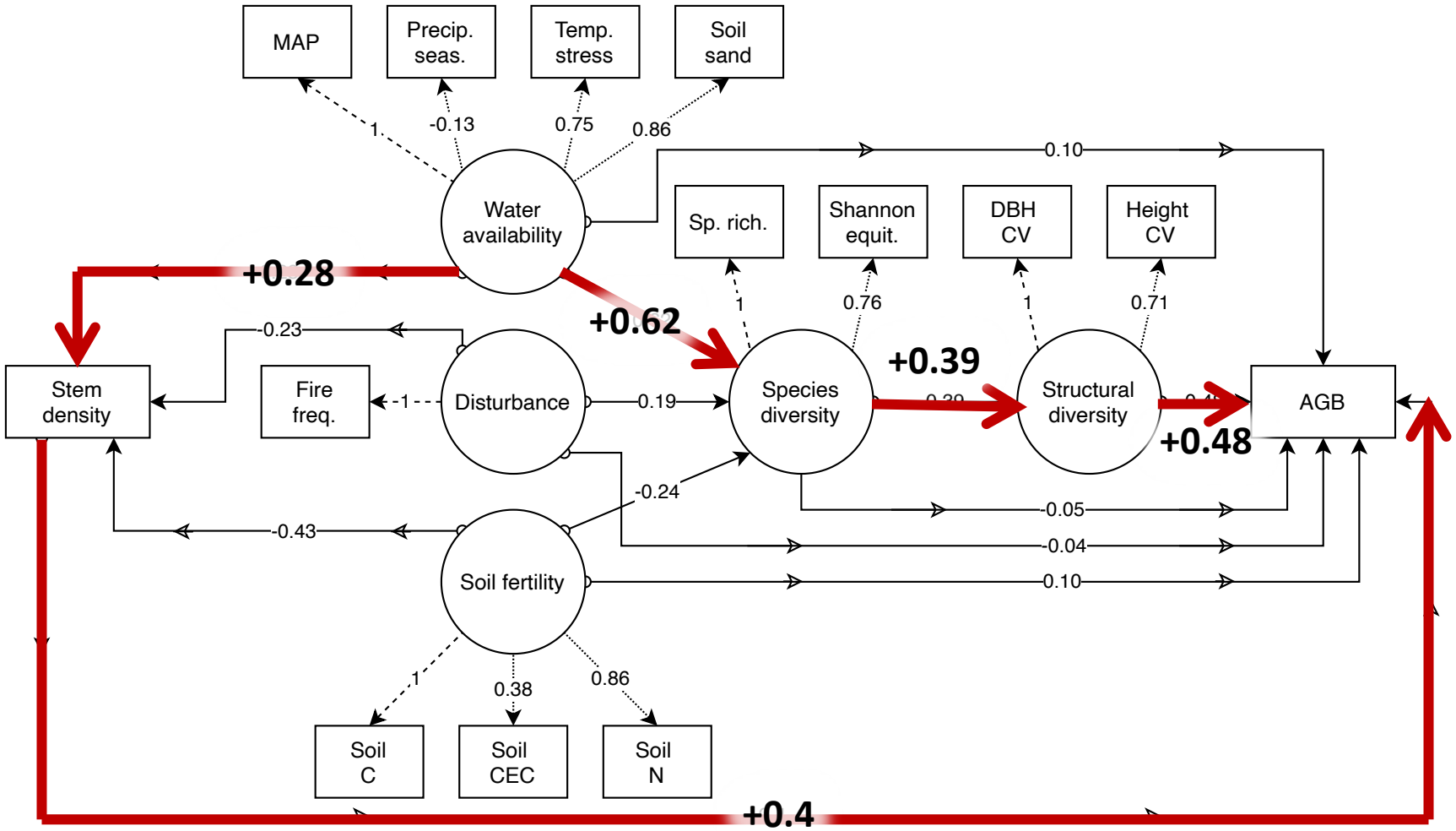
Godlee et al. (2021) *New Phytologist*

Determinants of woody biomass in African savannas

1. Water availability drives biomass via species diversity and stem density

2. Structural diversity as an axis of niche differentiation

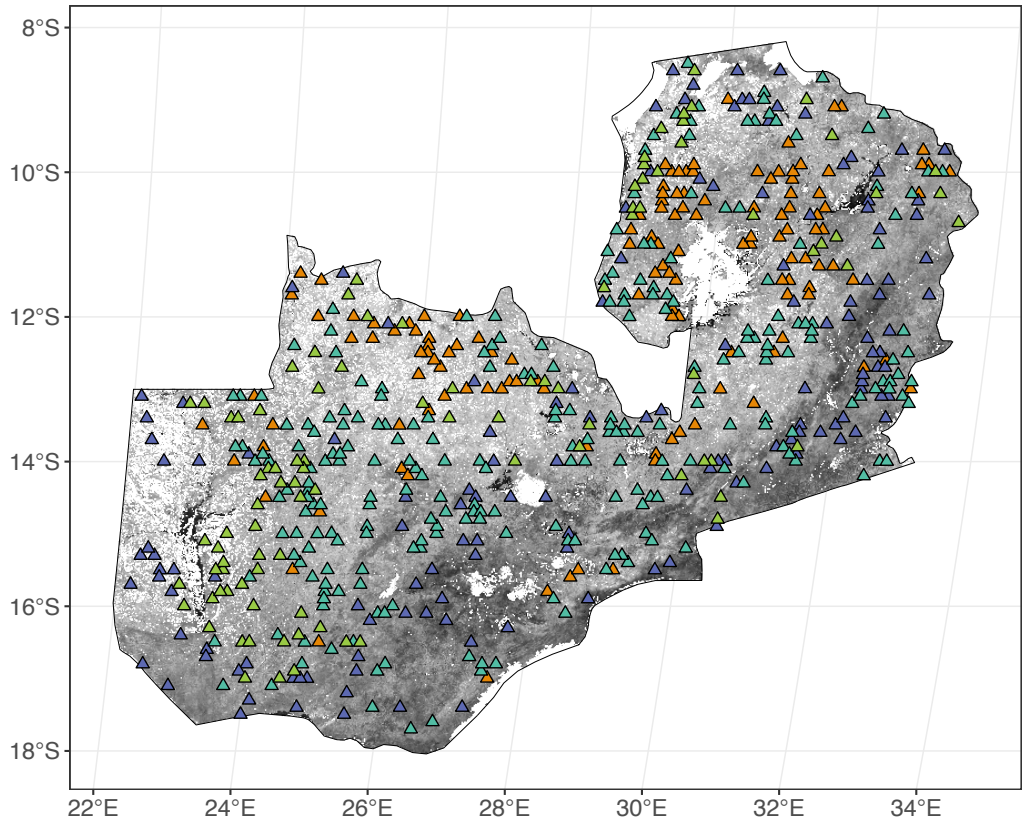
3. Bootstrapping: Stem density mediates species diversity – biomass relationship



Godlee et al. (2021) *New Phytologist*

Linking land surface phenology and diversity

Zambian Integrated Land Use Assessment – 617 plots



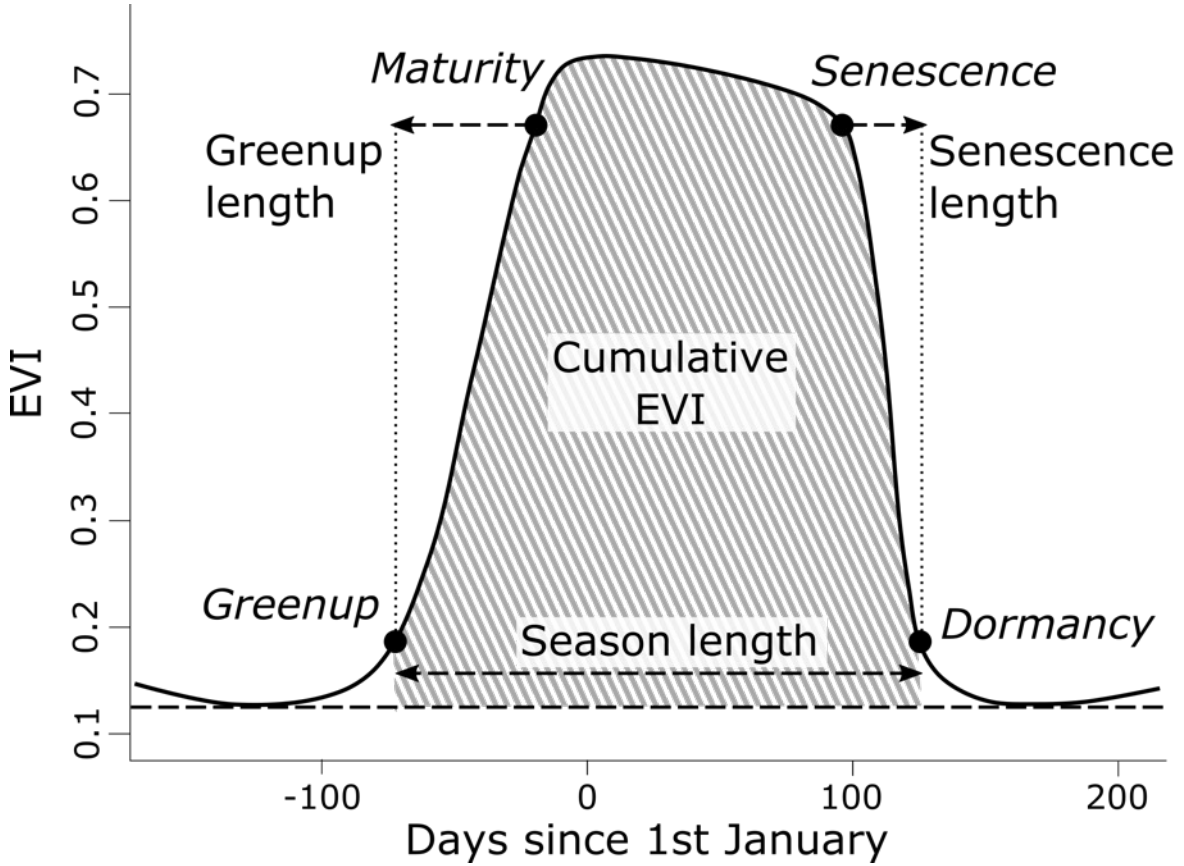
Uapaca miombo

Julbernardia miombo

Combretaceae woodland

Cryptosepalum miombo

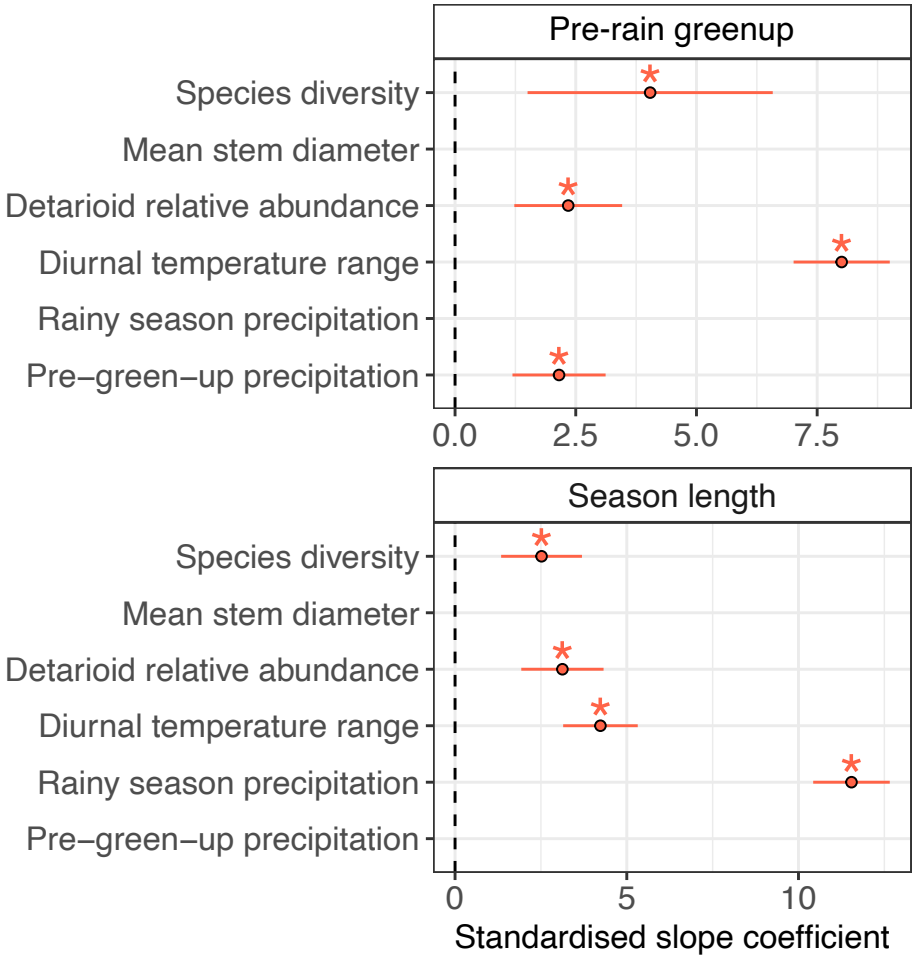
MODIS land surface phenology time series
EVI – Enhanced Vegetation Index

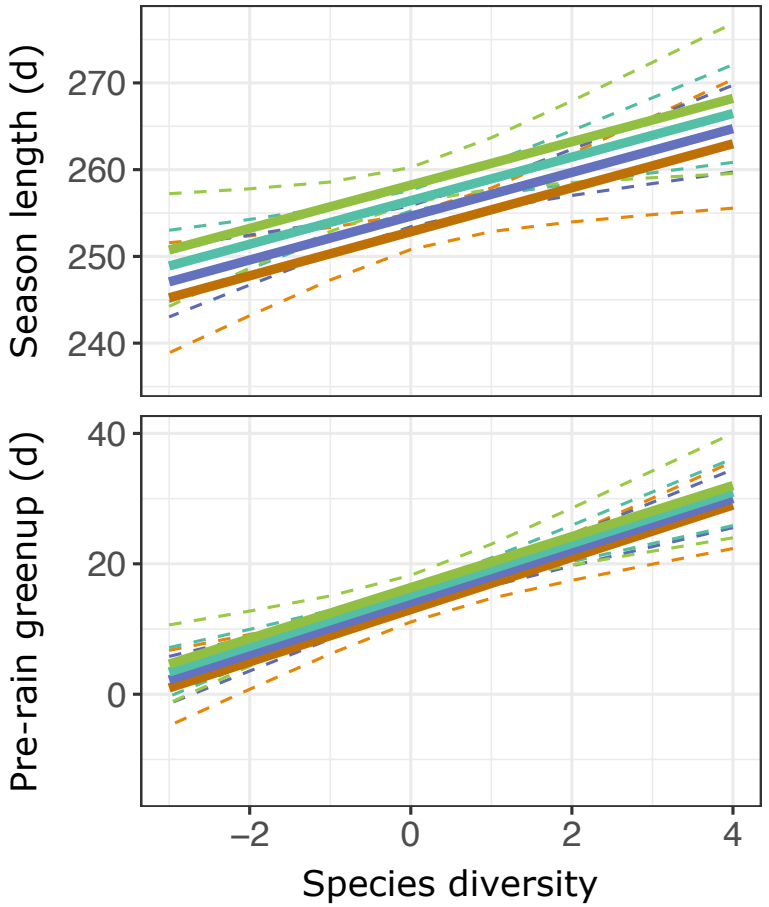


Godlee, Ryan, Siampale & Dexter (in revision Mar 2023) *Journal of Ecology*

Linking land surface phenology and diversity

Tree species diversity and detarioid legume abundance associated with longer growing season length, earlier pre-rain greenup.





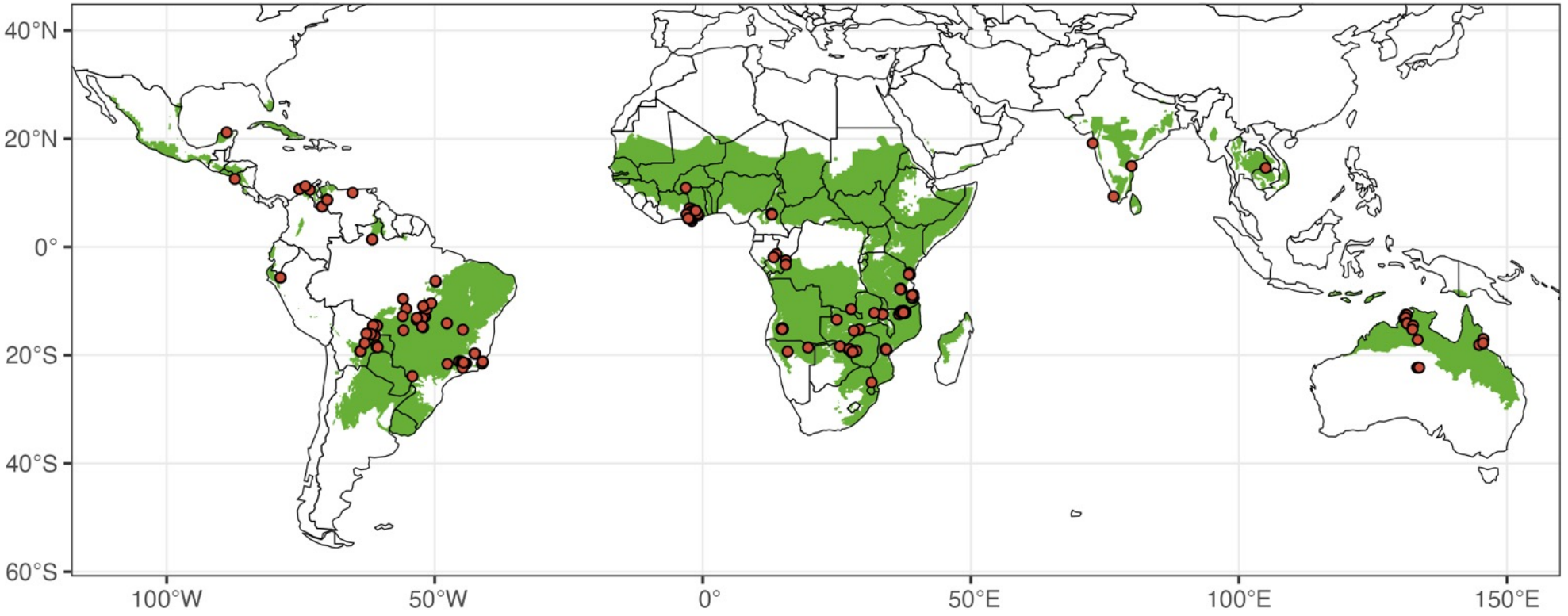
Godlee, Ryan, Siampale & Dexter (in revision Mar 2023) *Journal of Ecology*

Dry tropical carbon dynamics and demography

SECO - NERC Large Grant

Broad aim: Resolve uncertainties in the carbon cycle of the dry tropics.

My aim: Use long-term plot data to explore how biogeography and functional variation affects woody biomass dynamics.



Funded by:

NERC SCIENCE OF THE ENVIRONMENT

Collaboration with:

UNIVERSITY OF LEEDS

UNIVERSITY OF EXETER

FORESTPLOTS.NET

SEOSAW

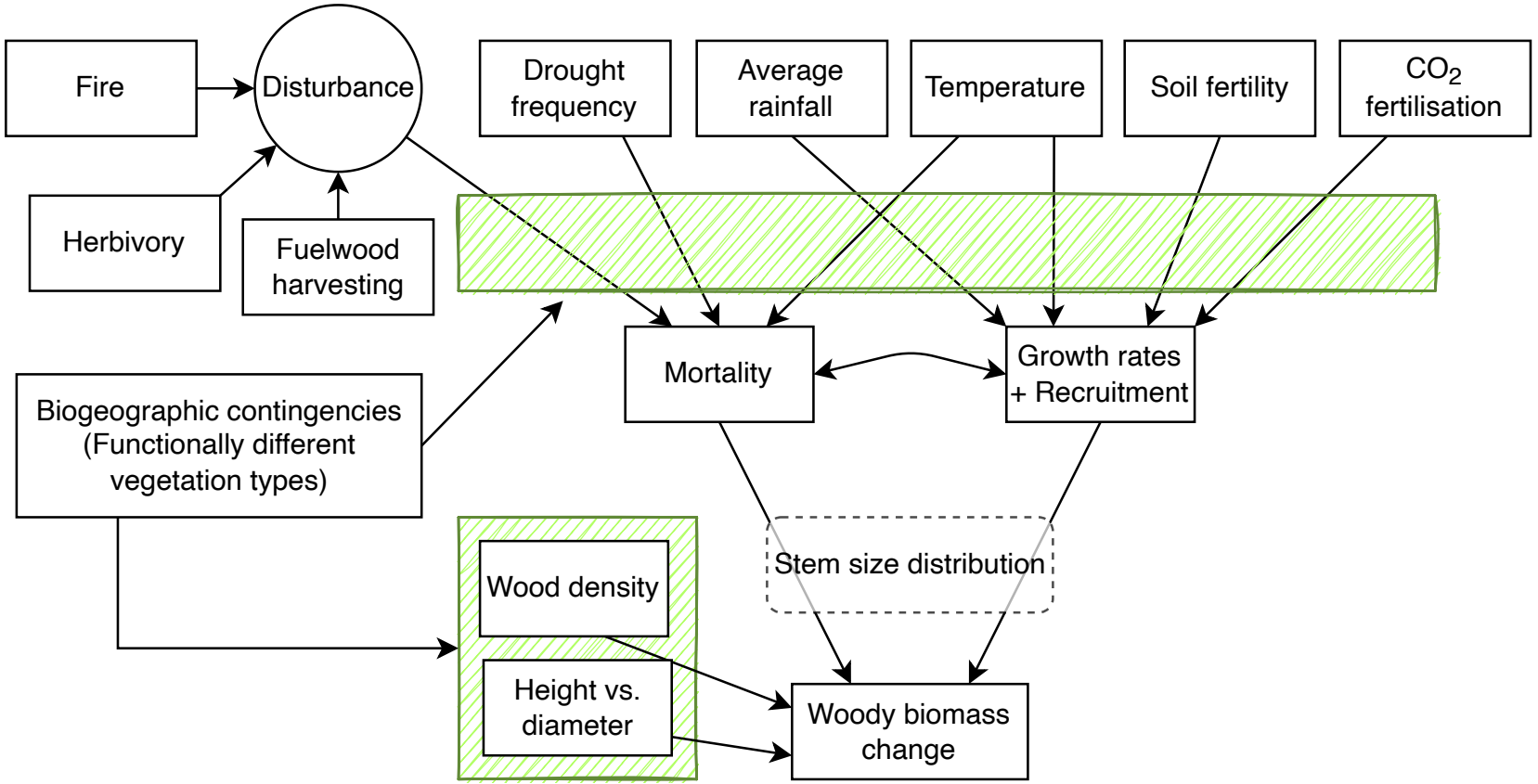
+22 international partners

Dry tropical carbon dynamics and demography

SECO - NERC Large Grant

Broad aim: Resolve uncertainties in the carbon cycle of the dry tropics.

My aim: Use long-term plot data to explore how biogeography and functional variation affects woody biomass dynamics.



Funded by:

NERC SCIENCE OF THE ENVIRONMENT

Collaboration with:

UNIVERSITY OF LEEDS

UNIVERSITY OF EXETER

FORESTPLOTS.NET

SEOSAW

+22 international partners

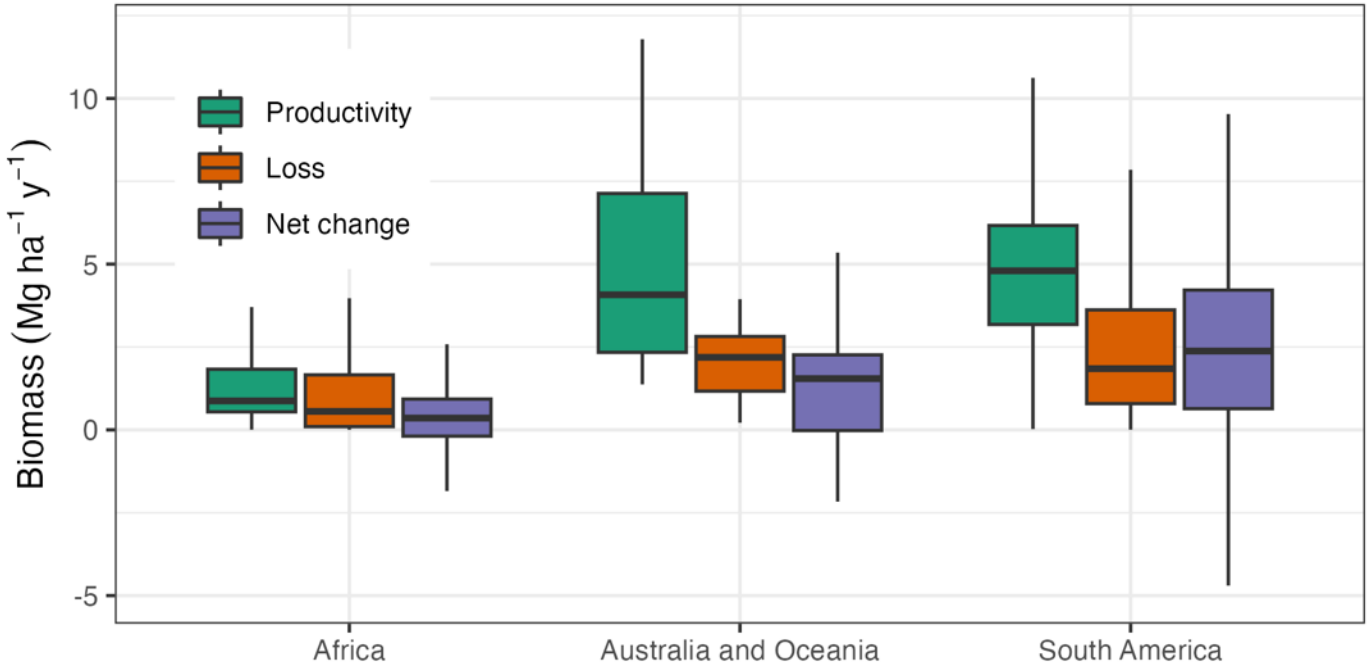
Dry tropical carbon dynamics and demography

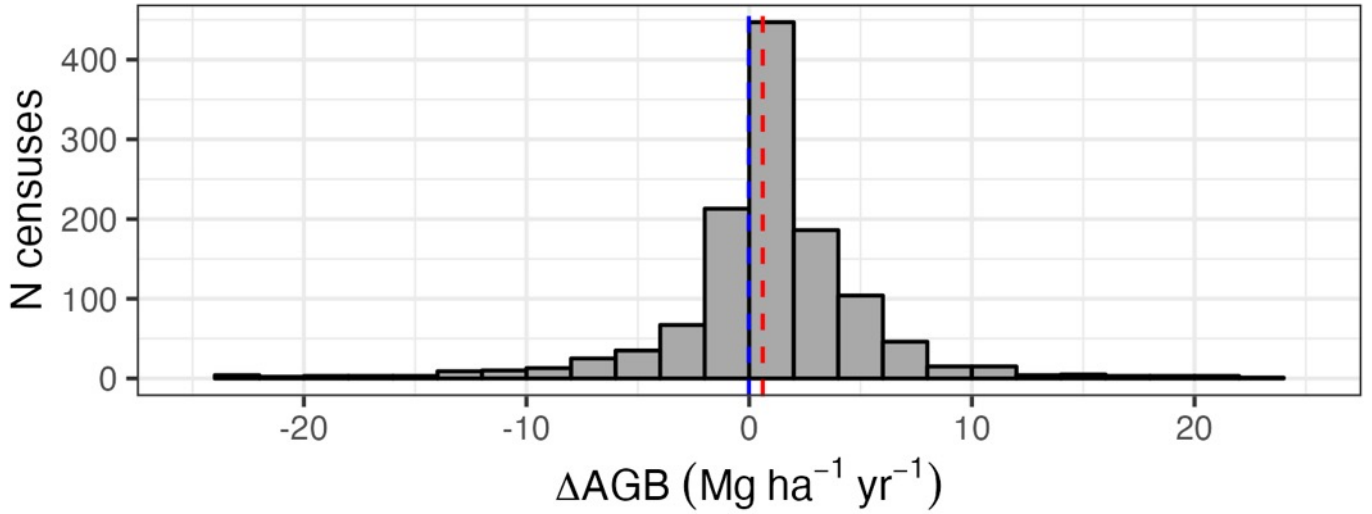
Preliminary results:

- Positive net biomass change across all continents.
- Some big losses in South America.
- Low biomass turnover in Africa.

Next steps:

- Explore phylogenetic associations with demographic rates.
- Project future biomass dynamics over the next century.



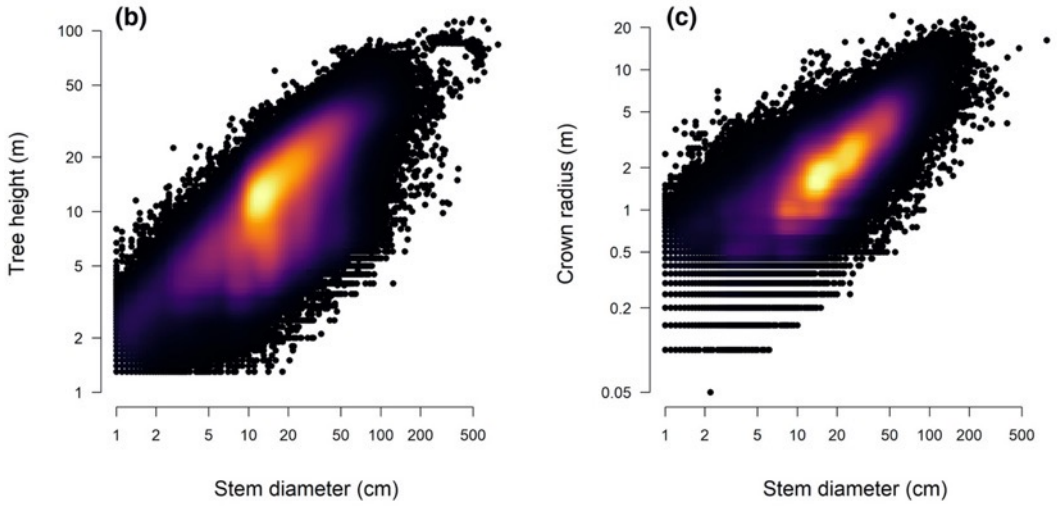


Please do not share

Broader collaborations

- SEOSAW – Socio-Ecological Observatory for Studying African Woodlands – steering committee
- Alliance for Tropical Forest Science (ATFS) – Tree Mortality Working Group
- “Tallo” - global tree allometry database
- Woodland Trust – Silvo-pastoral schemes on marginal agricultural land in the UK

SEOSAW network meeting – Mozambique 2018



Global patterns of tree diameter-height allometry

Jucker et al. (2022)

Woodland Trust regeneration scheme – North Yorks. 2022

Synergies of research and teaching

Research skills:

- Forest demography
- Empirical modelling of ecosystems
- Data science, statistical modelling
- UK flora field identification

Potential contributions:

- Demographic modelling of ecosystems (Hons.)
- MSc woodland management – with CSFL
- Field ecology skills (Pre Hons.)
- Data science and statistics (Pre Hons.)

Previous teaching experience:

- Co-organiser of Hons. course: Modelling Ecosystem Processes
- Field course demonstrating: Principles of Ecology, 4th year Ecology field course
- Data science tutoring across range of skill levels: Coding Club, Principles of Ecology
- Field assistant training: Angola, Namibia, Tanzania, Scotland
- PhD supervision: Co-supervisor of two students

The next five years: Research vision

Structure and demography in the dry tropics

Urgent issue: Dry tropical vegetation is poorly understood in the context of global environmental change and biodiversity loss.

1. Demographic processes, life-history strategies, and interaction with environment are poorly studied in dry systems.

2. Biomass estimation techniques in the seasonally dry tropics are poorly constrained, and ill-suited to shrubby vegetation.

3. Uncertainty in the environmental and determinants of dry tropical ecosystem structure.

Mortality risk and CO_2 in disturbed systems

CO_2 fertilization is predicted to increase tree growth rates across the tropics.

Strong positive feedbacks maintain low biomass in savannas through disturbance.

Questions for fire-prone savannas:

- **Will increased CO_2 lead to higher rates of biomass turnover, or a shift to closed canopy forest?**

- **Will all savannas respond similarly to increased CO_2? Does species identity determine response?**

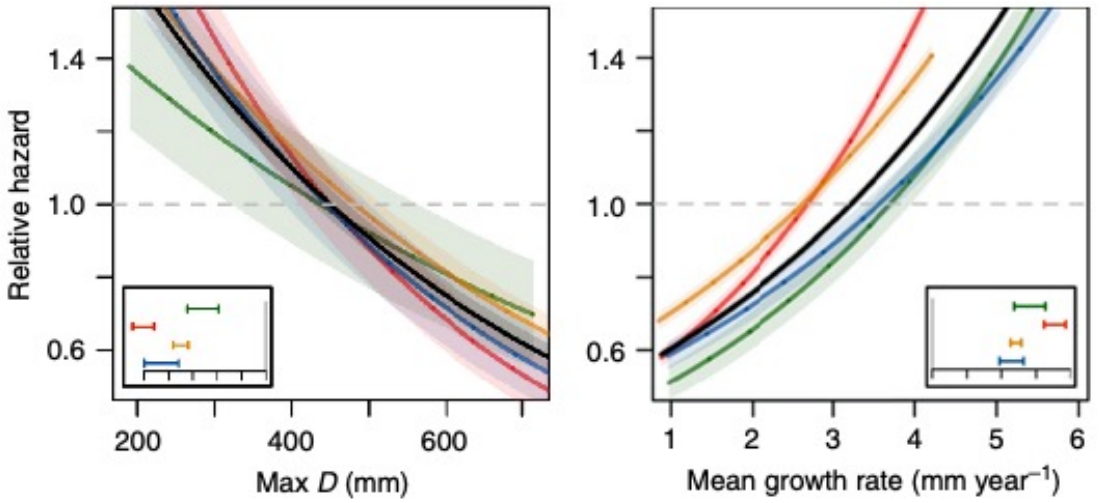
Collaborators/synergies at Edinburgh:

- Claudia Colesie – Drought ecophysiology
- Caroline Nichol - Ecophysiology

Collaborators outside Edinburgh:

- Adriane Esquivel-Muelbert (Birmingham)
- ATFS Tree Mortality Working Group

In wet forest: ↑growth rates = ↑mortality risk



Stevens et al. (2017), Esquivel-Muelbert et al. (2020)

Biomass of the largest and smallest trees

Big trees hold a disproportionate amount of biomass in forests and savannas, globally.

Small stems are rarely surveyed. In semi-arid systems they likely hold more biomass than presumed.

Current methods of estimating biomass in very small and very large trees are not precise or accurate.

- **Can a combination of terrestrial LiDAR and sonic tomography help us build better biomass allometries for large trees and shrubs?**

- **How do biomass dynamics respond to the covariation of ecosystem structure and climate?**

Collaborators/synergies at Edinburgh:

- Casey Ryan – biomass allometry
- Steve Hancock - LiDAR
- Patrick Meir – tropical forest ecology

Collaborators outside Edinburgh:

- Lindsay Hutley (Charles Darwin University)
- Tommaso Jucker (University of Bristol)
- Vera De Cauwer (Namibia Uni. Sci. Tech.)

Mapping ecosystem structure and change

Global environmental change is undoubtedly leading to changes in vegetation structure, can we quantify these changes using state-of-the-art mapping?

- **Can we create structural "fingerprints" of distinct savanna/dry forest communities?**
- **What factors determine the distribution of different structural types?**
- **Can we map change in demography through structure?**

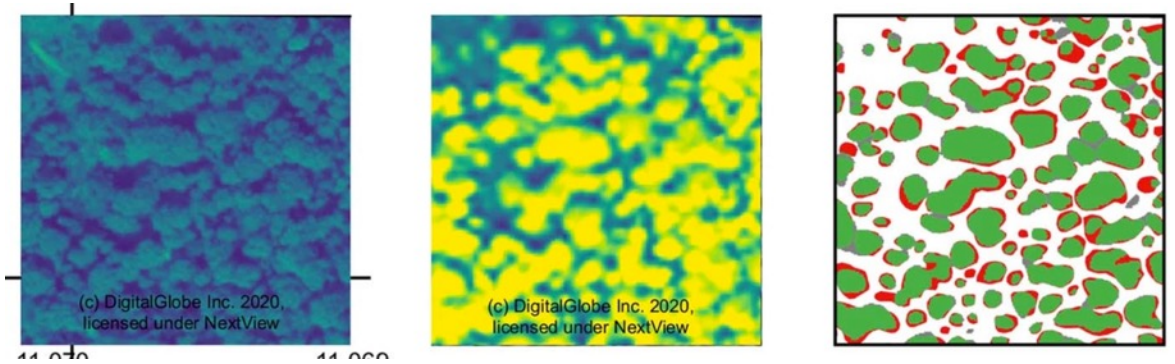
Collaborators/synergies at Edinburgh:

- Steve Hancock - LiDAR
- Ed Mitchard - Remote sensing
- Ally Phillimore – Land surface phenology

Collaborators outside Edinburgh:

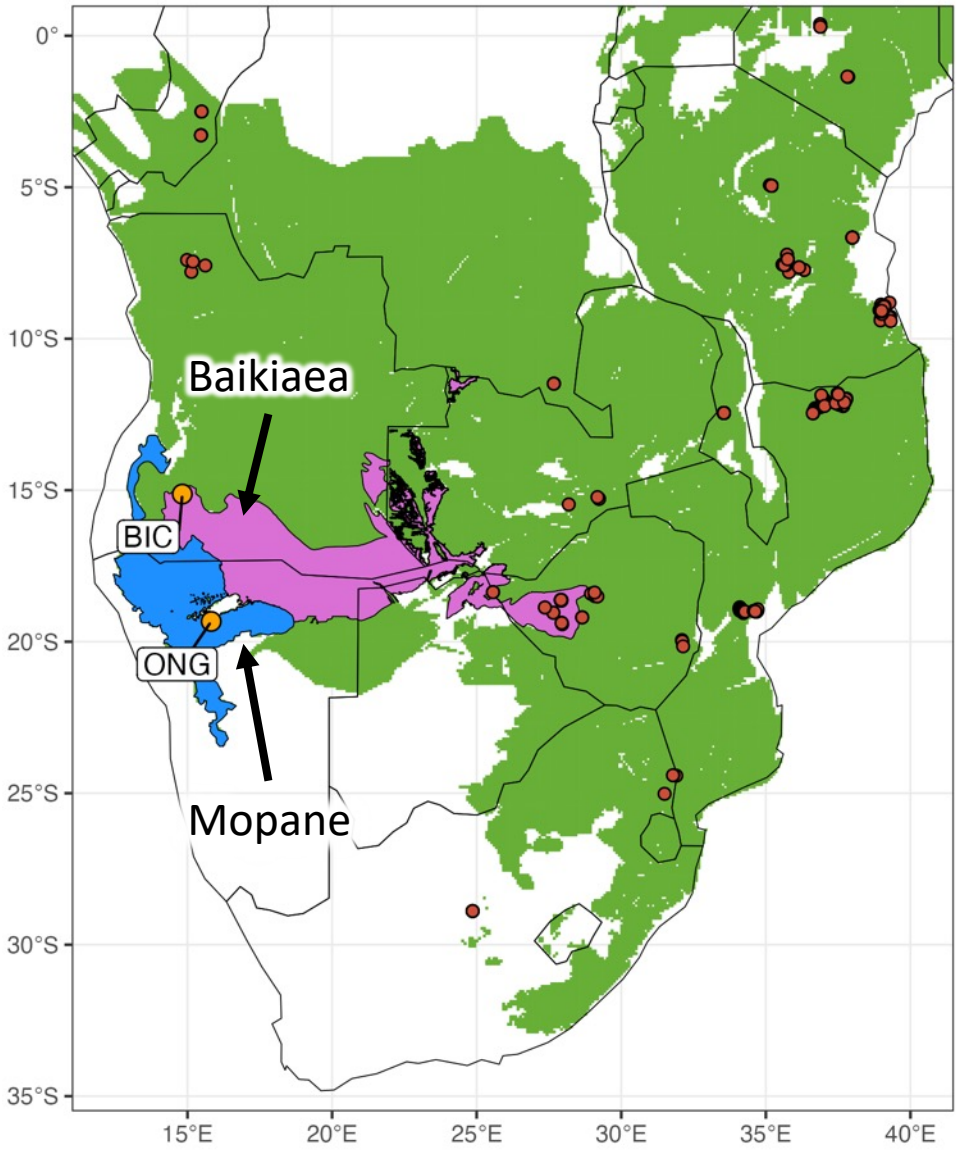
- Vera De Cauwer (Namibia Uni. Sci. Tech.)
- Mireia Torello-Raventos (James Cook Uni.)
- Martin Brandt (University of Copenhagen)

Using WorldView2 imagery to map trees in sparse savanna



Brandt et al. (2020)

Developing vegetation monitoring infrastructure



Miombo savanna, Bicuar National Park (BIC)

Succulent dry forest, Ongava Reserve (ONG)

Funded by:

NATIONAL GEOGRAPHIC

UKaid from the British people

Department for International Development

SEOSAW

Collaboration with:

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

ISCED
Instituto Superior de Ciências de Educação

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Godlee et al. (2020) *Diversity,* Tchamba et al. (2022) *African Journal of Ecology*, De Cauwer et al. (in review Mar 2023)

Funding landscape

NERC SCIENCE OF THE ENVIRONMENT

Pushing Frontiers
Up to £1M

erc European Research Council
Established by the European Commission

ERC Starting Grant
€1-1.5M

LEVERHULME TRUST

Research Leadership Award
Up to £1M

UKRI

UKRI Future Leaders
~£1M

Commercial partnership:

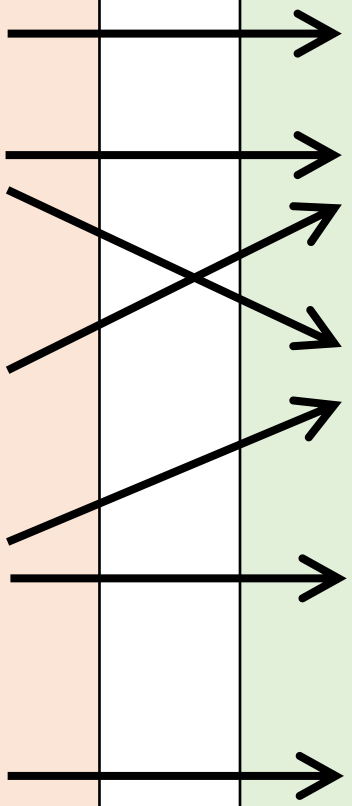
- Commercial forestry
- Protected area management
- Carbon accreditation schemes
- Tree planting schemes

Links to NERC Strategic Delivery Plan

Natural Environment Research Council

NERC Strategic Objectives:

1. Diversity of people in science.
2. Upgrading science infrastructure to unlock innovation.
3. UK scientists working with local communities internationally.
4. Realising the potential of data, remote sensing etc.
5. Addressing challenges of climate, biodiversity loss.



My research vision:

- Building capacity for long-term vegetation monitoring in southern Africa.
- High resolution mapping of ecosystem structure.
- Developing techniques for biomass estimation in semi-arid ecosystems.
- Understanding how biodiversity change and climate affect ecosystem structure and function.

Support within the University

ACE
CENTRE FOR ADAPTING TO CHANGING ENVIRONMENTS

DDI Data-Driven Innovation
Part of the Edinburgh & South East Scotland City Region Deal

CSFL

ecci EDINBURGH CLIMATE CHANGE INSTITUTE

THE UNIVERSITY of EDINBURGH
Edinburgh Earth Initiative

- **Spin-offs:** Developing commercial application of biomass estimation techniques.
- **Inter-disciplinary collaboration:** Inserting biodiversity data into earth system models.
- **UK woodland policy:** Applying ecological theory to UK woodland management for carbon and biodiversity.