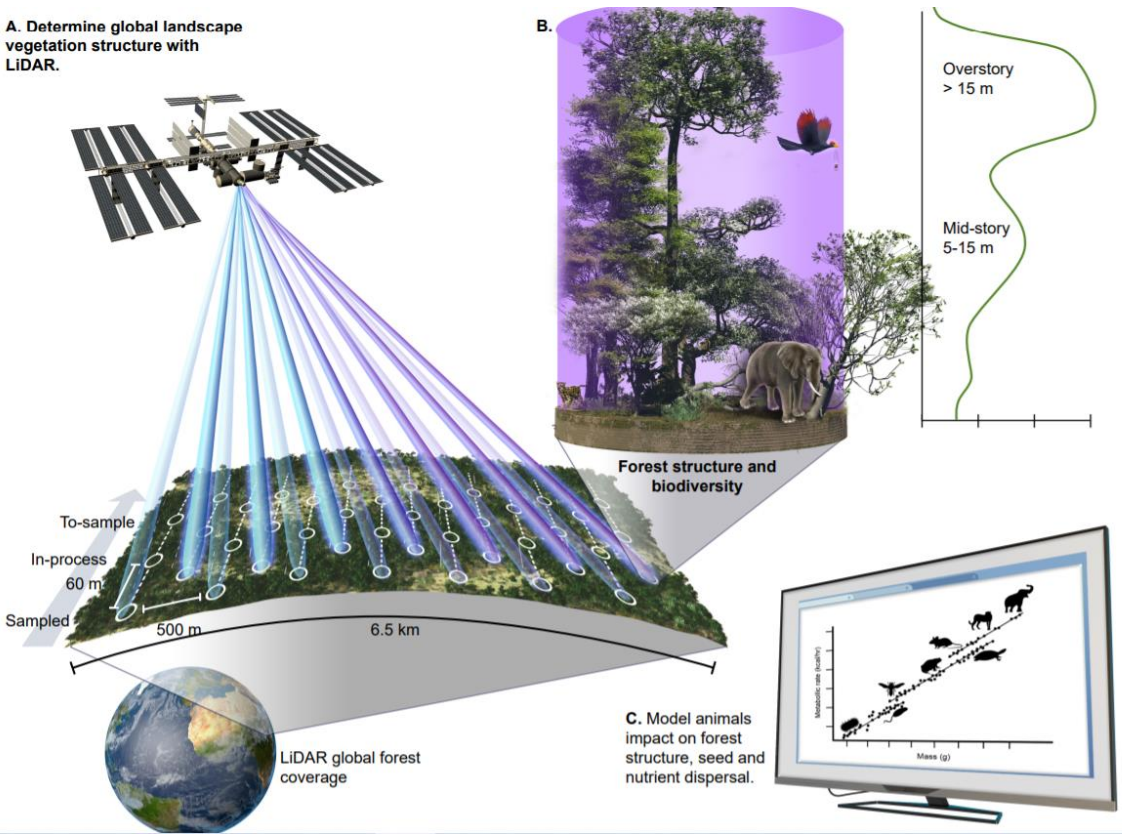
Adding space-based vegetation structure measurements to a global ecosystem model to simulate tropical forest animal communities and their role in ecosystem function



Chris Doughty[1], Camille Gaillard[1], Jenna Keany[1], Andrew Abraham[1], Scott Goetz[1], Patrick Jantz[1], Patrick Burns[1], Toby Jackson[2], Luca Santini[3], Mike Harfoot[4],

Northern Arizona University[1], Cambridge[2], Sapienza University [3], *UNEP-WCMC[4]*

NAU Northern Arizona University

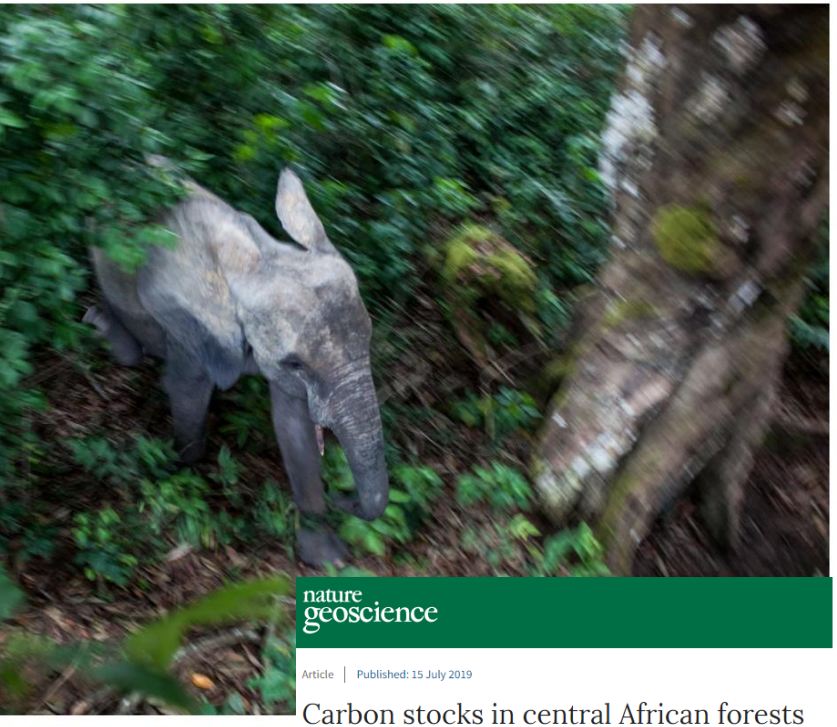
Ecological and Environmental Informatics

The Madingley Model

Animals impact global nutrient and carbon cycles

The Thick Gray Line: Forest Elephants Defend Against Climate Change

If the species is wiped out by poachers, Africa's vast rain forest will lose 7 percent of its carbon storage ability, scientists estimate.



Reserve in Gabon in 2012. There are fewer than 10
abon. Tyler Hicks/The New York Times

By Rachel Nuwer

Aug. 19, 2019

nature geoscience

Article | Published: 15 July 2019

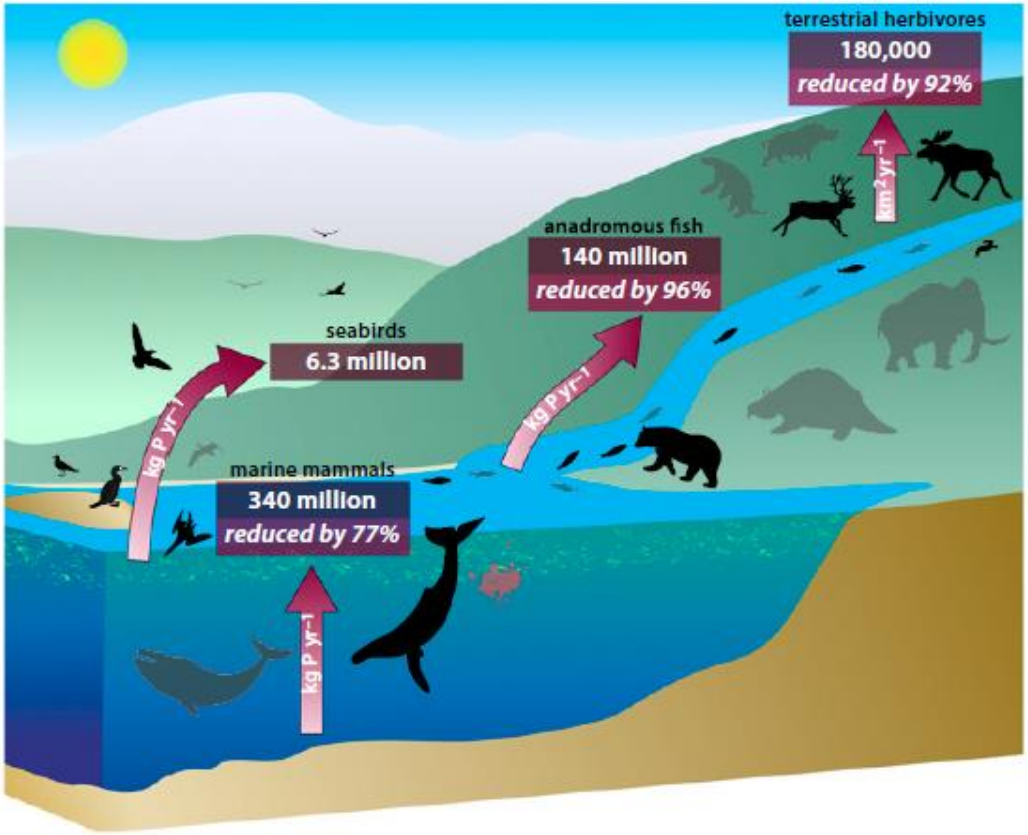
Carbon stocks in central African forests enhanced by elephant disturbance

Fabio Berzaghi, Marcos Longo, Philippe Ciais, Stephen Blake, François Bretagnolle, Simone Vieira, Marcos Scaranello, Giuseppe Scarascia-Mugnozza & Christopher E. Doughty

Nature Geoscience (2019) | Download Citation

Global nutrient transport in a world of giants

Christopher E. Doughty[a,1], Joe Roman[b,c], Søren Faurby[d], Adam Wolf[e], Alifa Haque[a], Elisabeth S. Bakker[f], Yadvinder Malhi[a], John B. Dunning Jr.[g], and Jens-Christian Svenning[d]

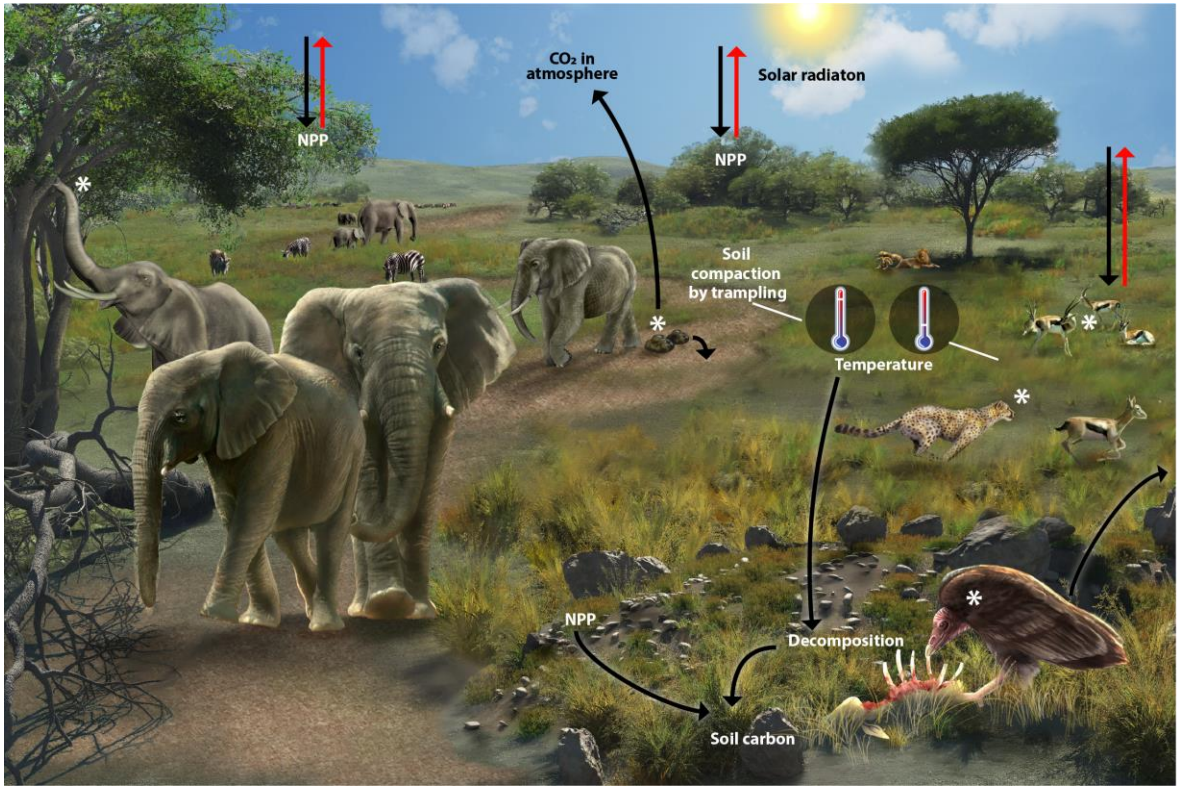


- What about:
- Landscapes of fear?
- Human influences?
- Climate change?
- The combined influences?

- We need a global mechanistic model

The Madingley Model

- Predation influences movement and biogeochemical patterns.
- Humans impact movement patterns.
- Temperature impact ecto and endotherms differently.



Schmitz et al. (2018), *Science*

Madingley General Ecosystem Model

OPEN ACCESS Freely available online PLOS | BIOLOGY

Emergent Global Patterns of Ecosystem Structure and Function from a Mechanistic General Ecosystem Model

Michael B. J. Harfoot[1,2]*, Tim Newbold[1,2], Derek P. Tittensor[1,2,3], Stephen Emmott[2], Jon Hutton[1], Vassily Lyutsarev[2], Matthew J. Smith[2], Jörn P. W. Scharlemann[1,4], Drew W. Purves[2]

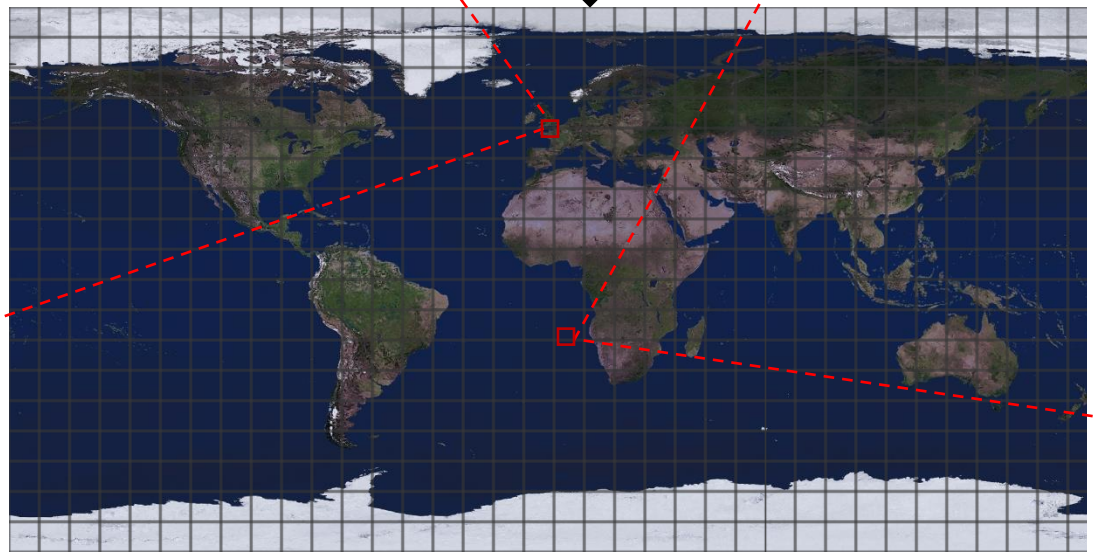
April 2014 | Volume 12 | Issue 4 | e1001841

The Madingley Model

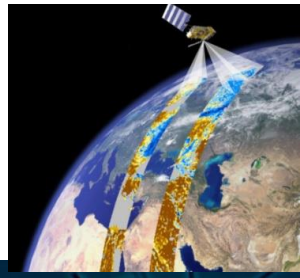
Terrestrial: data constrained carbon model (Smith *et al.*, 2013 Biogeosciences)

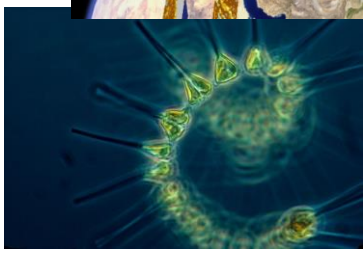
Realistic geography, ocean circulation, environmental conditions (air & ocean temperature, precipitation)

+

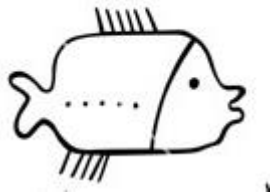


Marine: remotely sensed phytoplankton concentration

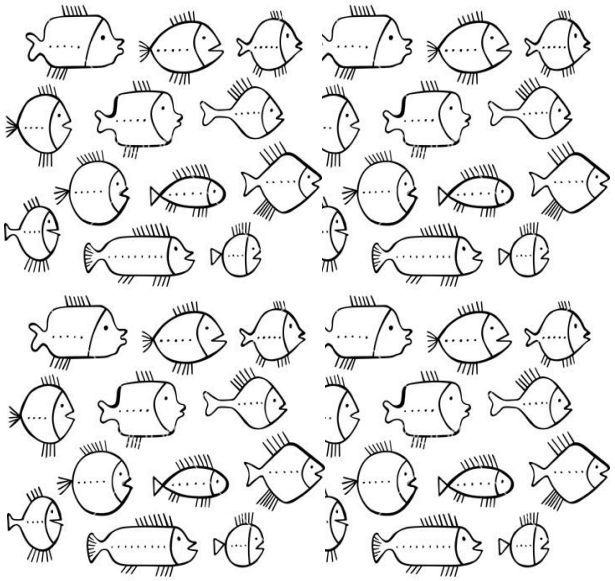




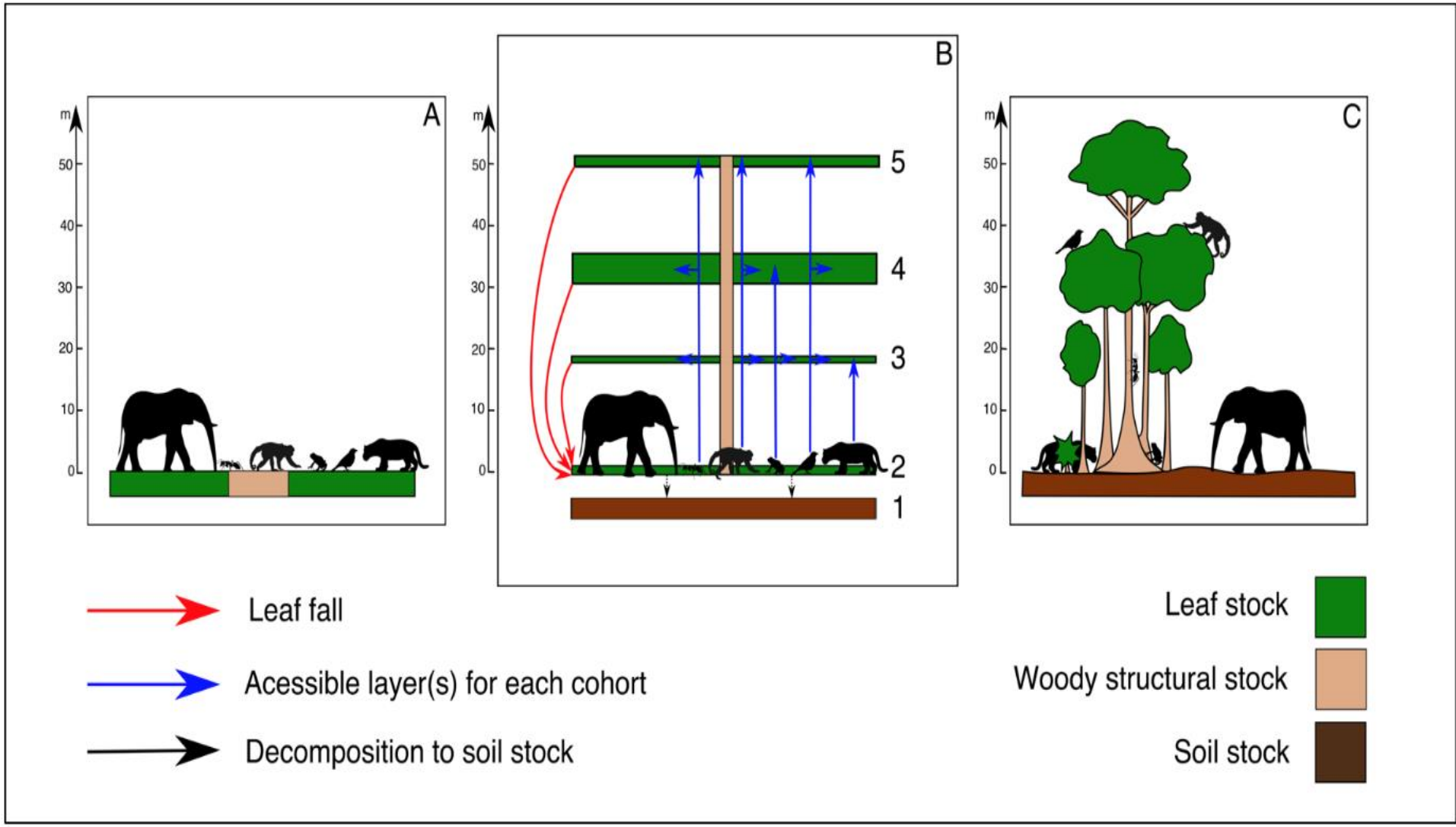
Animals – cohort-based approach



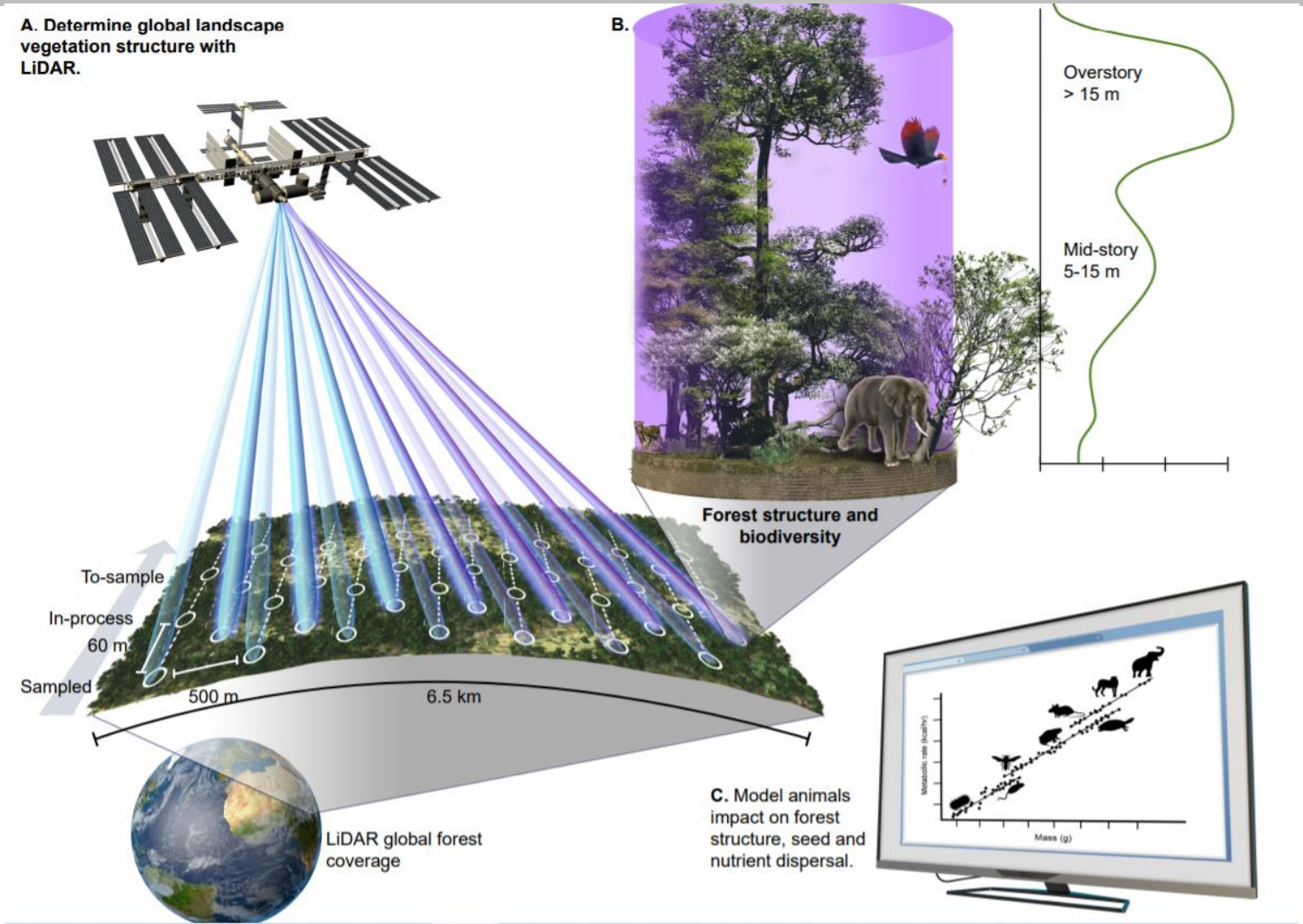
Herbivore / omnivore / carnivore
Ecotherm / Endotherm
Active disperser / passive disperser
Iteroparous / semelparous
Adult body mass
Juvenile body mass
Current body mass



Herbivore / omnivore / carnivore
Ecotherm / Endotherm
Active disperser / passive disperser
Iteroparous / semelparous
Adult body mass
Juvenile body mass
Current body mass
Abundance

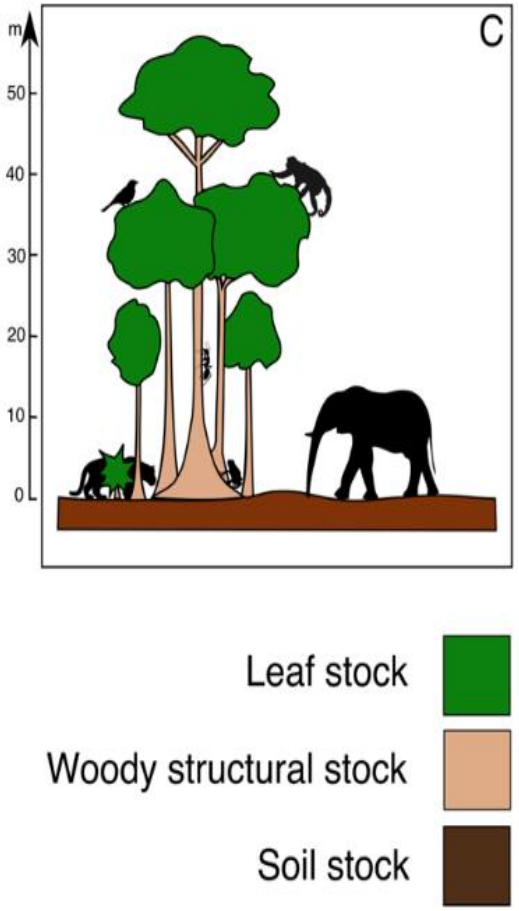

A
B
C
m
50
40
30
20
10
0
5
4
3
2
1
Leaf fall
Acessible layer(s) for each cohort
Decomposition to soil stock
Leaf stock
Woody structural stock
Soil stock

Adding space-based vegetation structure measurements to a global ecosystem model to simulate tropical forest animal communities and their role in ecosystem function

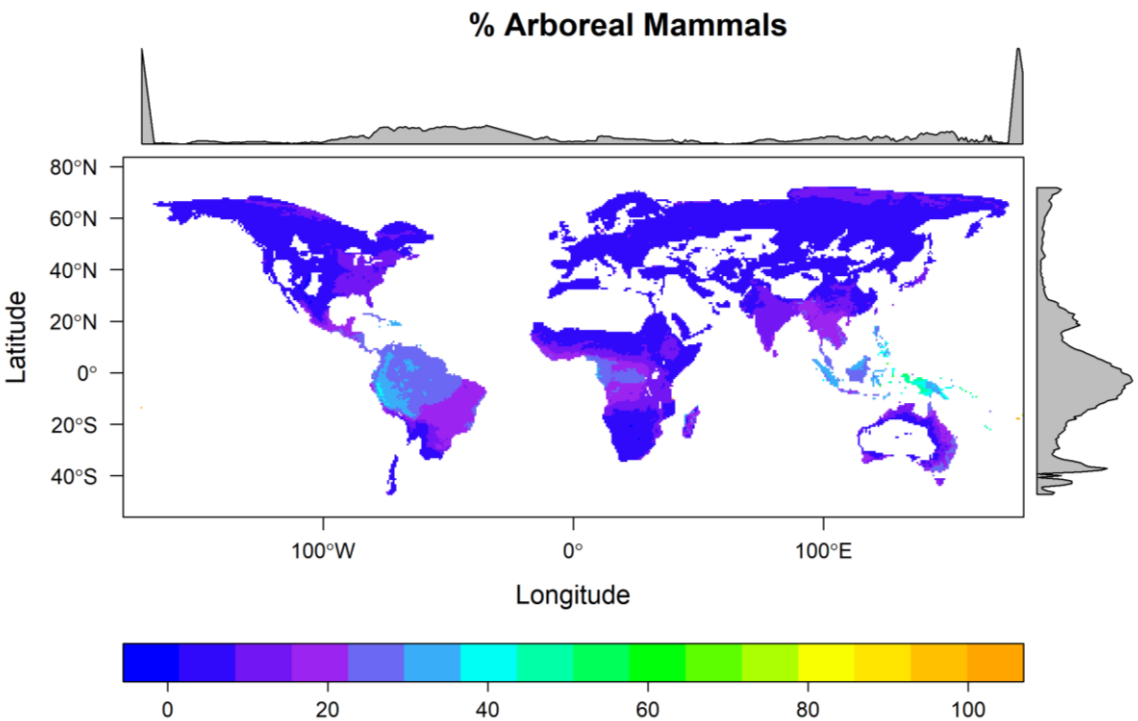


Project goals

- Add climbing cohort and GEDI data to Madingley.
- Add ecosystem engineer cohort to Madingley
- Provide RCP scenarios and EBVs to key stakeholders in Gabon, Peru, and Brazil



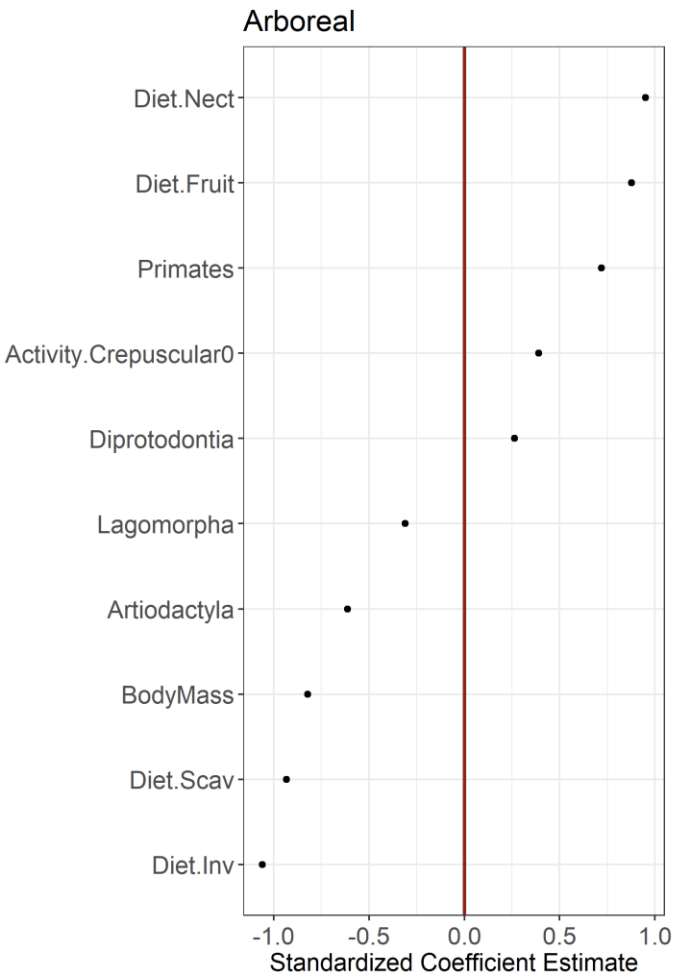
What traits are important for arboreality?



- % nectar and fruit in diet are most important functional traits positively associated with arboreal mammals.
- Body mass is negatively associated with arboreal mammals.

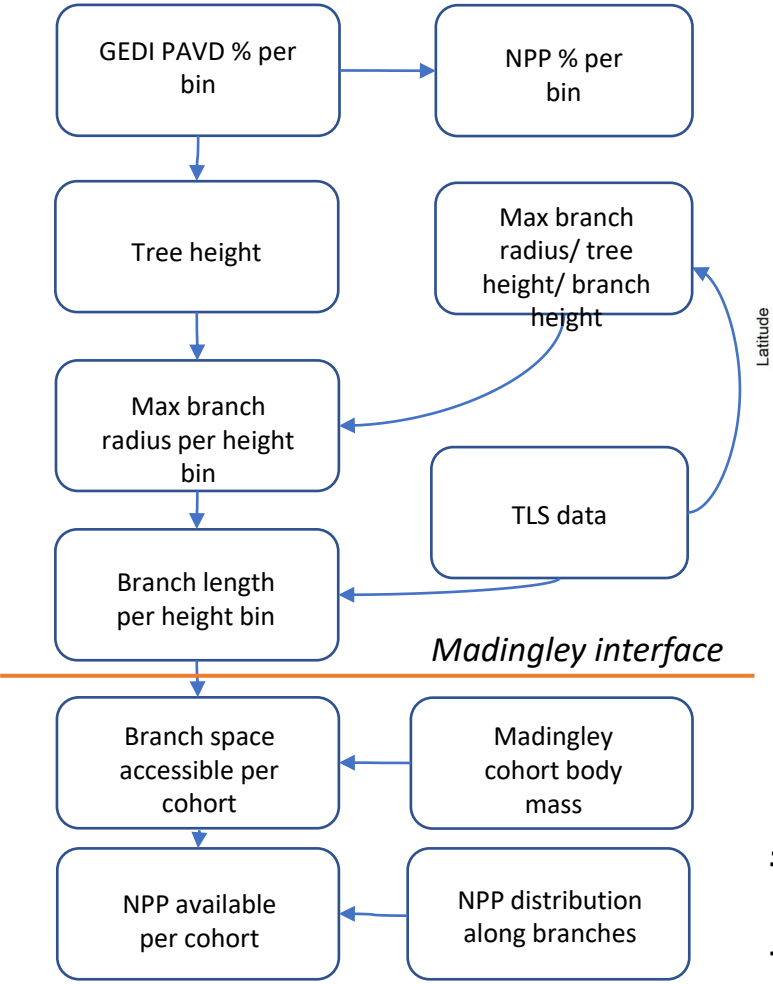
Jantz et al to be submitted to functional ecology

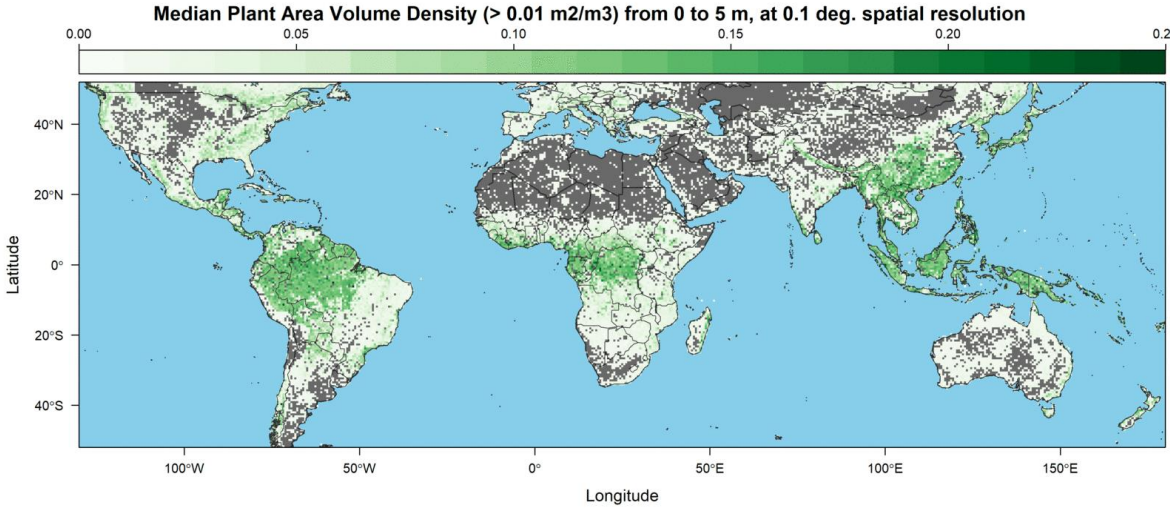
- Top 10 glmnet coefficients predicting arboreal foraging mammals

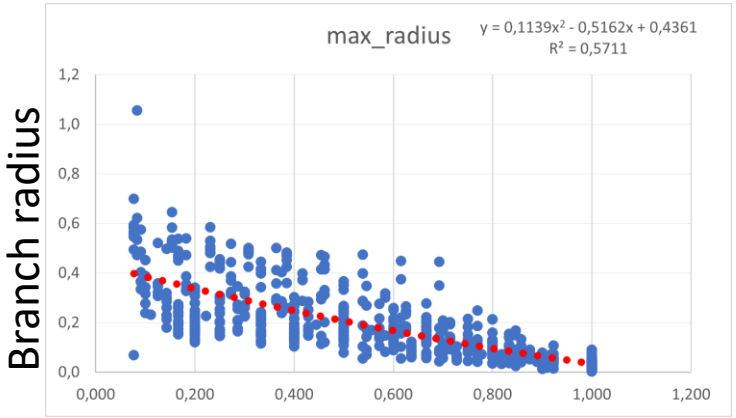


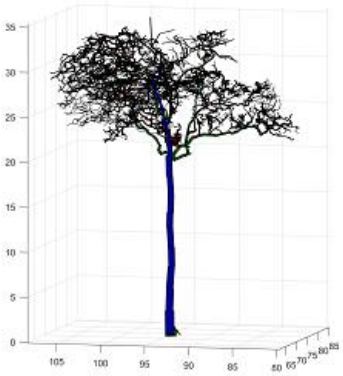
Add climbing cohort and GEDI data to Madingley.

GEDI/TLS Data processing





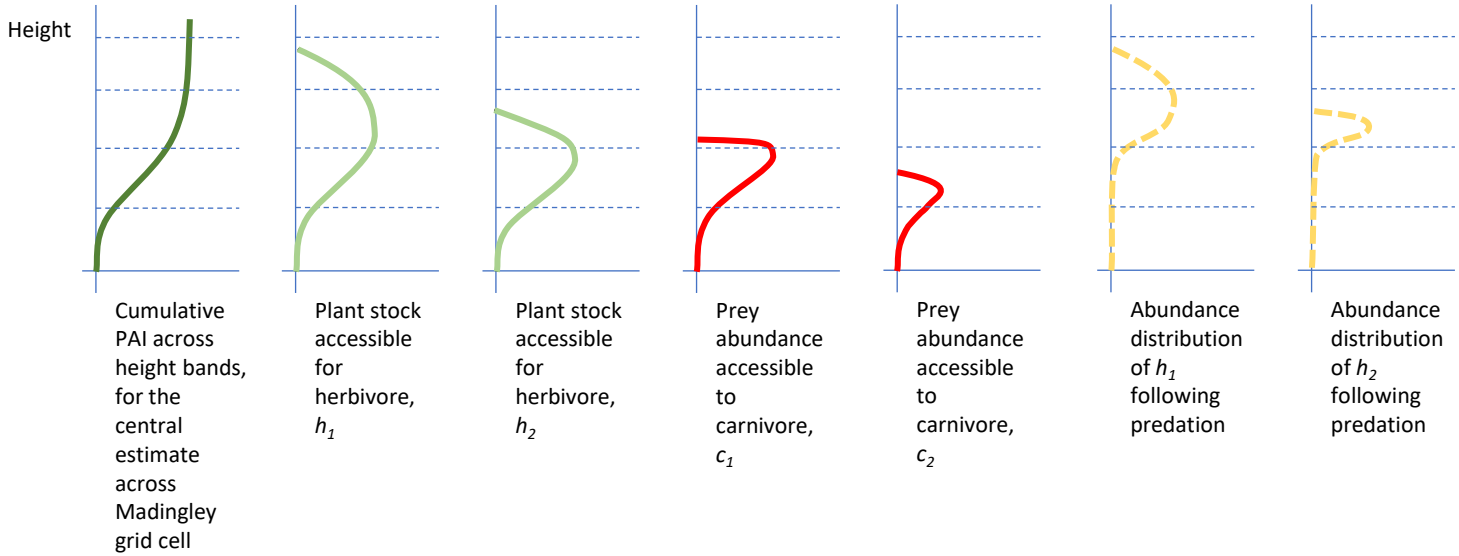




Gaillard et al in prep

Add climbing cohort and GEDI data to Madingley.

Individuals will be proportional to the amount of resource they are consuming in each level.



h_2 has larger body mass than h_1, so cannot access resources as high in the vegetation

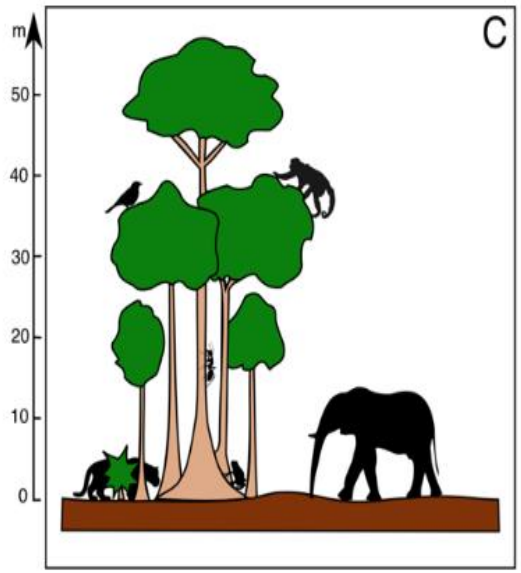
c_2 has larger body mass than c_1, so cannot access resources as high in the vegetation

h_1 escapes predation above the vertical accessibility of predators, so it can maintain abundance at greater height.

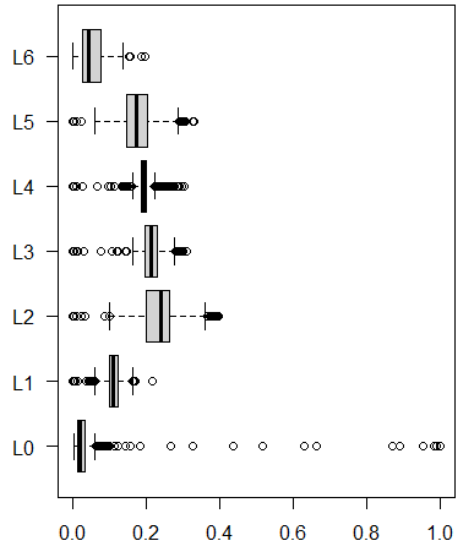
Harfoot et al in prep

Simulation results

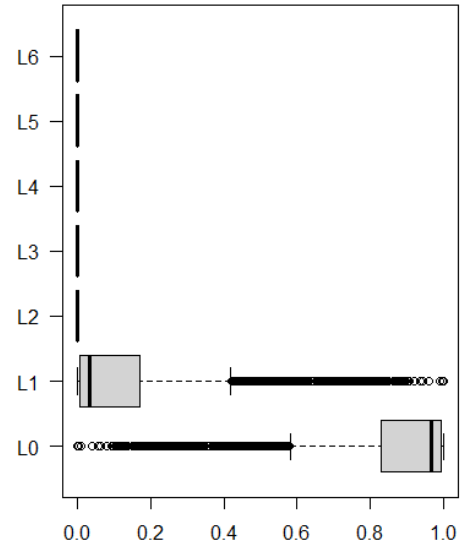
Cohorts are now using vertical space



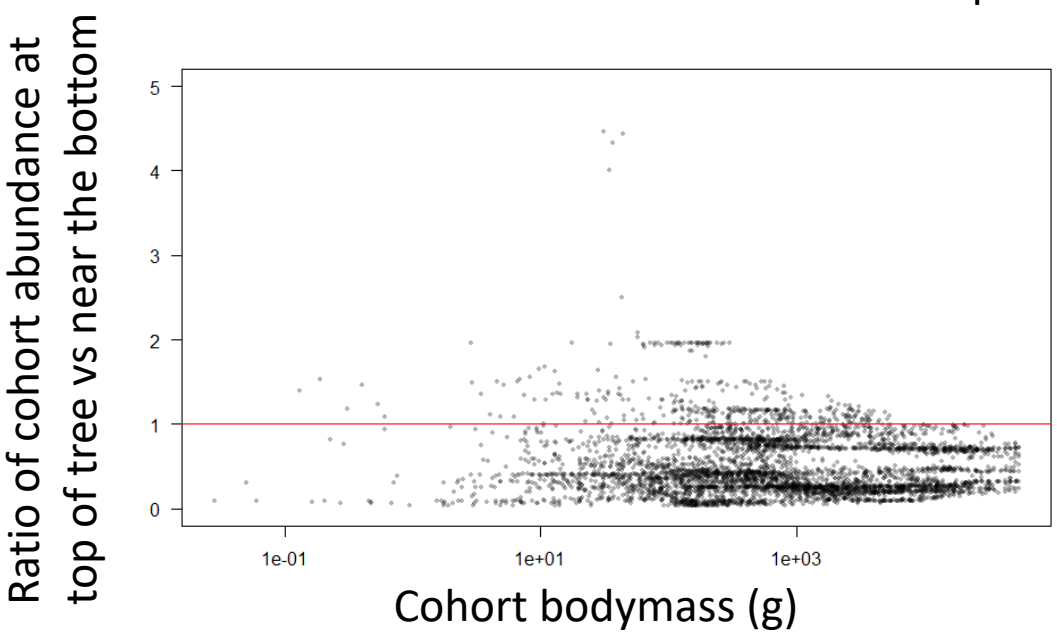
Forest ecosystem



Savannah ecosystem



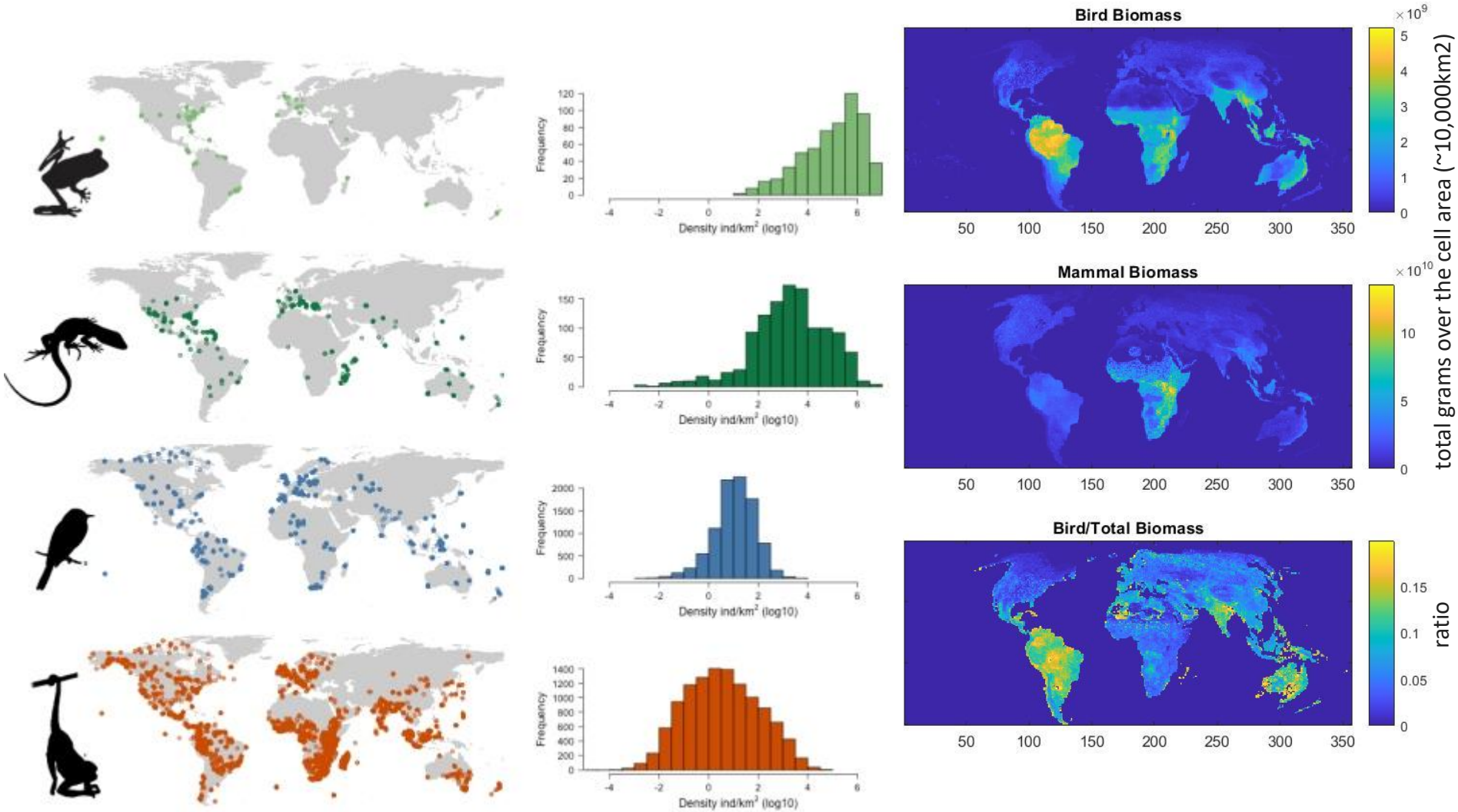
Proportion of time spent in each vertical layer



For larger organisms, we find greater abundance at lower levels than upper levels

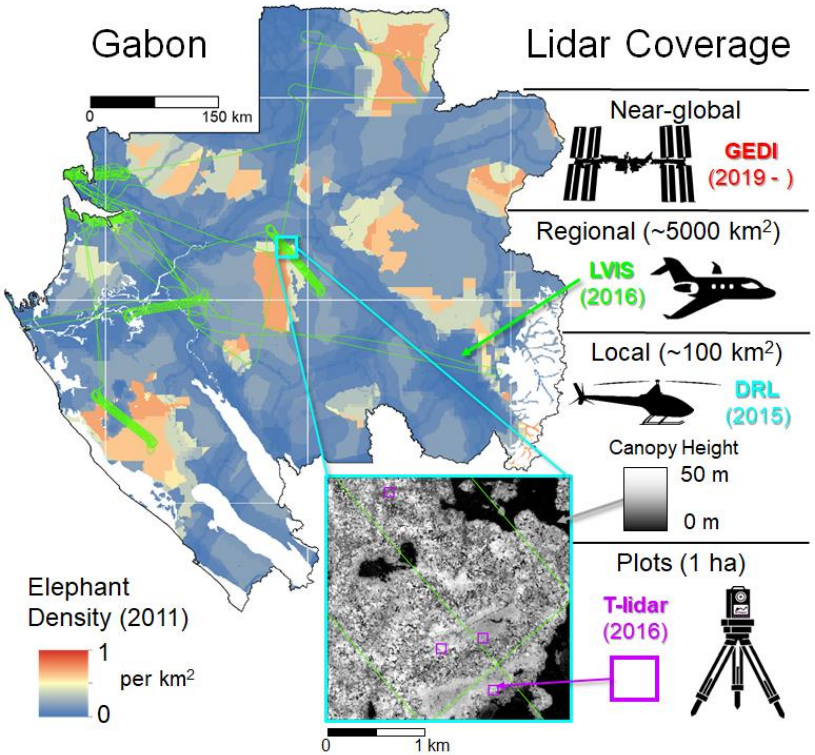
How do we know we are right?

- Compare to tetradensity total biomass for different groups.

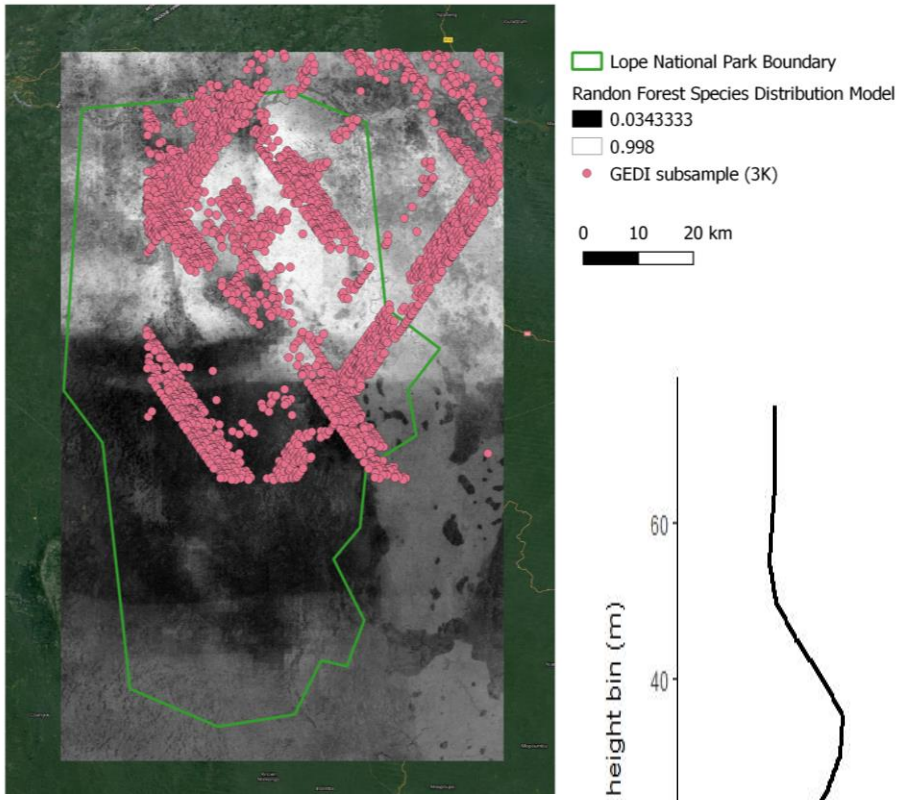


Global Ecology and Biogeography, Volume: 27, Issue: 8, Pages: 968-979, First published: 24 August 2018, DOI: (10.1111/geb.12758)

Add ecosystem engineers to Madingley



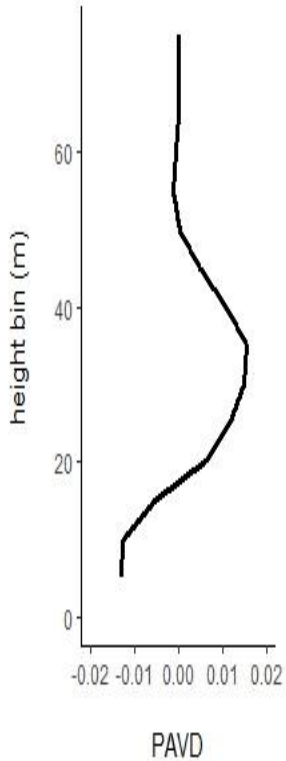
Species Distribution Model with overlapping GEDI shots



Lidar:

- Airborne DRL - 2015
- T-lidar – 2016
- Airborne LVIS – 2016
- GEDI - 2019 to present

Difference profile between high and low elephant suitability in Lope

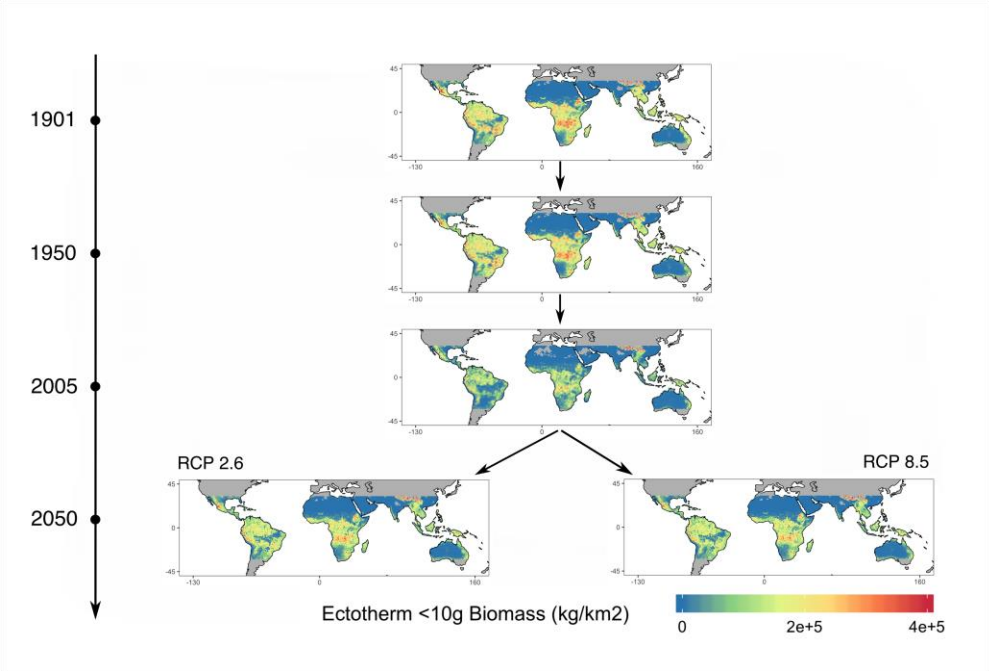


Keany et al in prep and poster

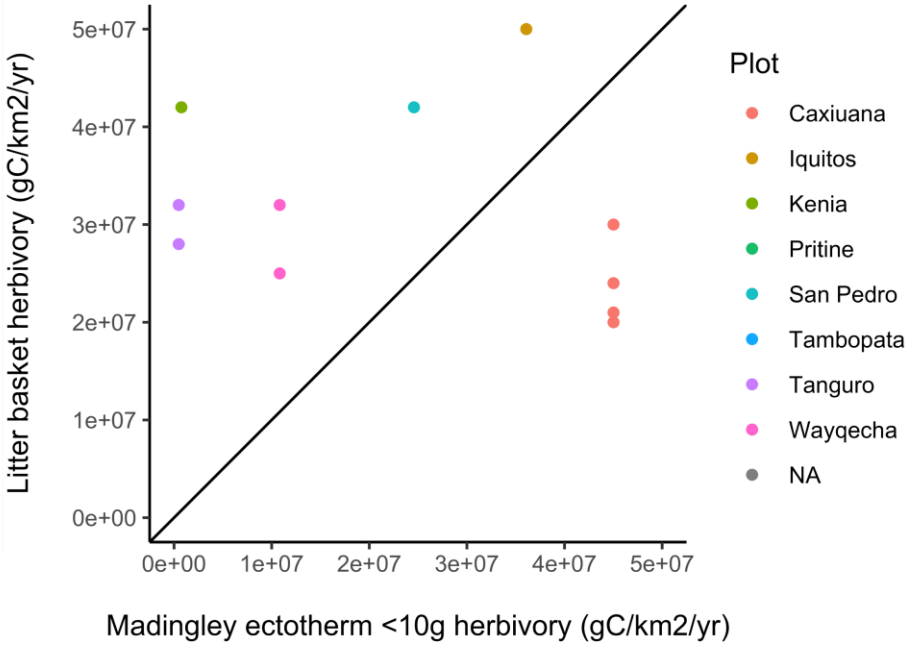
Use Madingley to understand how climate change might impact insects.

Madingley does a good job predicting net insect herbivory/abundance compared to empirical estimates.

Next, we will predict abundance under different RCP scenarios



Abraham et al in prep



Provide RCP scenarios and EBVs to key stakeholders in Gabon, Peru, and Brazil

- Predict scenarios for climate change, selective logging, extinctions, trophic loss, land use change.
- EBV Madingley results available for scientists, the public or policy makers as a map and a time series PDF.
- Available in five languages

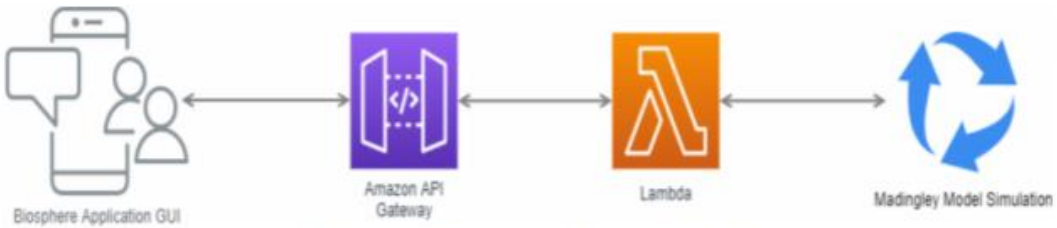
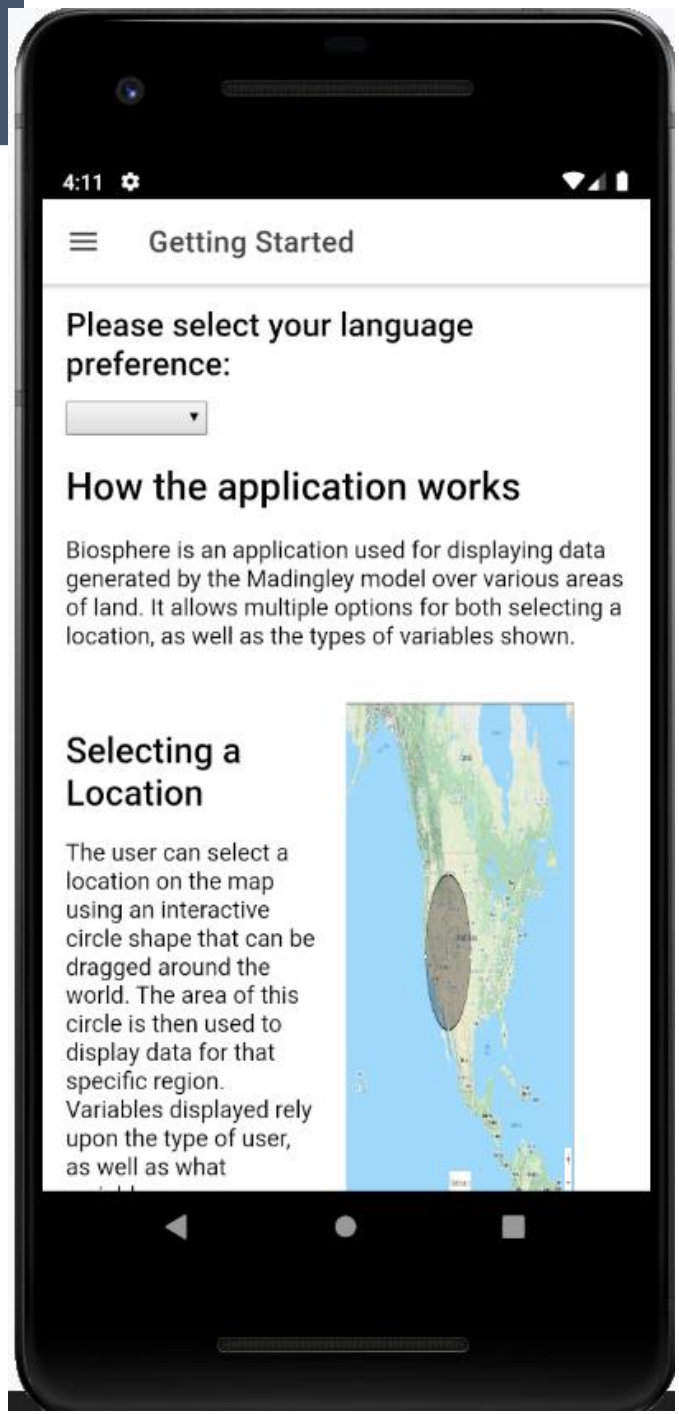


figure 4.1.3 - Application Data Flow Chart



This work was funded by NASA grant **award number - 80NSSC19K0206**

Questions?

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