Large-scale alterations of African dry forests and woodlands:

Drivers of change in biodiversity and productivity

&

Species distribution modelling with ILUA II data

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THE WOODS HOLE RESEARCH CENTER

Outline

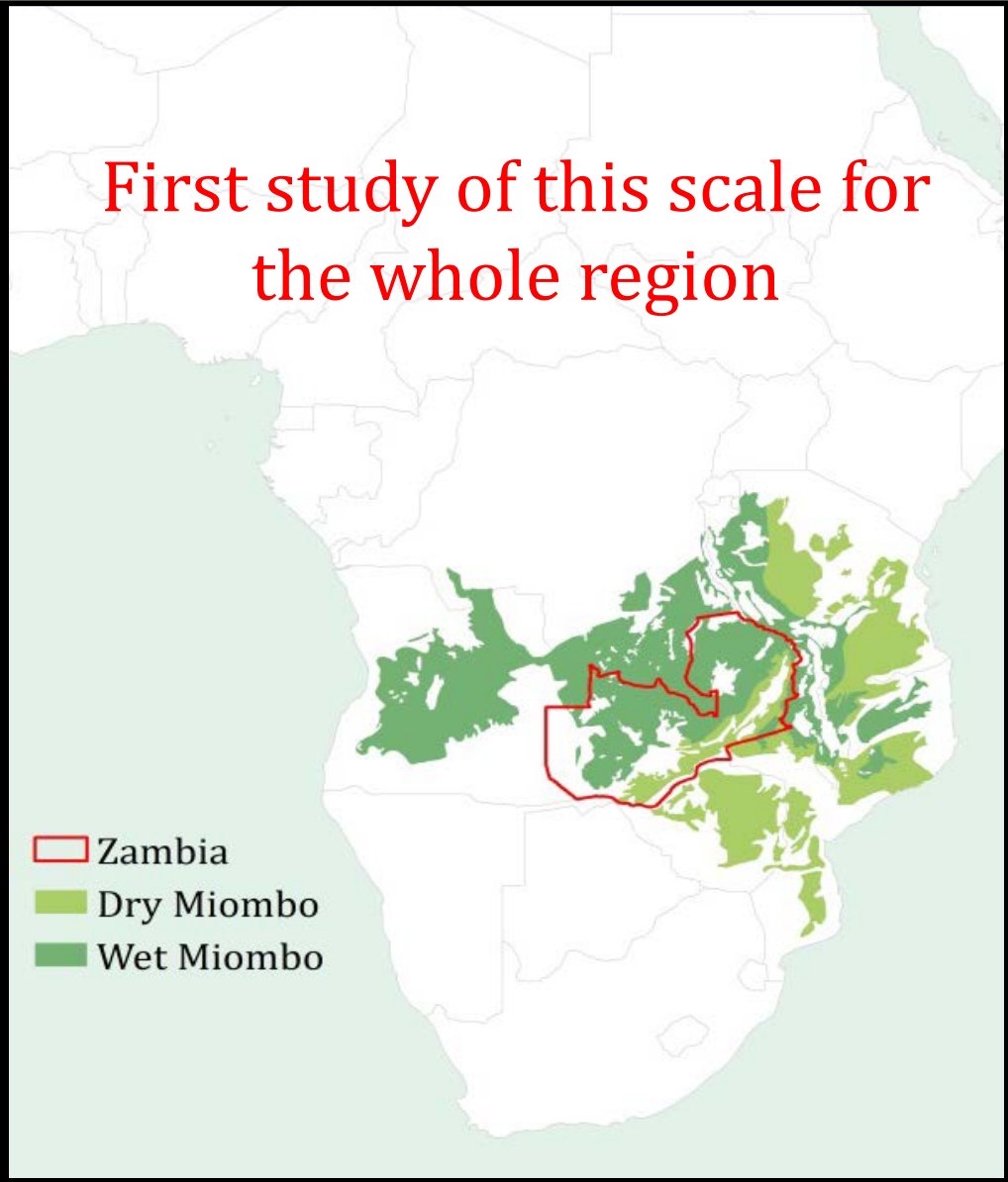
1. Present results from analysis of the change between ILUA I & II
2. Show preliminary results of species distribution modelling performed with the ILUA II data

Large-scale alterations of African dry forests and woodlands

Johanne Pelletier, Alain Paquette, Keddy Mbindo, Noah Zimba, Abel Siampale, Bwalya Chendauka, Freddie Siangulube, Jonathan Wesley Roberts

Aim

Evaluate the drivers of change in biodiversity and productivity of African dry forests and woodlands



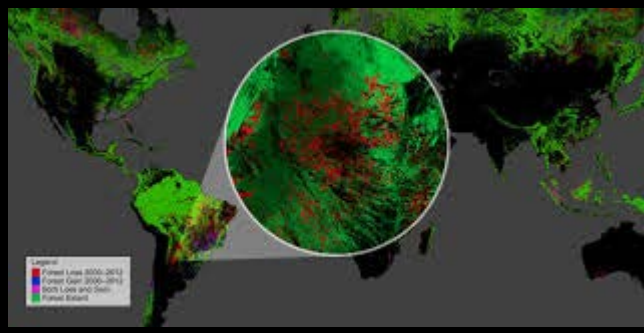
(Pelletier et al., in review)

Large-scale alterations?

High-Resolution Global Maps of 21st-Century Forest Cover Change

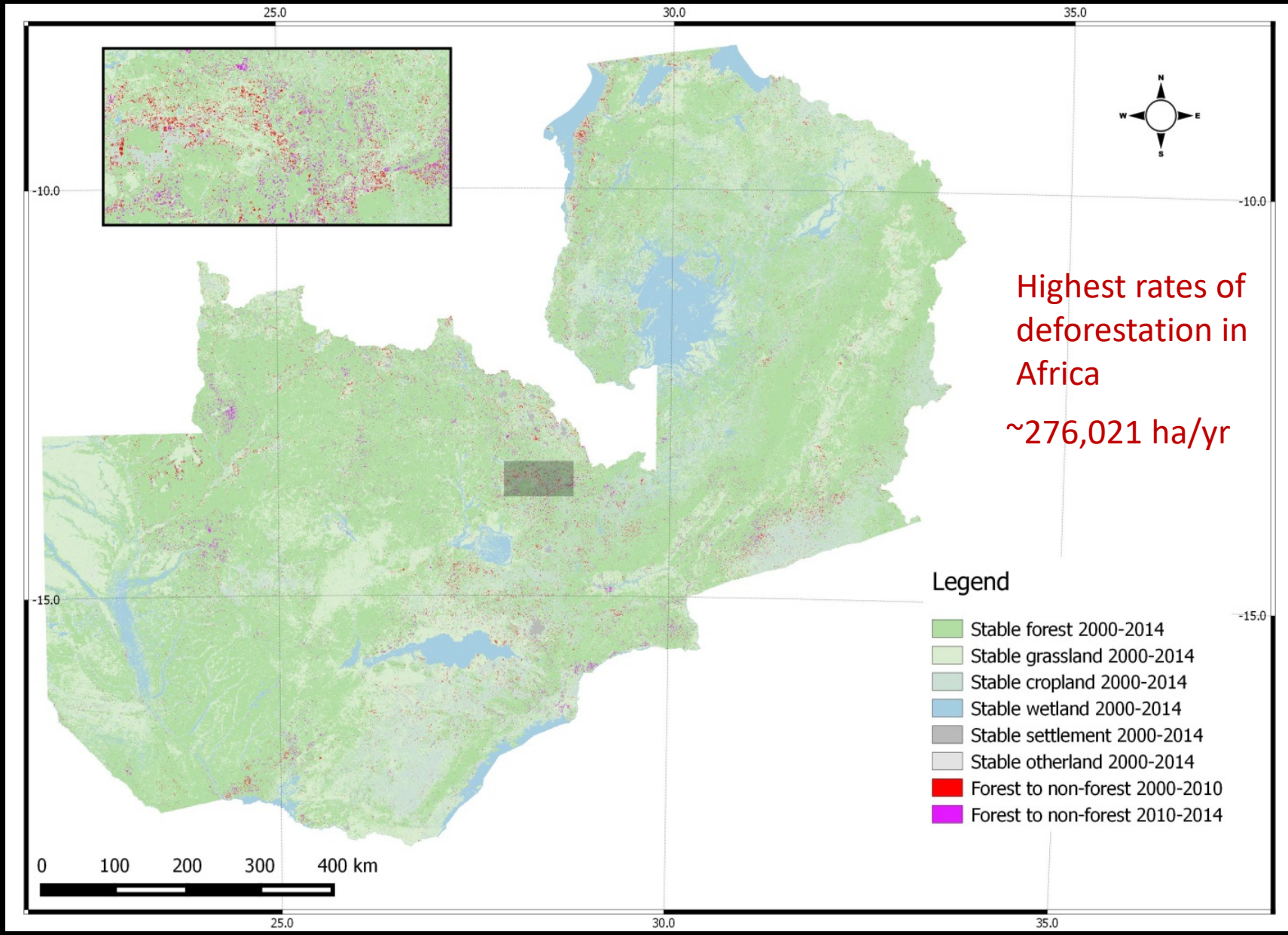
M. C. Hansen,[1*] P. V. Potapov,[1] R. Moore,[2] M. Hancher,[2] S. A. Turubanova,[1] A. Tyukavina,[1] D. Thau,[2] S. V. Stehman,[3] S. J. Goetz,[4] T. R. Loveland,[5] A. Kommareddy,[6] A. Egorov,[6] L. Chini,[1] C. O. Justice,[1] J. R. G. Townshend[1]

Brazil's well-documented reduction in deforestation was offset by increasing forest loss in Indonesia, Malaysia, Paraguay, Bolivia, Zambia, Angola, and elsewhere.



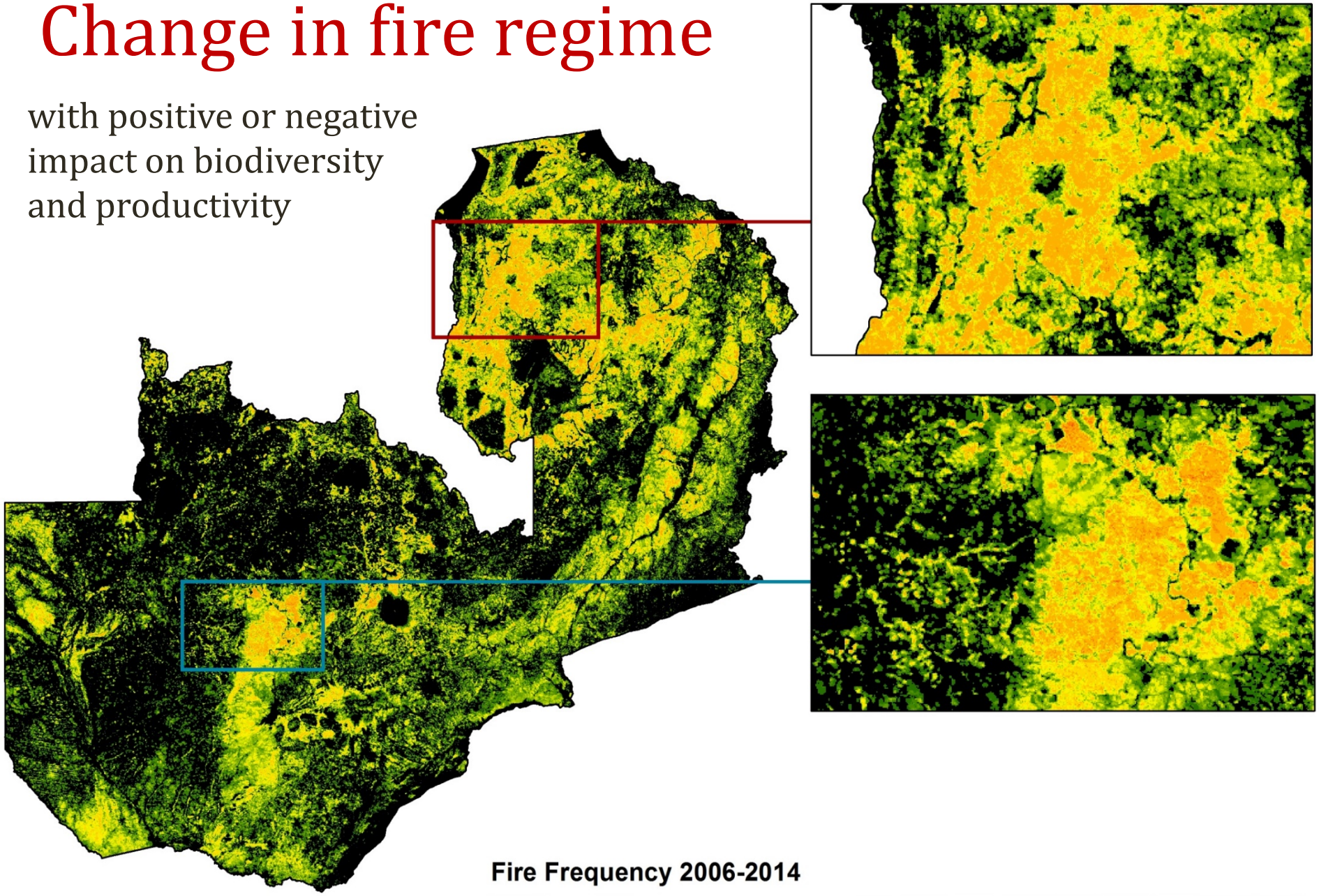
National analysis estimates deforestation rates of 250,000 ha/yr from 2000-2010 and 341,067 ha/yr from 2010-2014

Land-use change



Change in fire regime

with positive or negative impact on biodiversity and productivity



Pelletier et al., in review

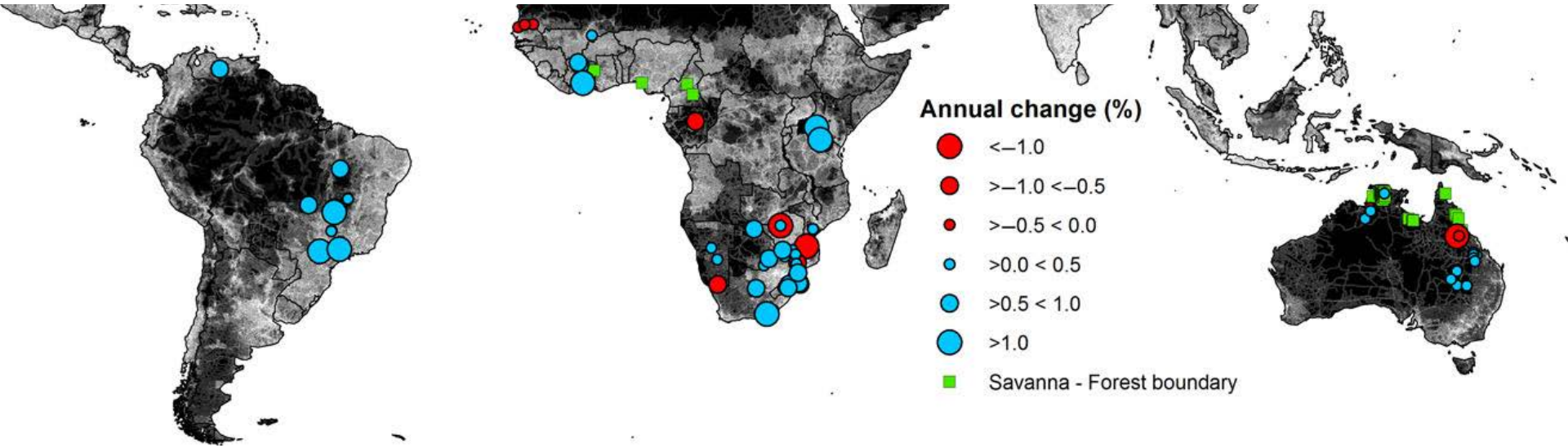
CO_2 fertilization

Global Change Biology

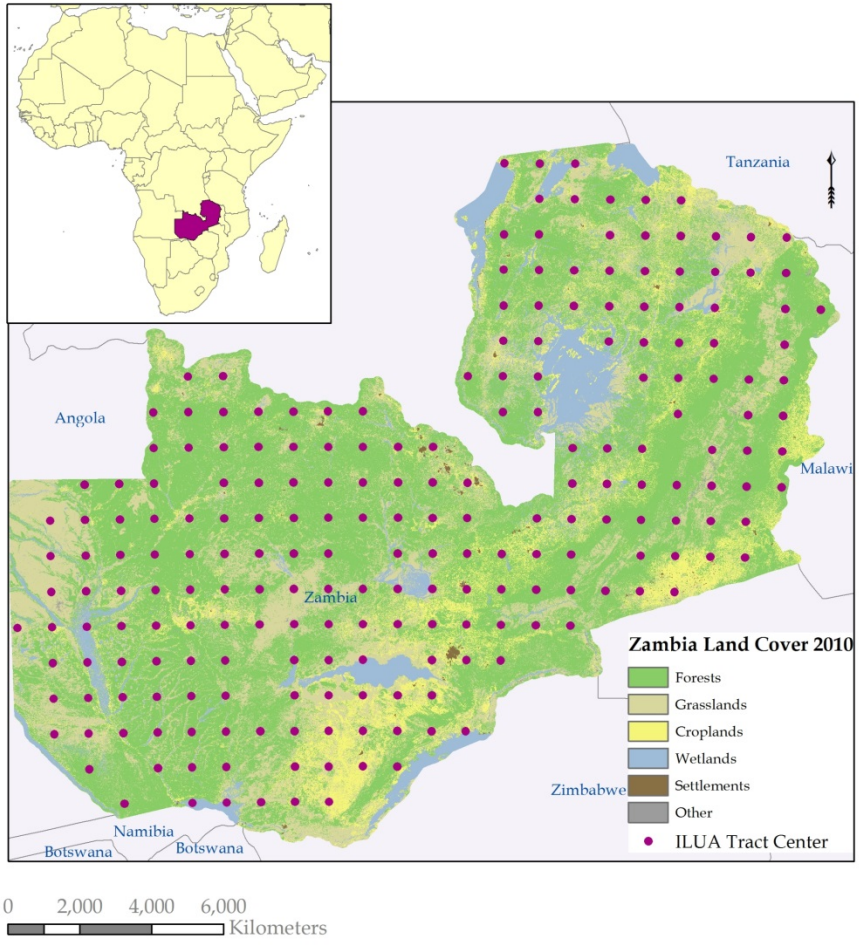
Global Change Biology (2017) **23**, 235–244, doi: 10.1111/gcb.13409

Savanna woody encroachment is widespread across three continents

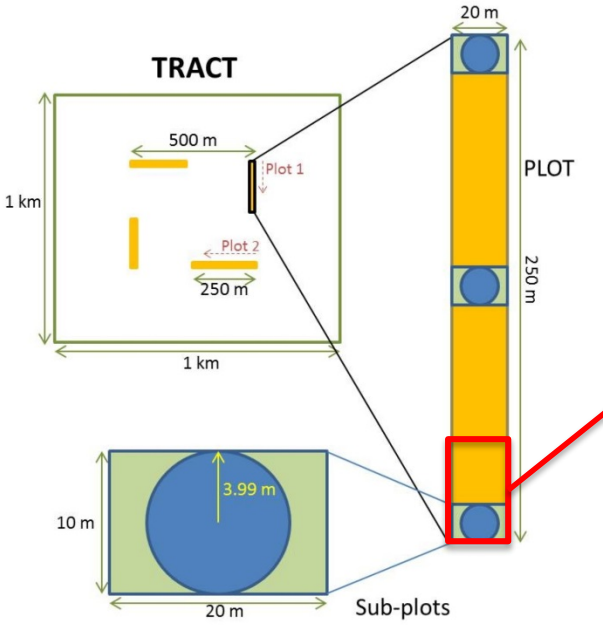
NICOLA STEVENS[1,2], CAROLINE E. R. LEHMANN[3], BRETT P. MURPHY[4] and GISELDA DURIGAN[5]



Integrated Land Use Assessment



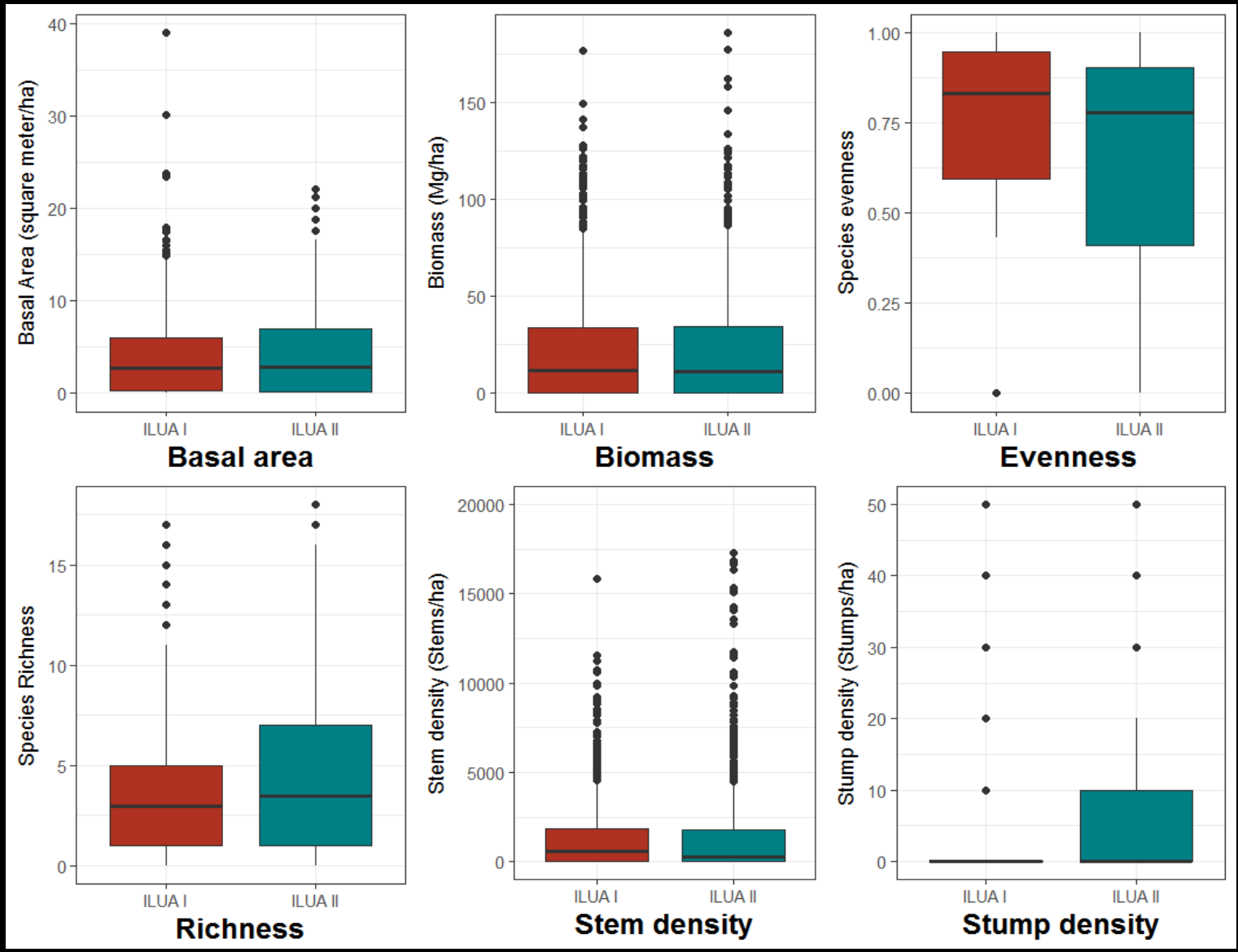
Sampling Design



Compare the area of overlap between ILUA I & ILUA II

Re-measured Area= 1,000 m^2

What is the change in different forest indicators between the two inventories?



Significant gain in richness ($t = -2.8571,\ df = 753, p - value = 0.0043$) **(a), stump density** ($V = 10521, p - value = 1.206e^{-05}$) **(b), basal area** ($V = 84824, p - value =$

Summary table

	Δ Biomass (Mg/ha)	Δ Species richness	Δ Stem density	Δ Basal Area	Δ Stump density	Δ Evenness
	Cluster level (N=211)					
Mean difference	8.48	1.94	-89.66	0.99	2.37	-0.08
Nb with Gain	118	122	56	128	87	72
Nb with Loss	84	65	144	74	48	127
Nb with no change	9	24	24	9	76	12
25th percentile	-3.35	-1.00	-150.00	-0.49	0.00	-0.24
median	1.88	1.00	-50.00	0.63	0.00	-0.05
75th percentile	15.04	6.00	5.00	2.64	5.00	0.06
	Plot level (N=829)					
Mean difference	7.42	1.03	-147.37	0.83	2.34	-0.06
Nb with Gain	475	428	146	470	192	255
Nb with Loss	254	221	565	260	84	425
Nb with no change	100	180	118	99	553	149
25th percentile	-2.36	-1.00	-220.00	-0.46	0.00	-0.25
median	1.96	1.00	-60.00	0.50	0.00	-0.02
75th percentile	14.90	3.00	0.00	2.69	0.00	0.07

On average, we find that forests and woodlands show a gain in biomasss

Emissions vs Absorptions

	Area (in ha)	C budget (in MgC; using mean growth rates)[1]	C budget (in MgC; using median growth rates)
Stable forests (2000-2014)	41,859,392	-695,471,508	-407,734,190
Forest loss 2000-2010[2]	2,500,032	59,670,332	59,670,332
Forest loss 2010-2014	1,364,268	32,562,113	32,562,113
Difference between emissions and absorptions from forest		-603,239,062	-315,501,745

[1] Growth rates for forest plots remaining forest plots is 1.19 MgC ha^{-1} yr^{-1} for the mean and 0.696 MgC ha^{-1} yr^{-1} for the median.

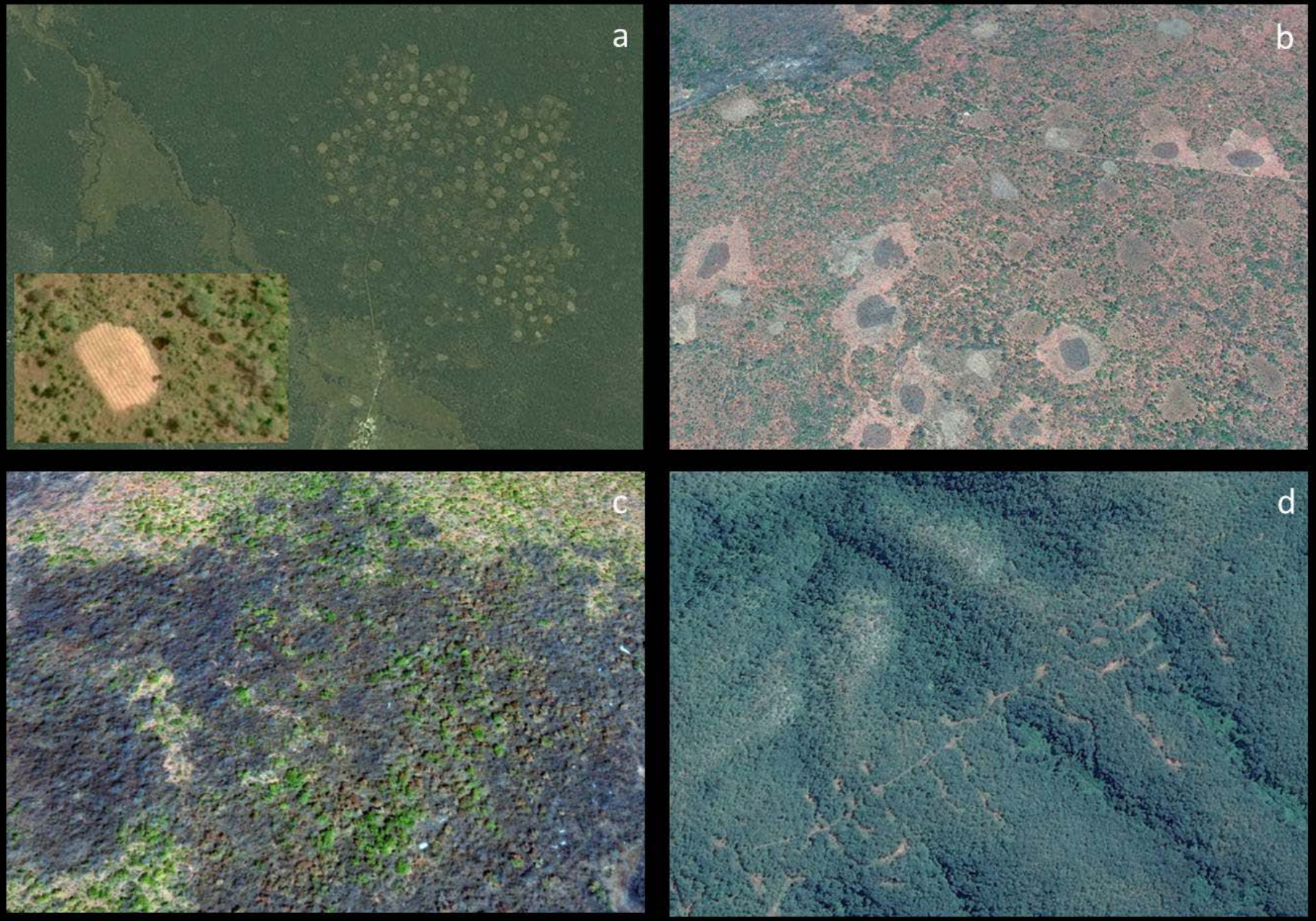
[2] Deforestation area estimates and associated emissions (converted to Mg C) were obtained from the Forest Reference Emission Levels of the Republic of Zambia submitted to the UNFCCC.

Findings

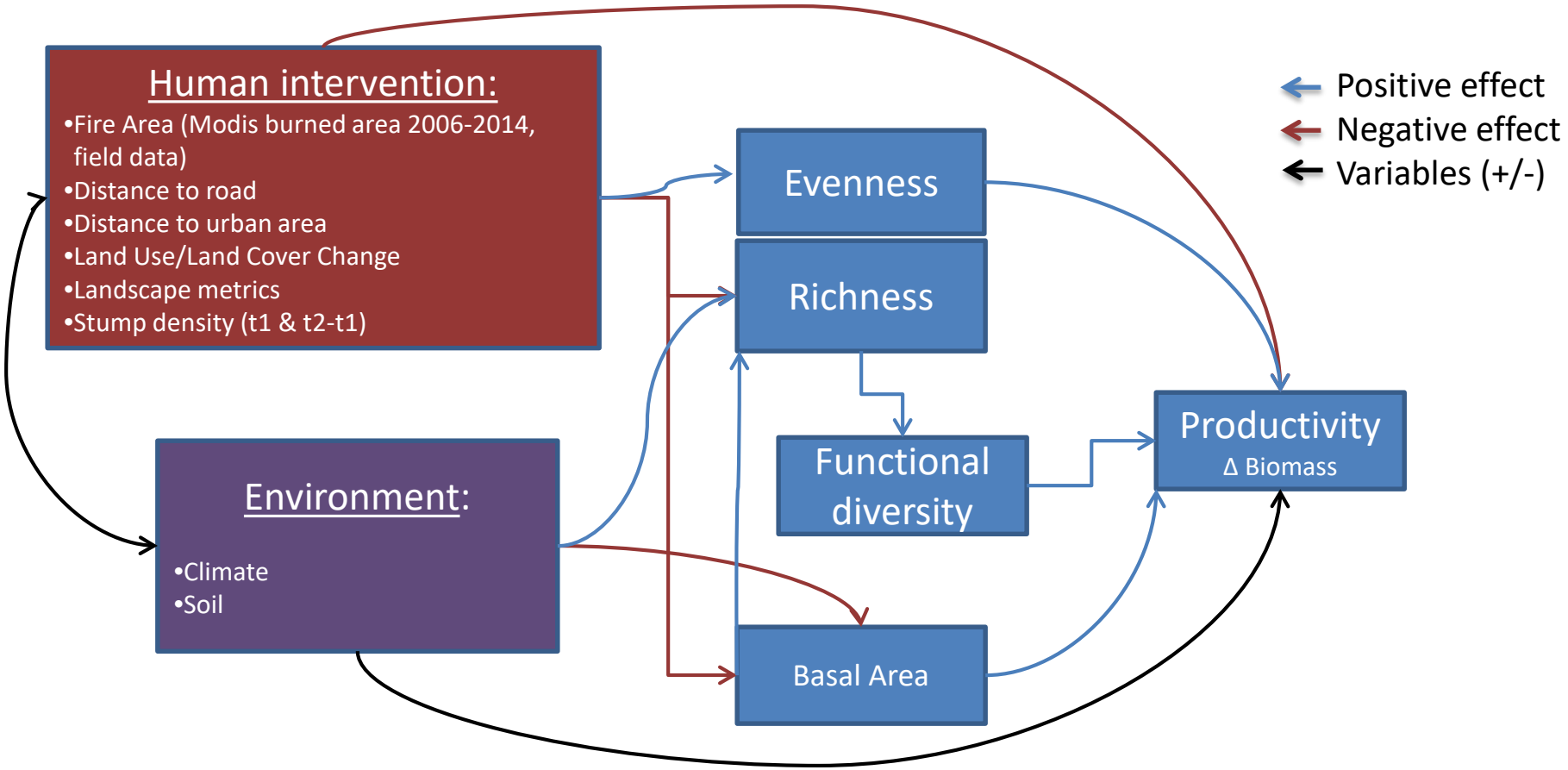
- Significant gain in biomass
- Significant decline in evenness
- Increase in stump density
- Absorptions surpass emissions

→ Carbon sink

What are the main human and natural drivers under different trajectories of change?

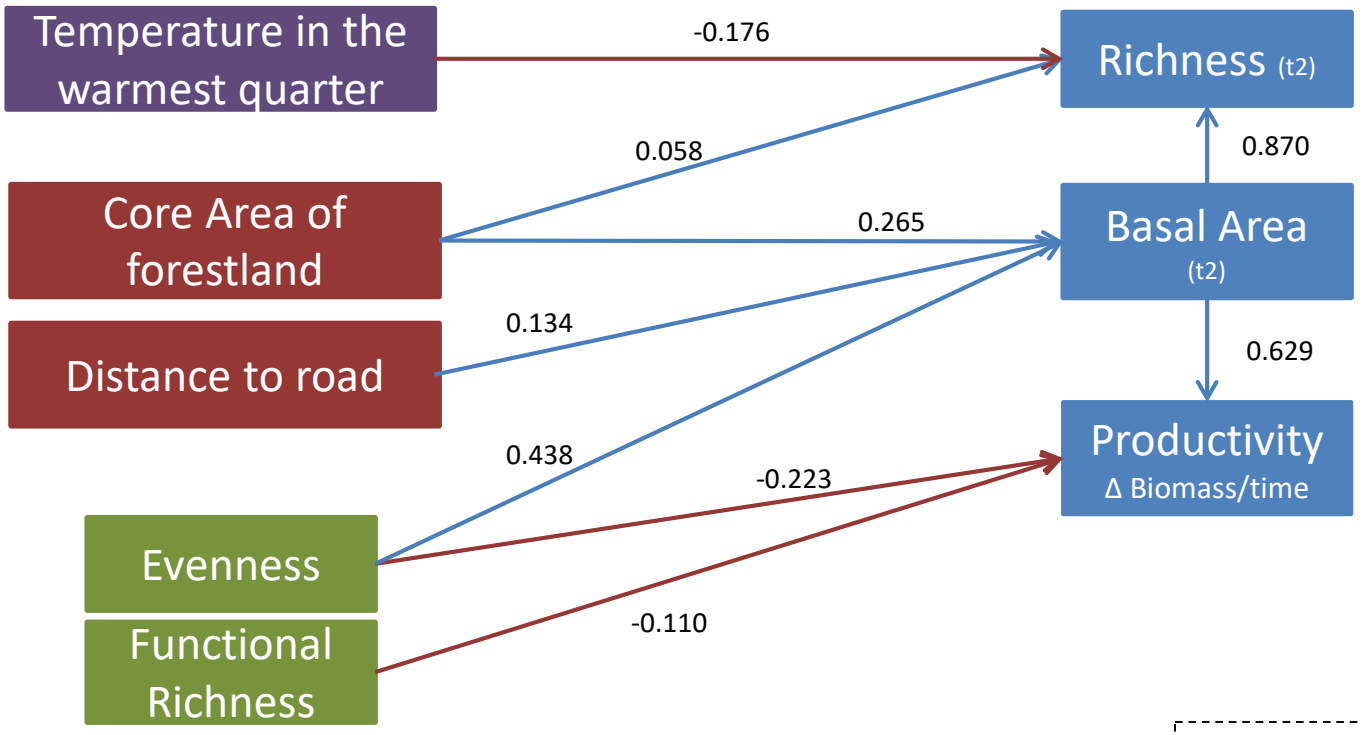

a
b
c
d

Conceptual framework



Test hypotheses about causal factors affecting productivity

All plots

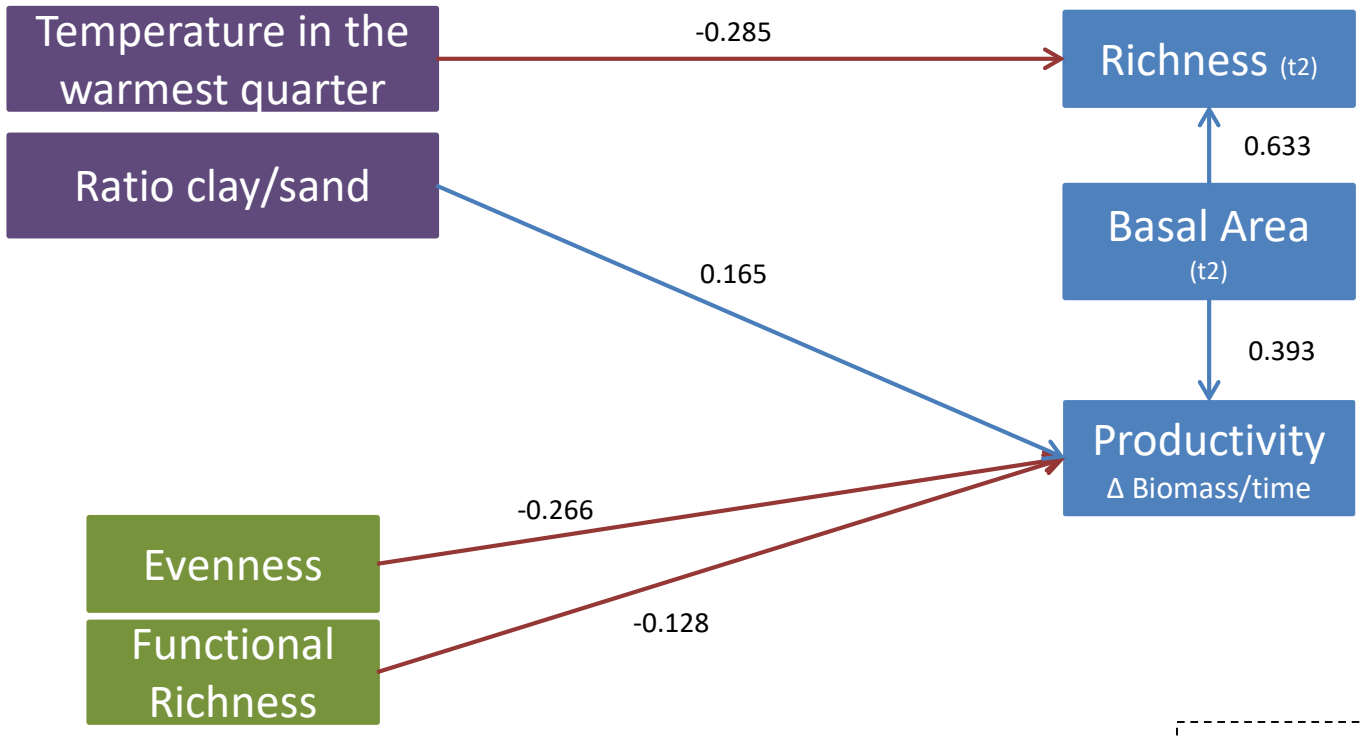


R-Square:

	Estimate
Richness	0.803
Productivity	0.342
Basal area	0.280

Pelletier et al., in review

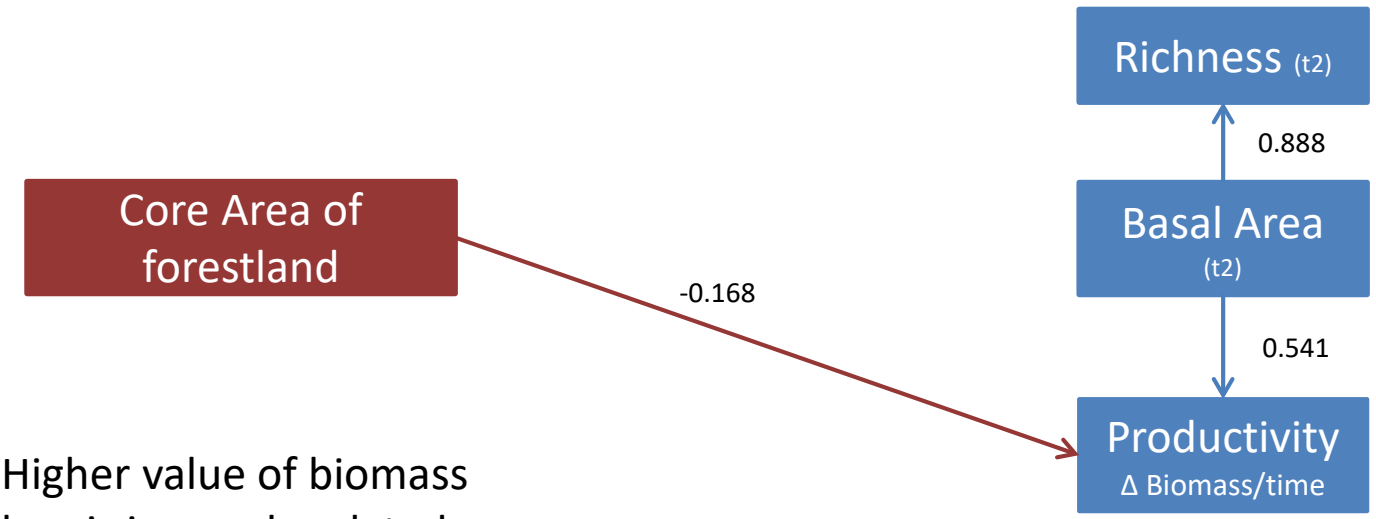
Plots- *Forest remaining forest*



R-Square:	Estimate
Richness	0.475
Productivity	0.277

Pelletier et al., in review

Plots- *Forest to non-forest*

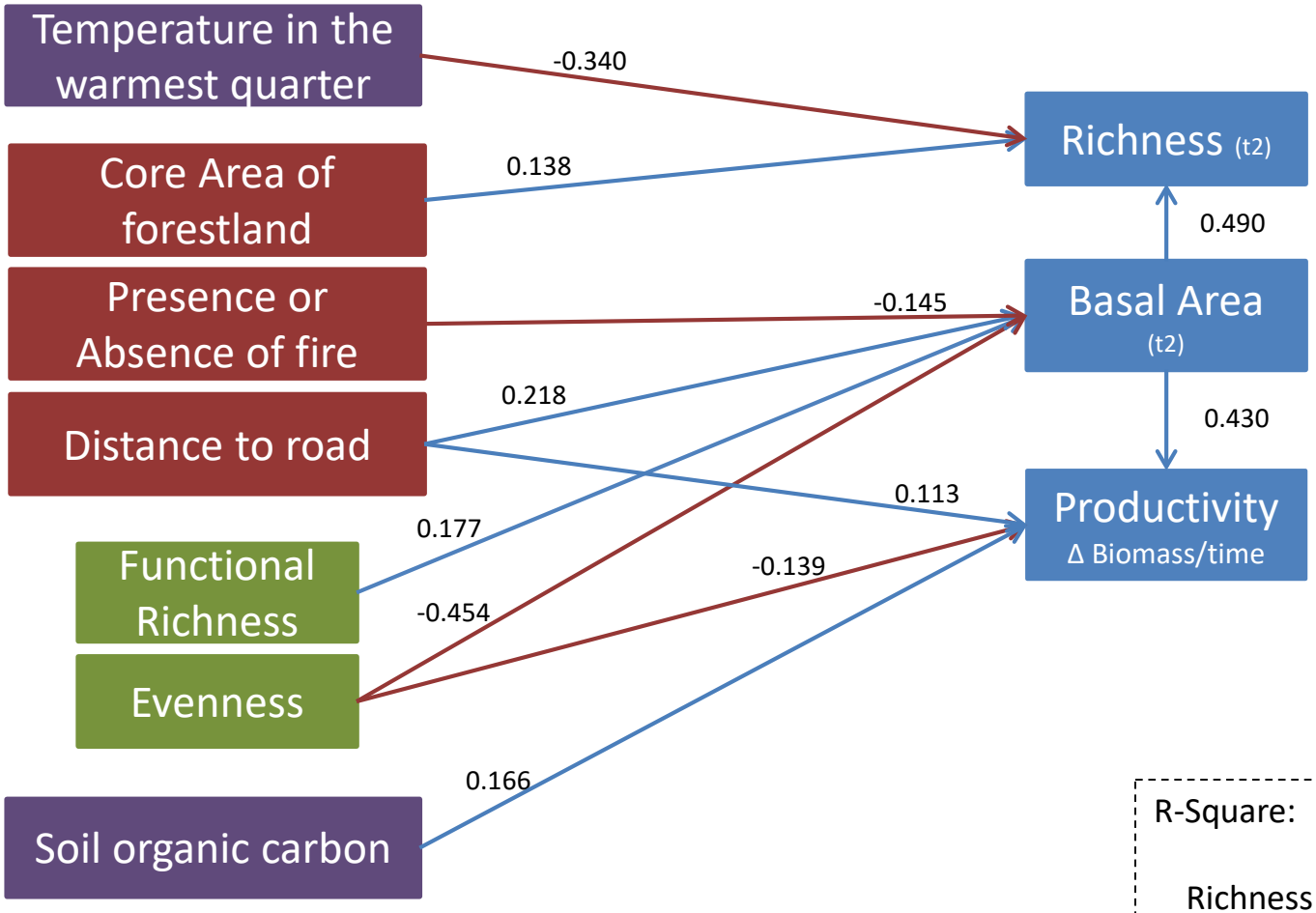


Higher value of biomass loss is inversely related to core area of forestland

R-Square:	Estimate
Richness	0.788
Productivity	0.313

Pelletier et al., in review

Plots- *with biomass gain*



R-Square:	Estimate
Richness	0.381
Productivity	0.331
Basal area	0.341

Pelletier et al., in review

Findings

- Different trajectories of change caused by different drivers
- Fragmentation, distance to roads affect stocks and productivity

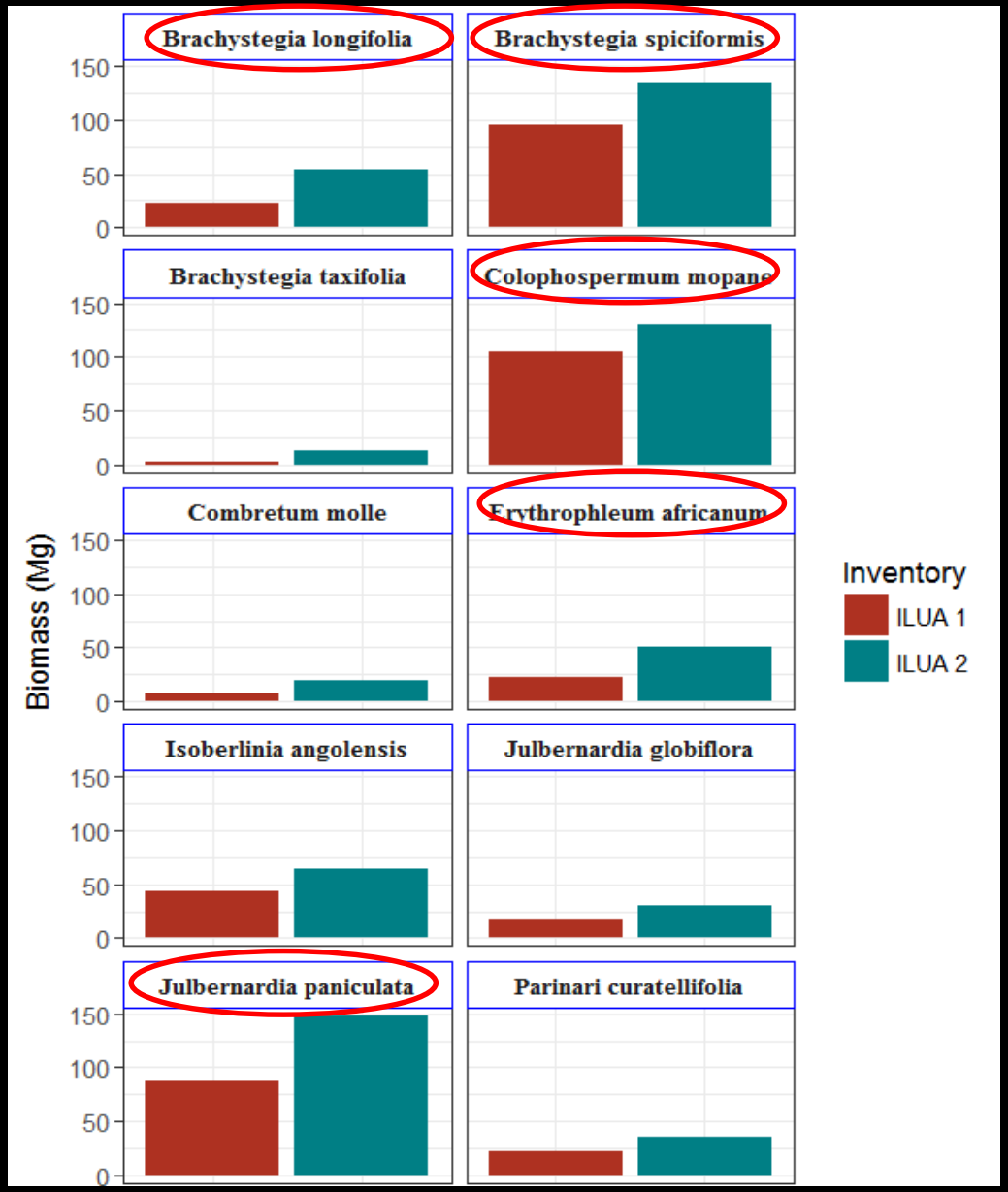
- Functional richness and dominance are important causal factors in less impacted sites

What are the species mostly associated with biomass change?

Top weight gainer species

- All belong to the Fabaceae family and Caesalpinioideae sub-family
- Most gain in *Julbernardia paniculata, Brachystegia spiciformis, Brachystegia longifolia, Erythrophleum africanum, Colophospermum mopane*

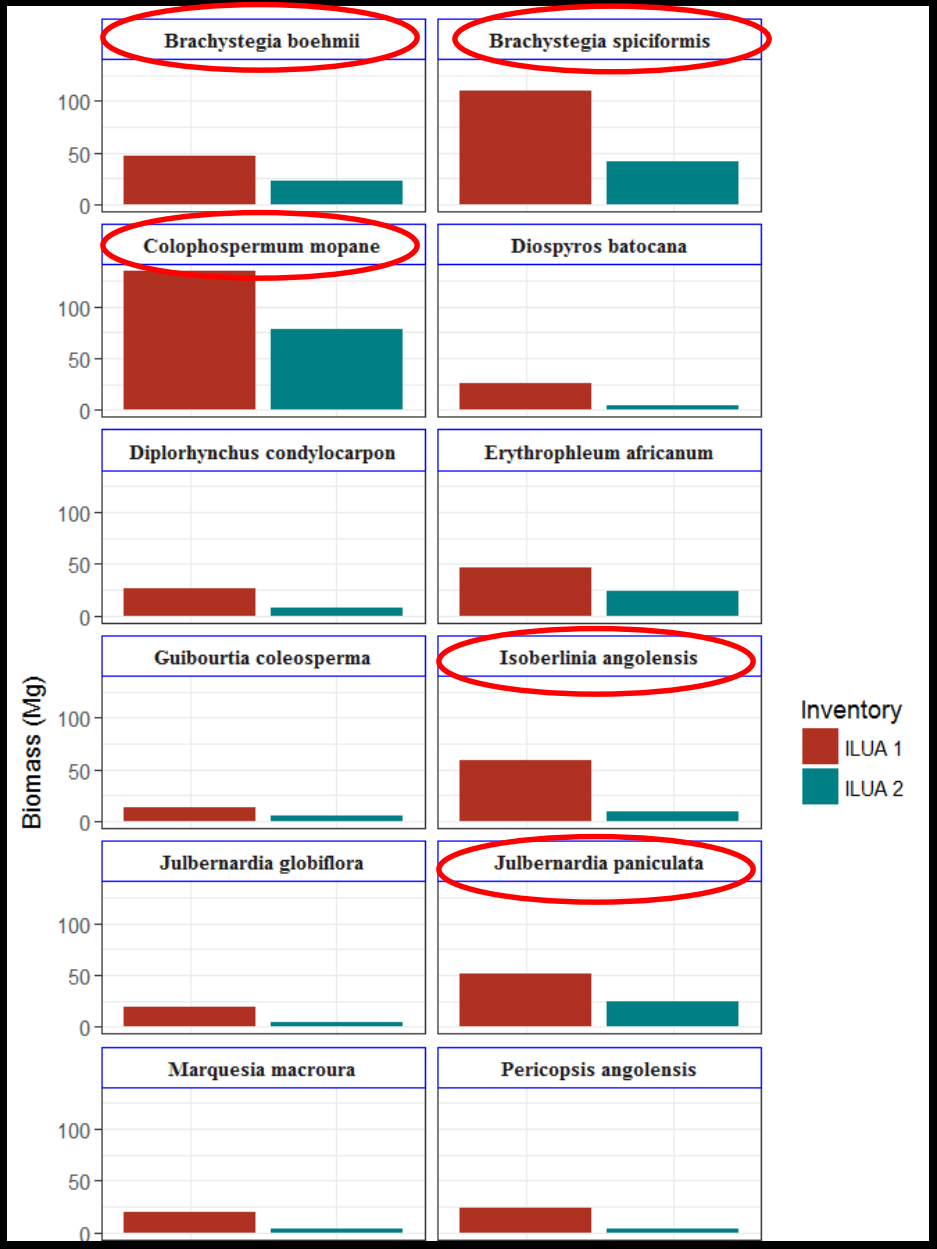
Plots showing biomass gain



Top losers

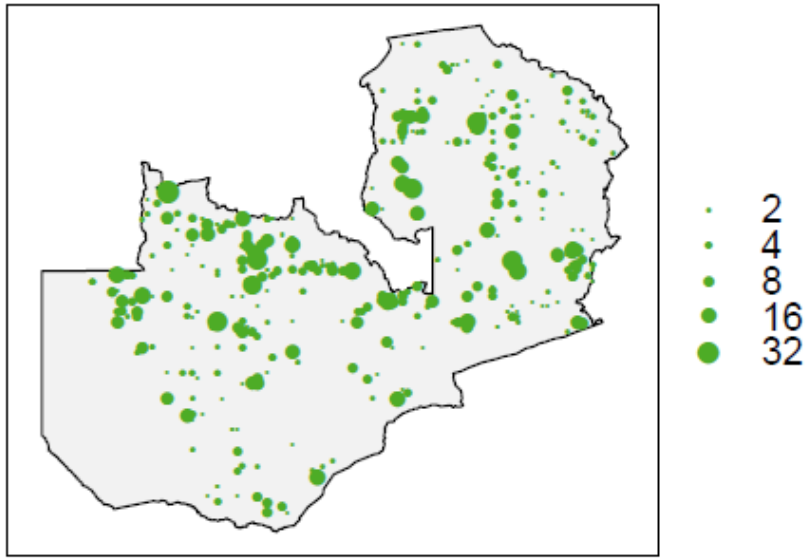
Large biomass loss for these species with the greatest losses observed for *Brachystegia spiciformis, Colophospermum mopane, Isoberlinia angolensis, Julbernardia paniculata, Brachystegia boehmii*.

Plots showing biomass loss or no change

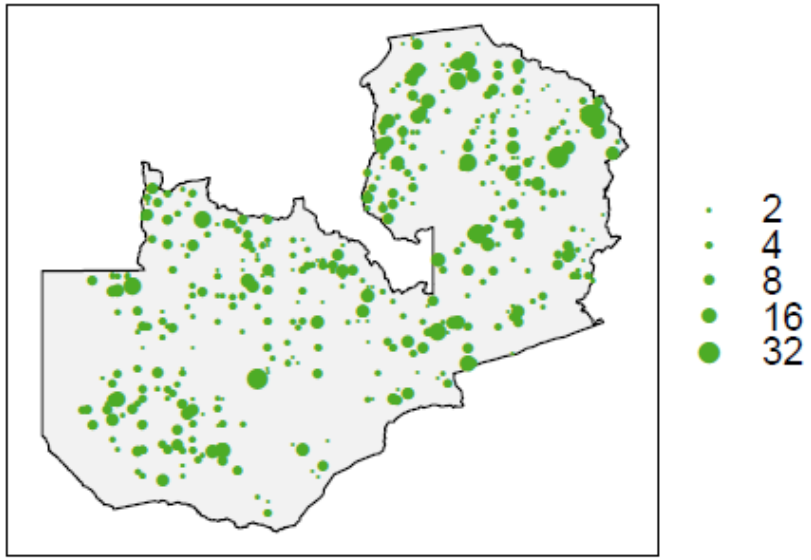


Species gaining biomass

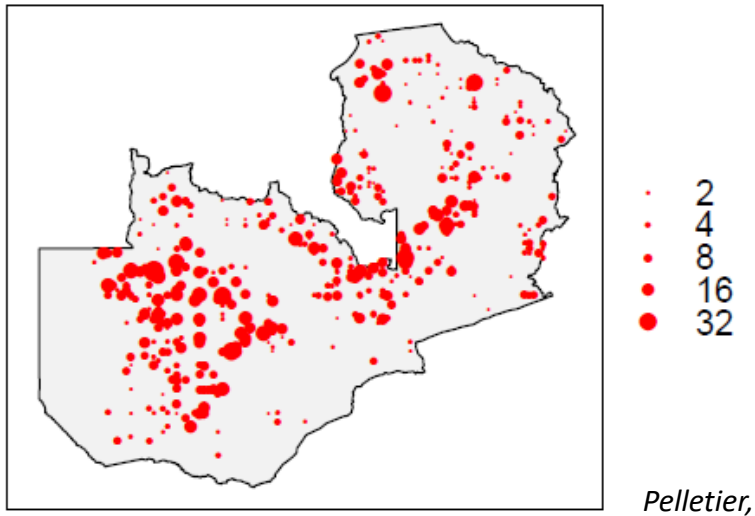
B. longifolia abundance



B. spiciformis abundance

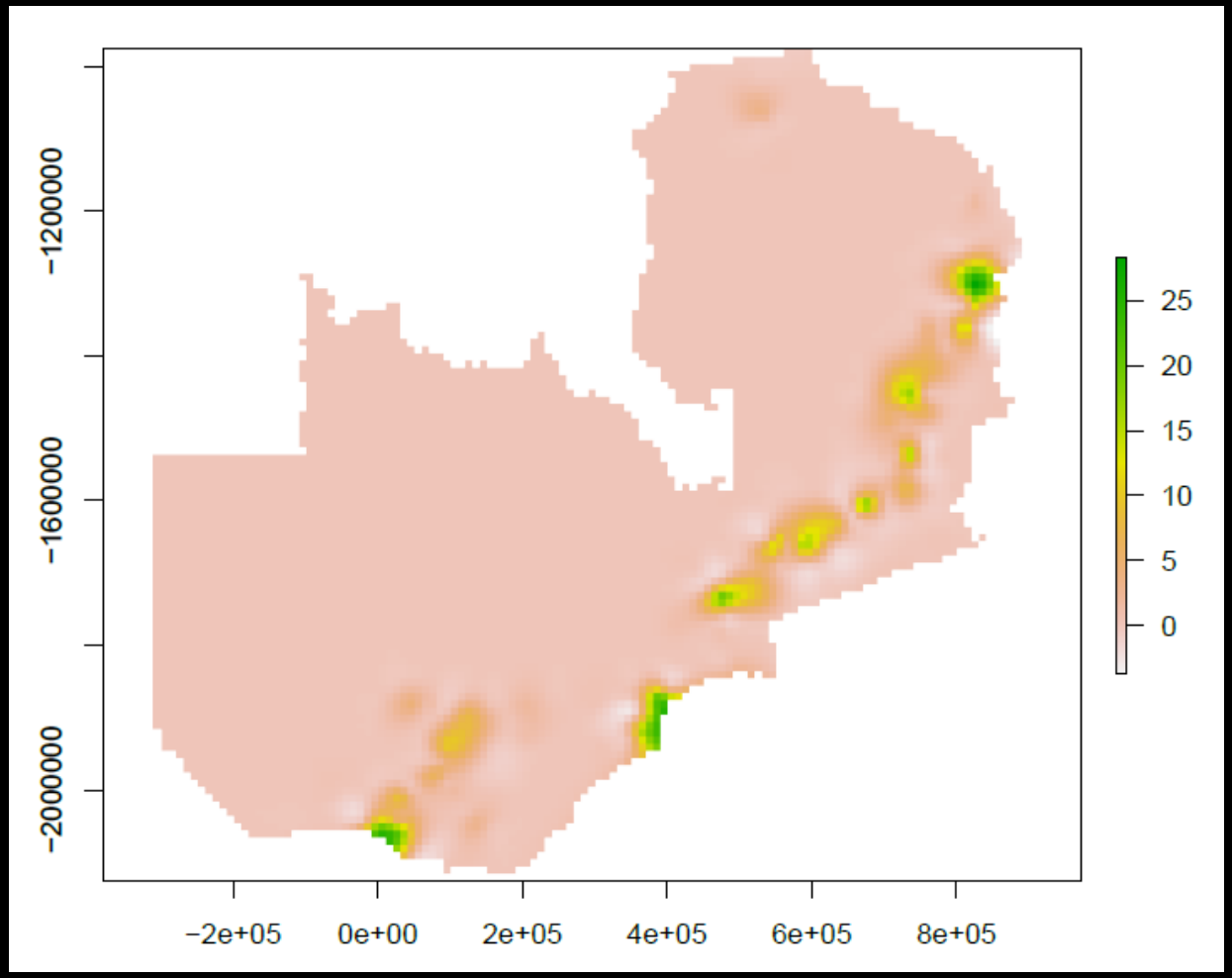


J. paniculata abundance



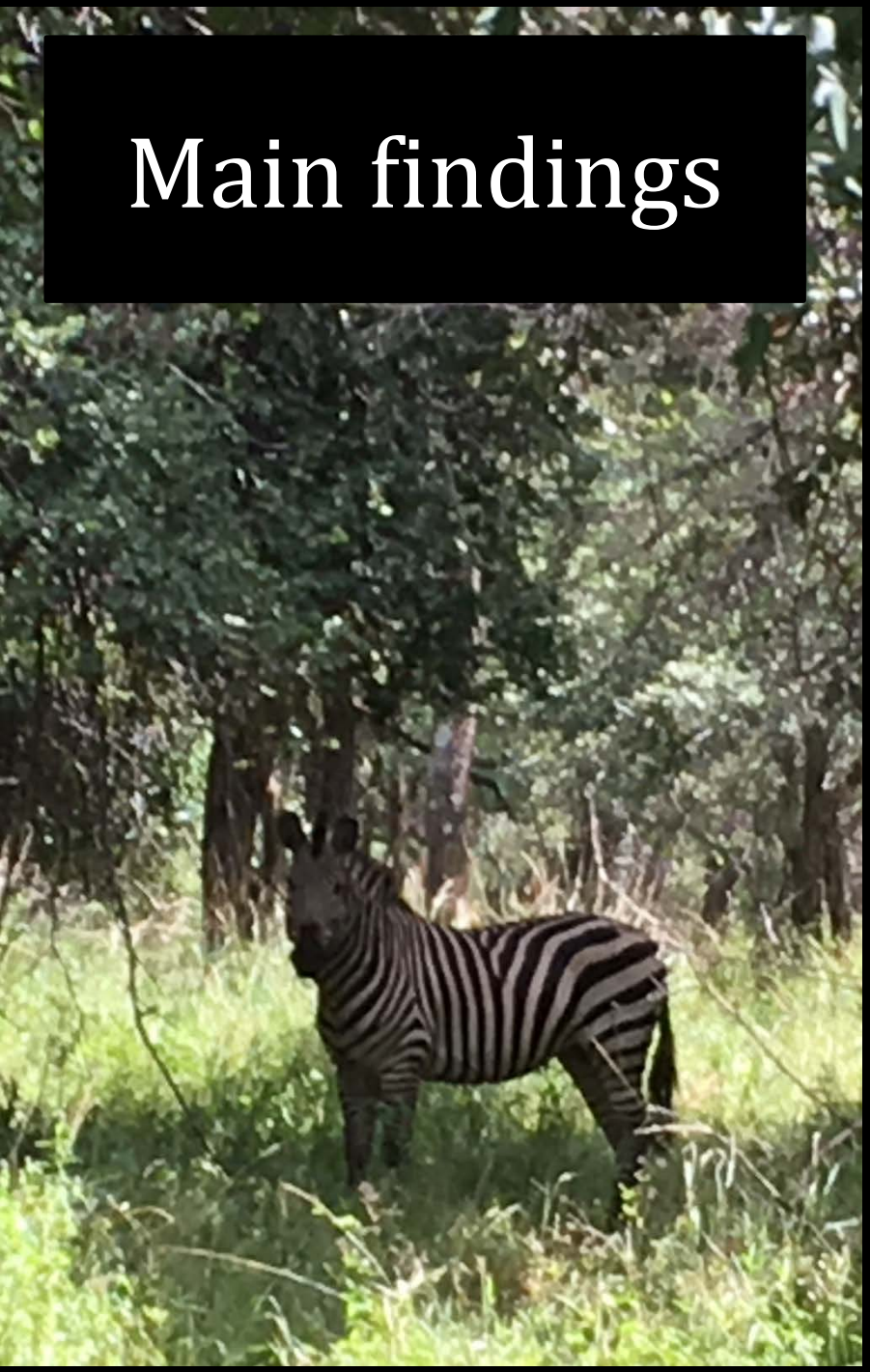
Pelletier, in prep

Net biomass loss for certain species



Colophospermum mopane

(Pelletier, in prep)



Main findings

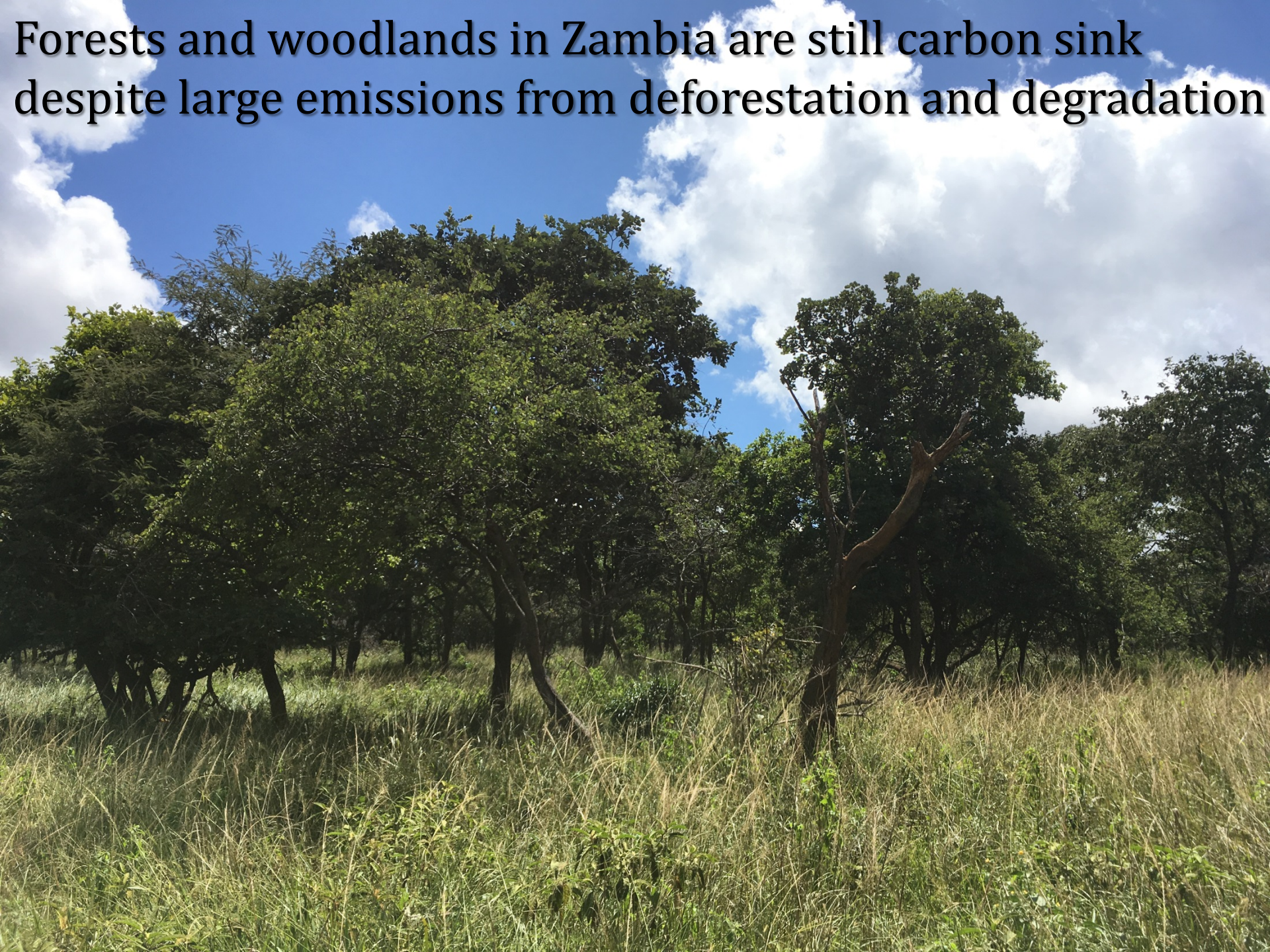
Contrasting stories: loss or gain

I assumed a biomass decline

Overall significant biomass gain

&

Increasing dominance of some species


Forests and woodlands in Zambia are still carbon sink
despite large emissions from deforestation and degradation

What can explain the gain?

CO_2 fertilization ?

Global Change Biology

Global Change Biology (2017) **23**, 235–244, doi: 10.1111/gcb.13409

Savanna woody encroachment is widespread across three continents

NICOLA STEVENS[1,2], CAROLINE E. R. LEHMANN[3], BRETT P. MURPHY[4] and GISELDA DURIGAN[5]

In Africa and Australia, rising atmospheric CO_2, changing land management and rainfall are likely causes. We argue that the functional traits of each woody flora, specifically the N-fixing ability and architecture of woody plants, are critical to predicting encroachment over the next century and that African savannas are at high risk of widespread vegetation change.

Only one species coincide (*Colophospermum mopane*)
All species gaining weight in Zambia are non-nodulating
Most species are characterized by ectomyccorhizal symbiosis

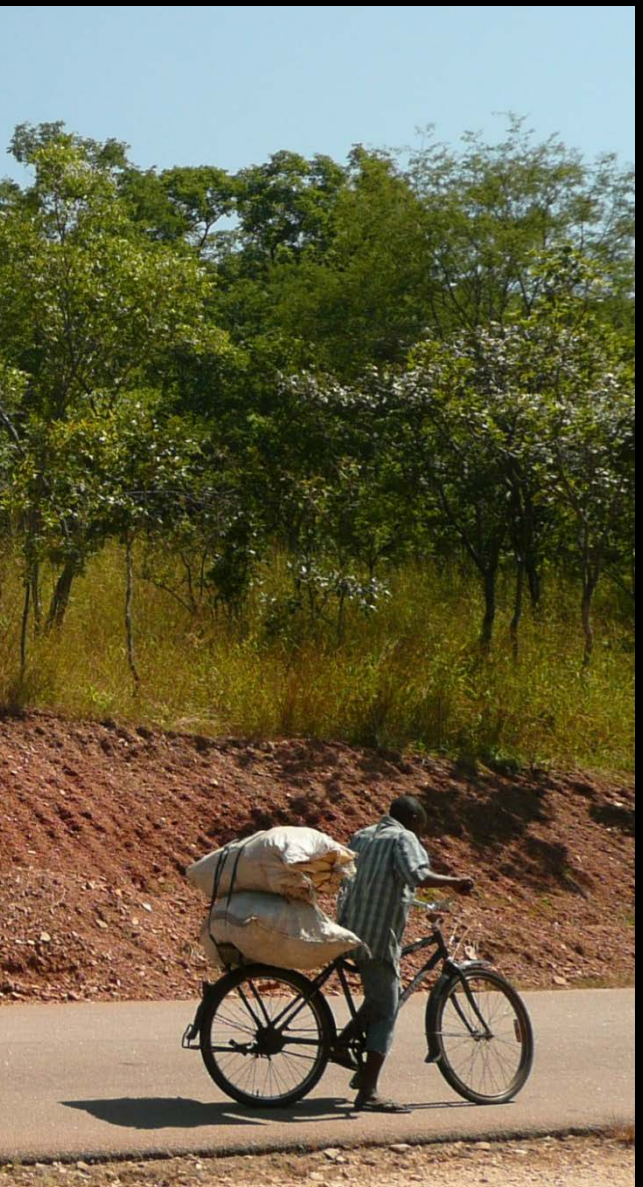
The Miombo woodlands is characterized by different ecosystem processes and response

Drivers of change

- Global driver: rising CO_2 ? More study needed
- Fragmentation and accessibility (land-use change)- Important for road planning
- Fire – *limited role on productivity or impact overridden by increasing productivity?* Need for higher resolution fire area data
- Large gain and loss in biomass in dominant species

There is large-scale alteration of the vegetation

Species distribution modelling



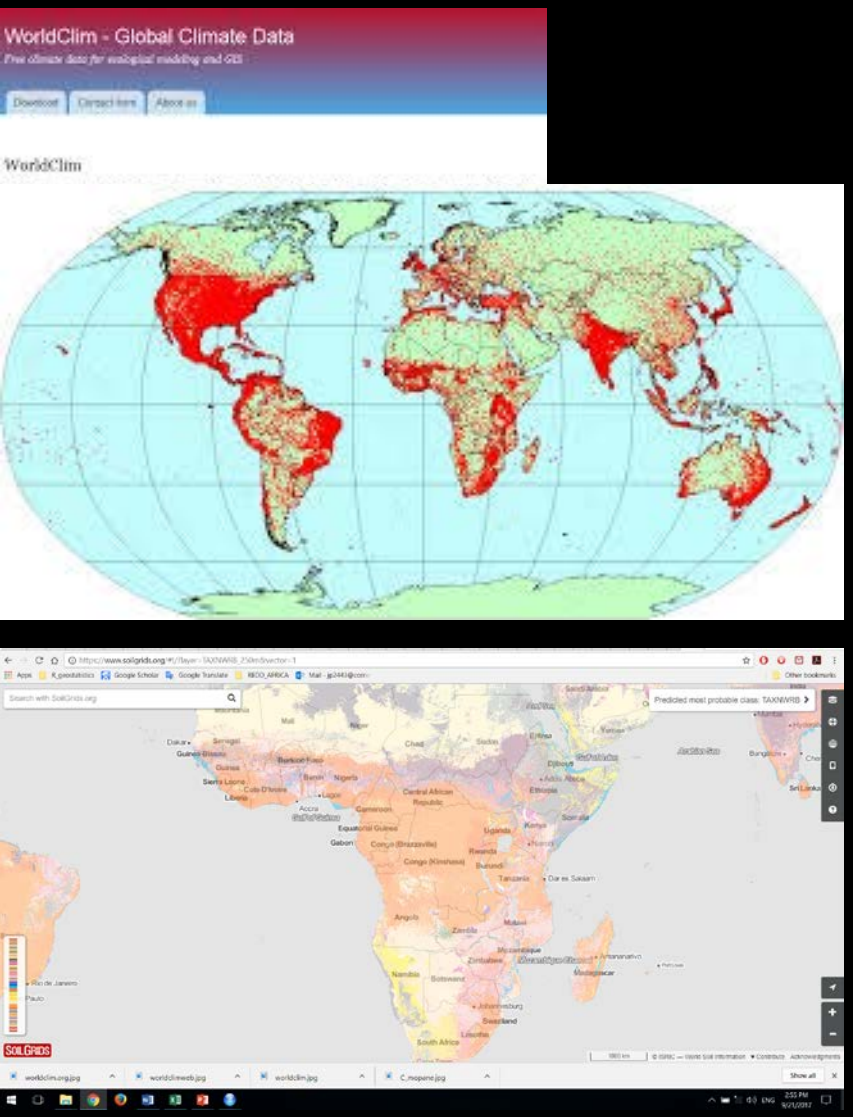
AIM

- Provides a baseline for the country and the region
- Allow to make predictions on potential impacts of climate change and other human impacts on biodiversity
- 15 most abundant species based on ILUA II data

How does it work?

- Occurrence data for each species (presence and absence at each plot locations)
- Build a series of predictors that can explain the distribution of the species
- Build models based on the conditions where each species occur or not
- Predict the presence of each species at other areas

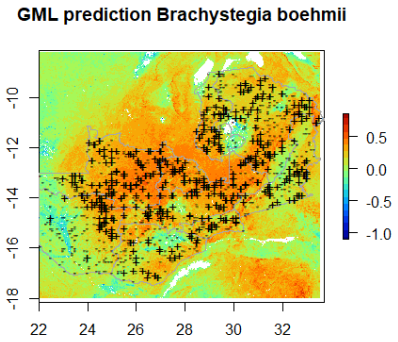
Predictors



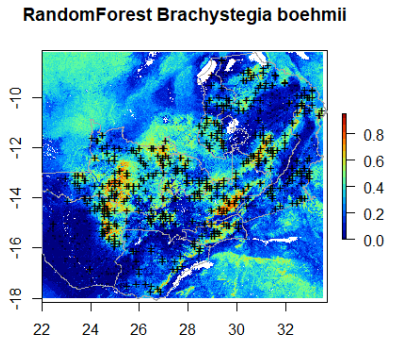
- Bioclimatic data (19 variables)
- Elevation and derived variables (slope, aspect, roughness)
- Soil physical and chemical properties – SOILGRIDS (250m)
- Fire – MODIS fire burned area
- Distance to roads, Distance to rivers

3 species distribution models

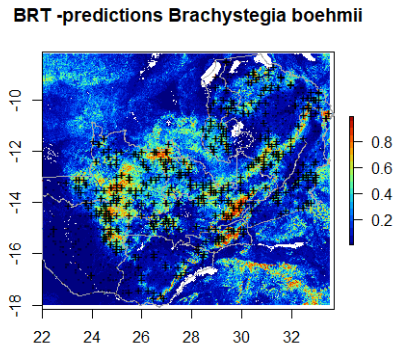
Generalized linear model (GLM)

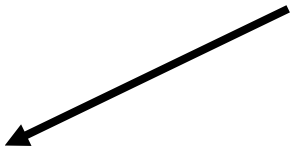


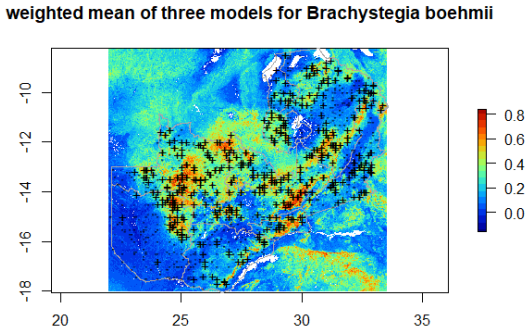
RandomForest (RF)



Boosted Regression Trees (BRT)

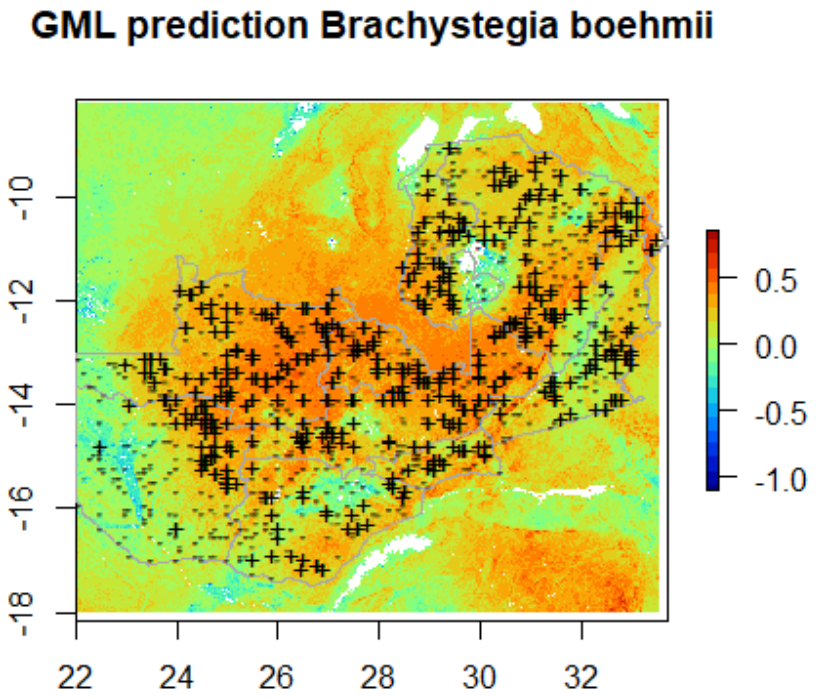


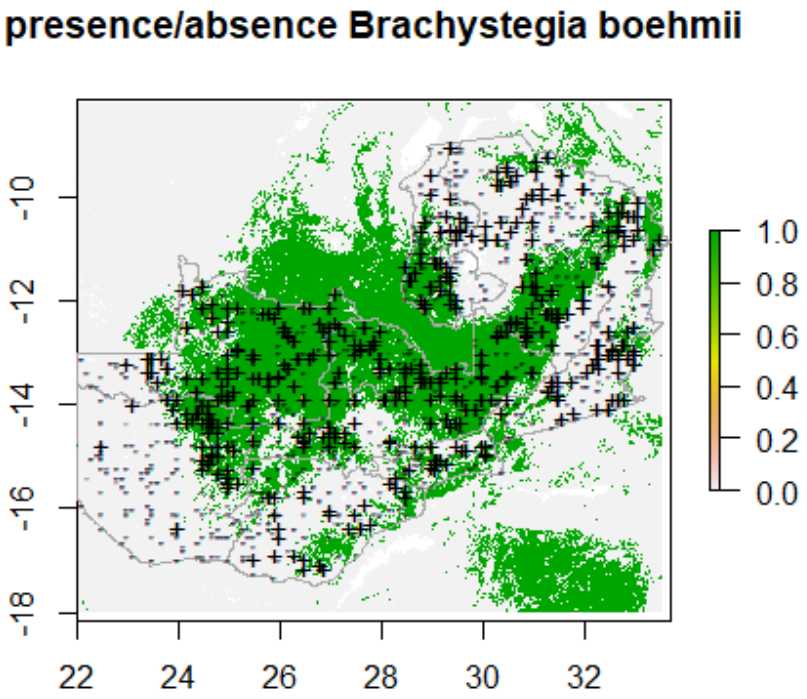




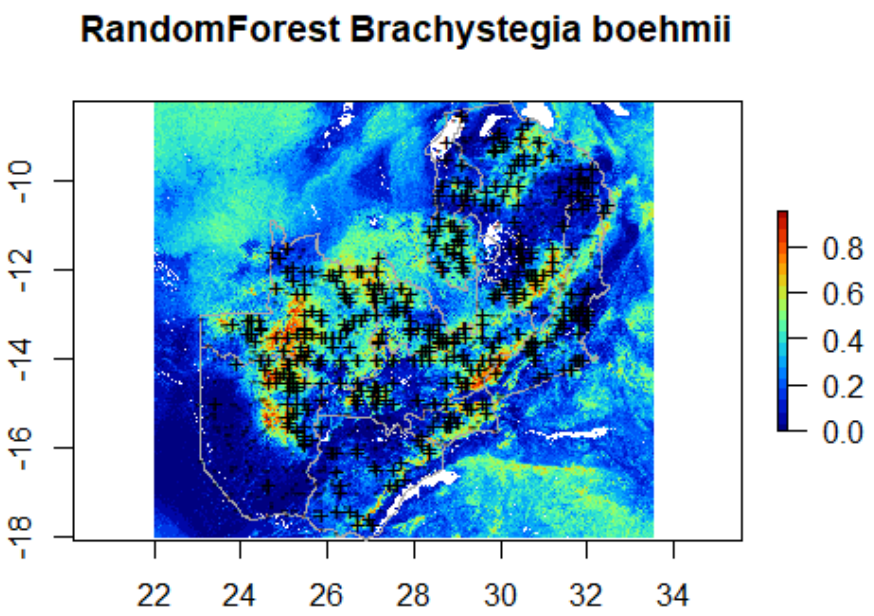
Weighted mean of the 3 models based on model evaluation index

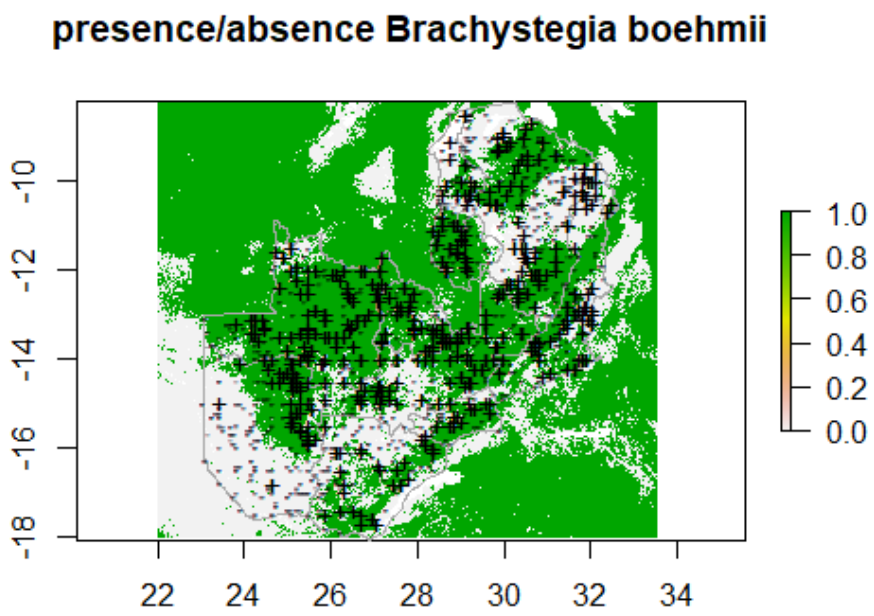
GLM model


GML prediction Brachystegia boehmii
-10
-12
-14
-16
-18
22
24
26
28
30
32
0.5
0.0
-0.5
-1.0

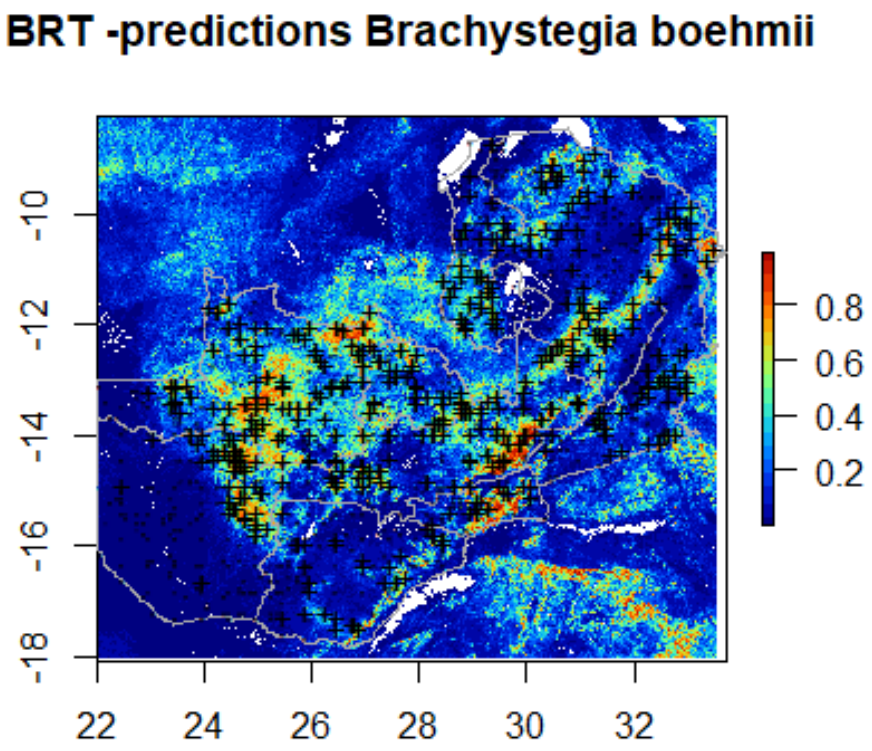

presence/absence Brachystegia boehmii
-10
-12
-14
-16
-18
22
24
26
28
30
32
1.0
0.8
0.6
0.4
0.2
0.0

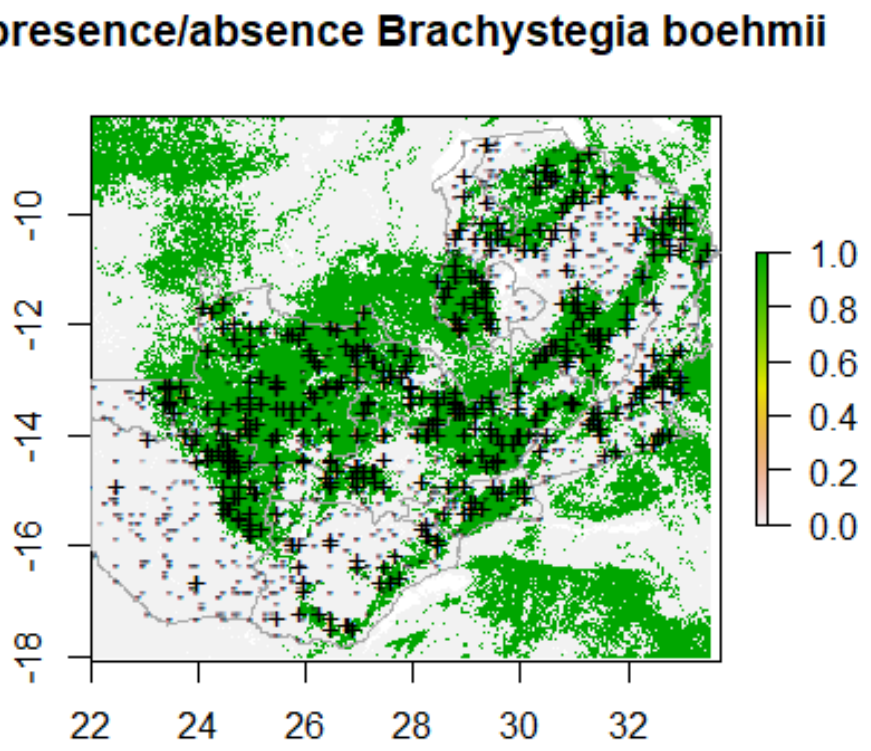
RandomForest model

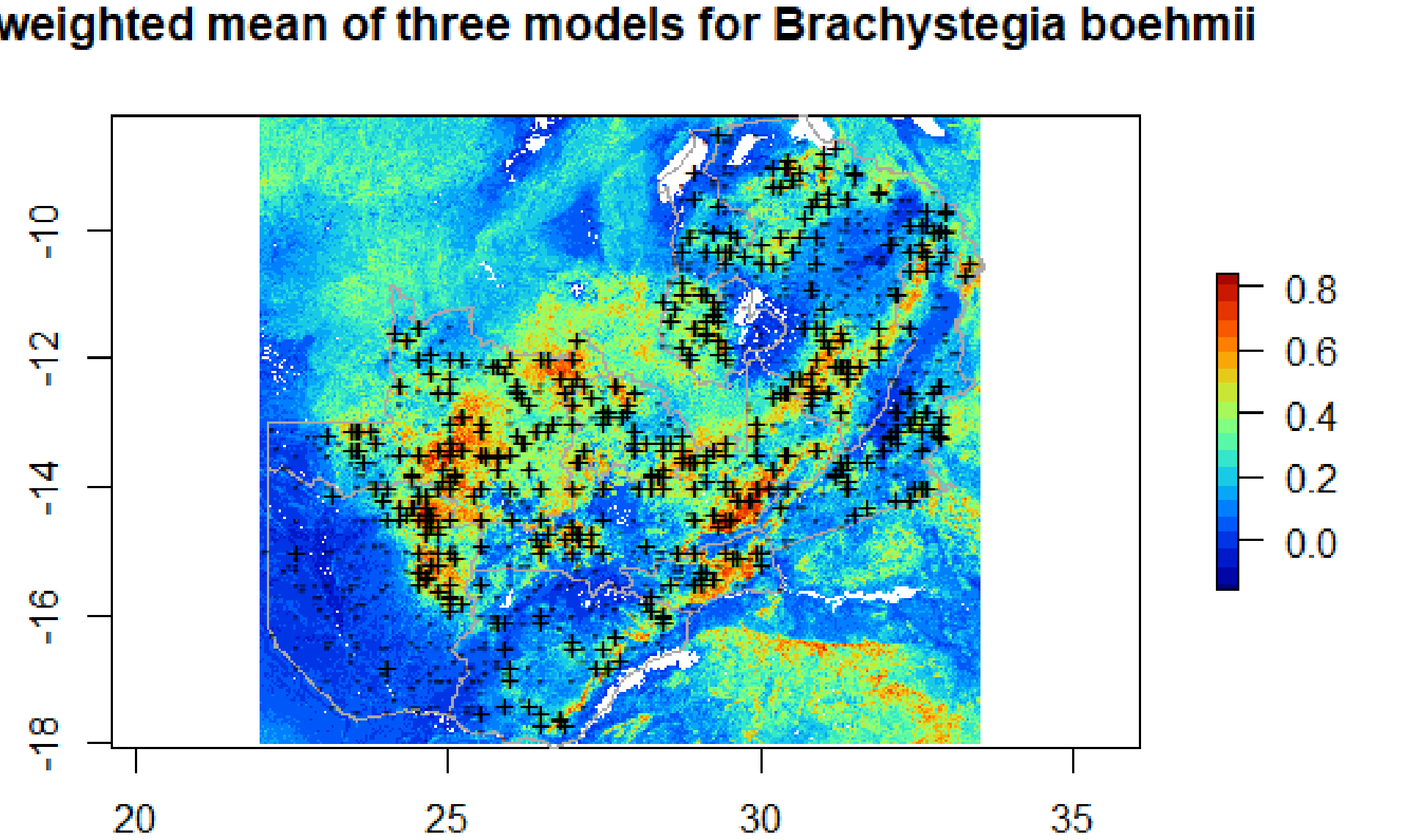




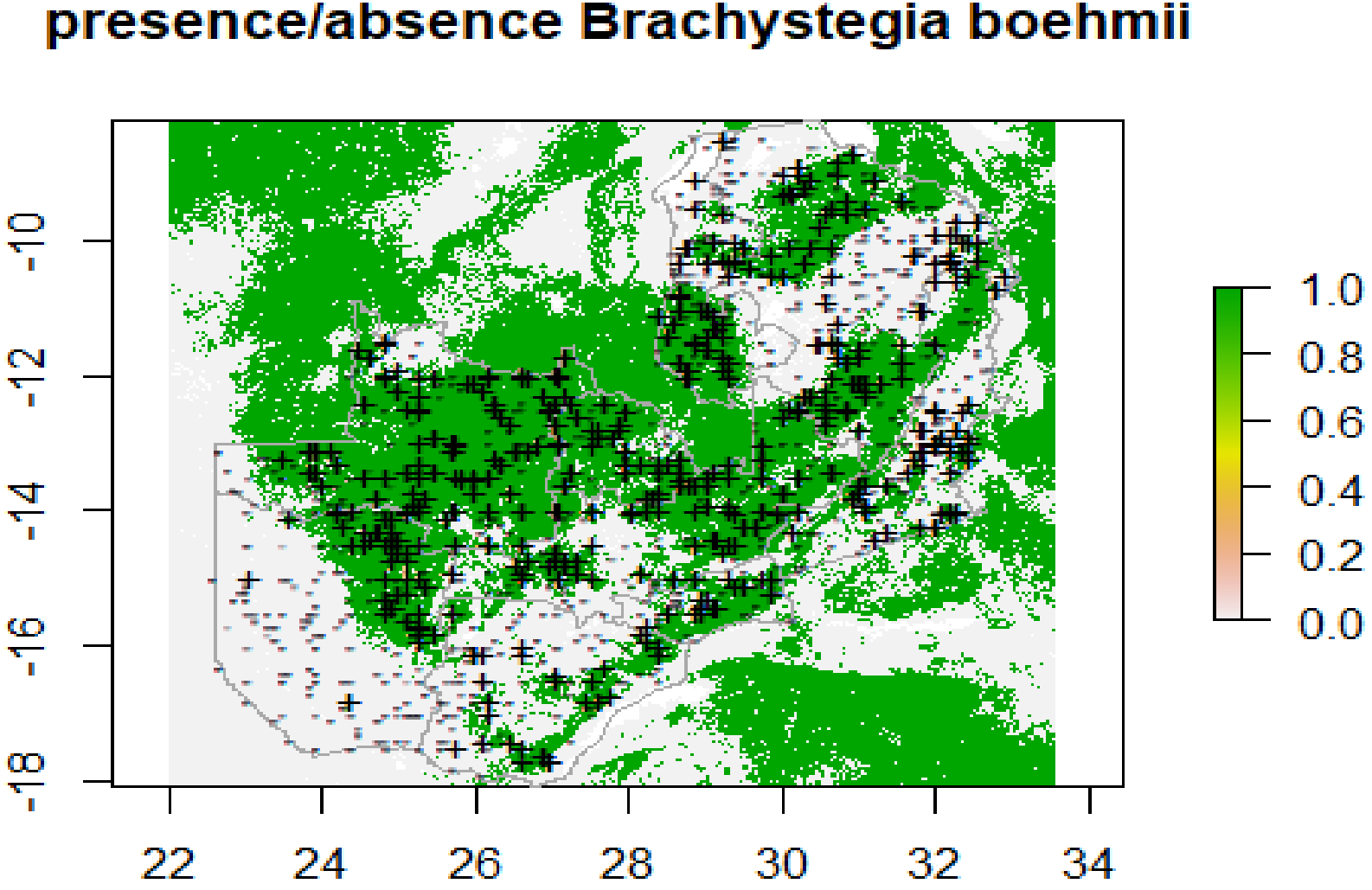
Boosted Regression Tree





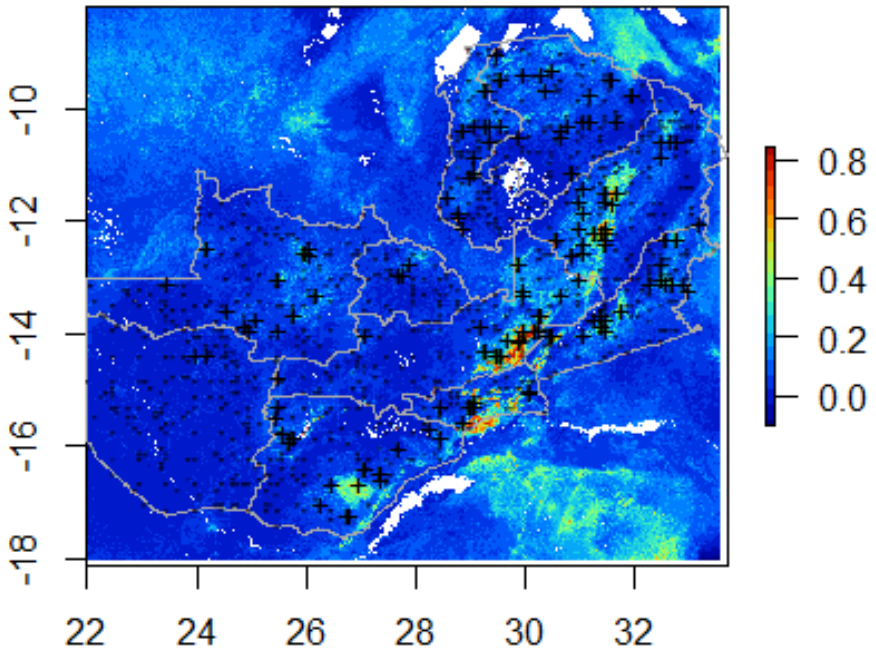


Models average

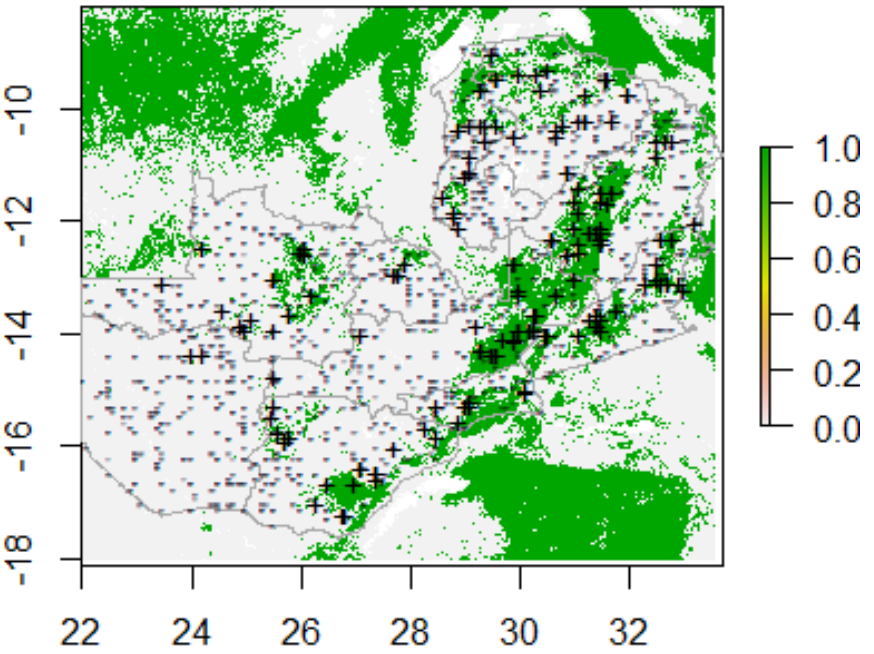


Models average

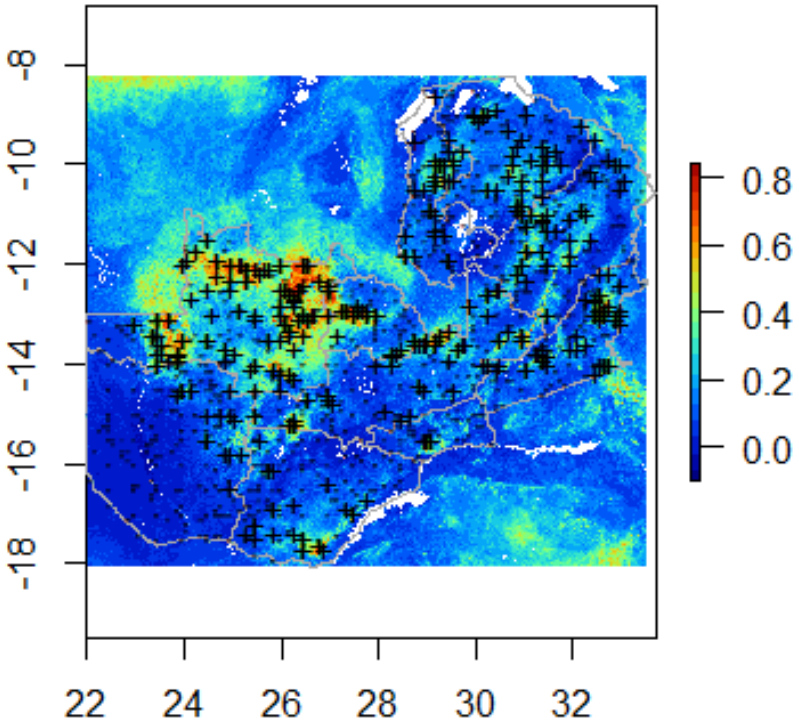
Models average for Brachystegia floribunda



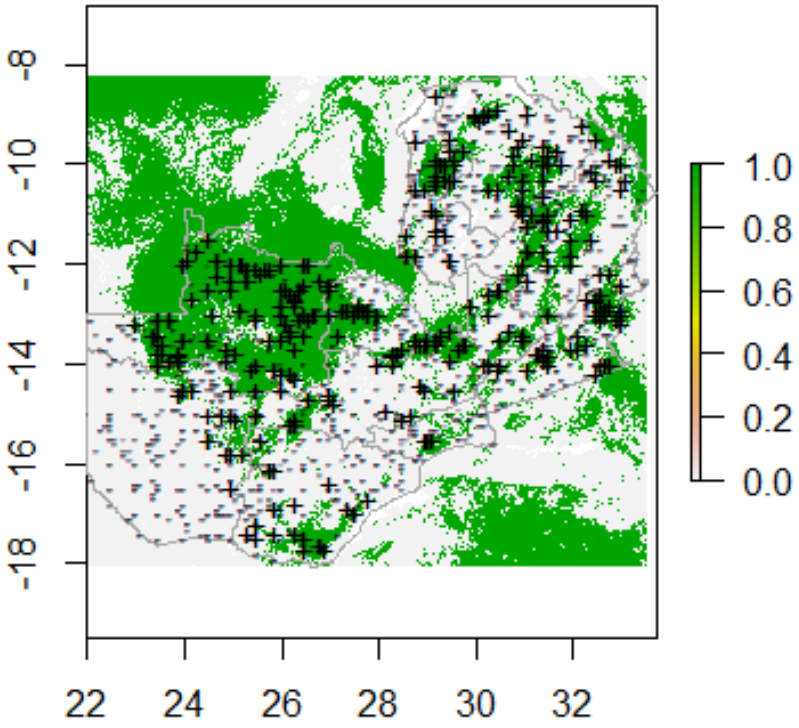
presence/absence Brachystegia floribunda



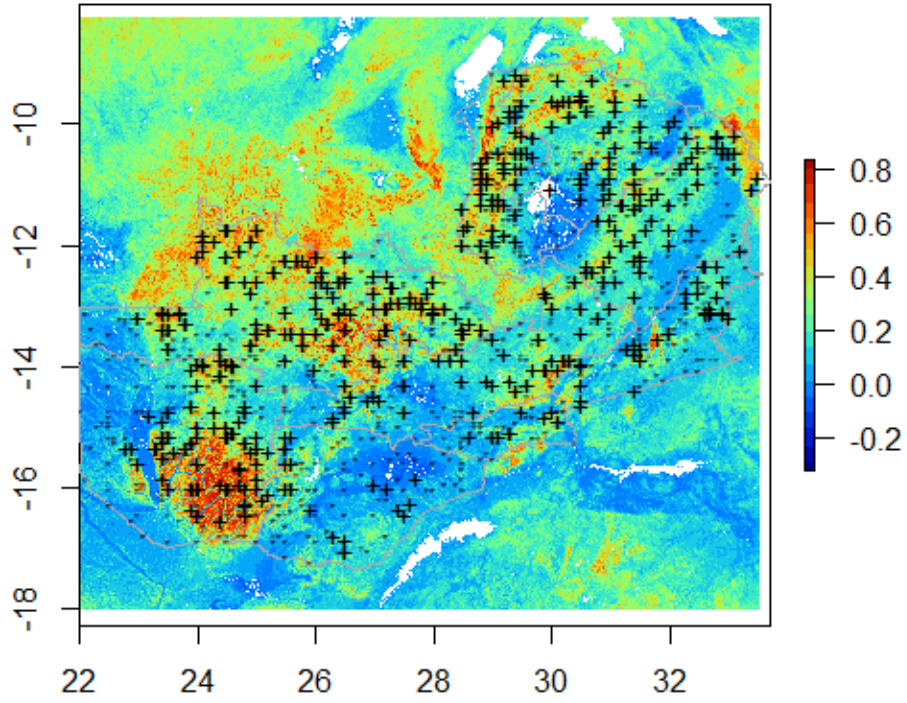
Models average for Brachystegia longifolia



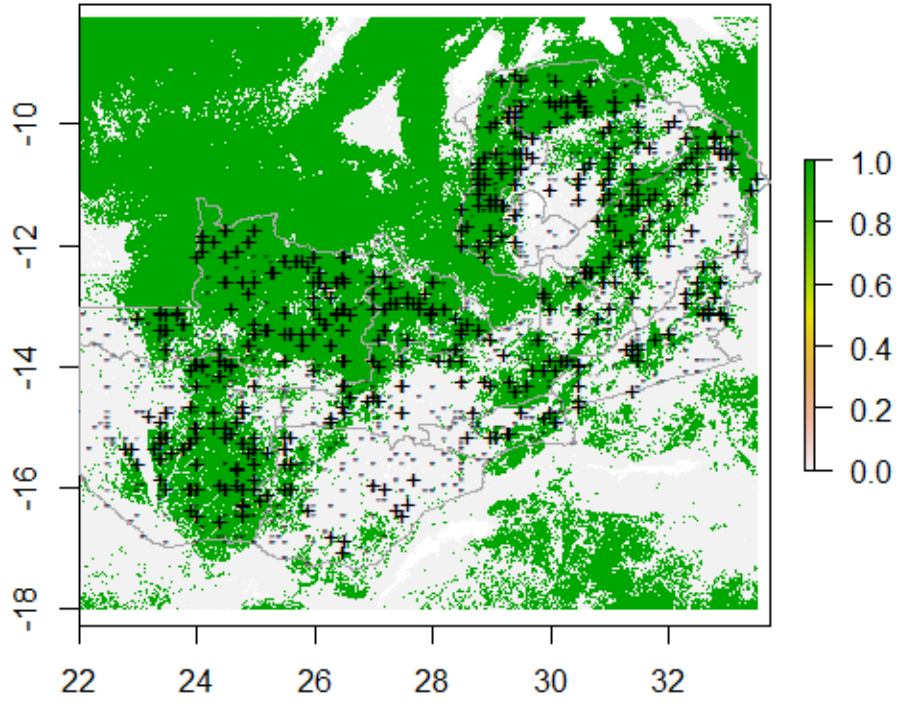
presence/absence Brachystegia longifolia

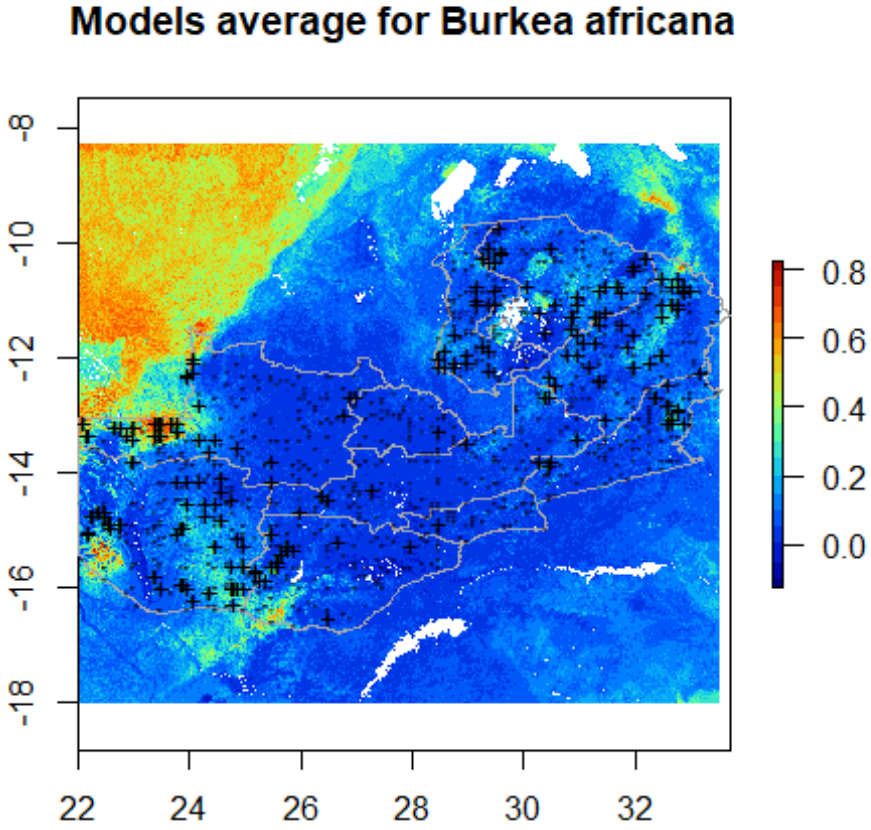


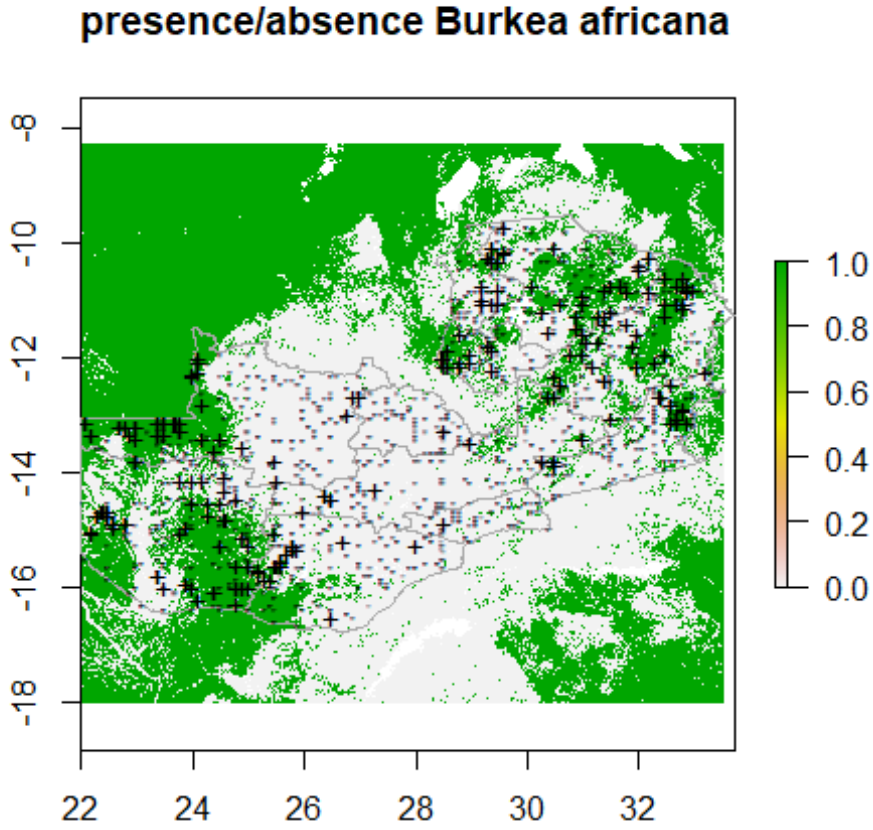
Models average for Brachystegia spiciformis



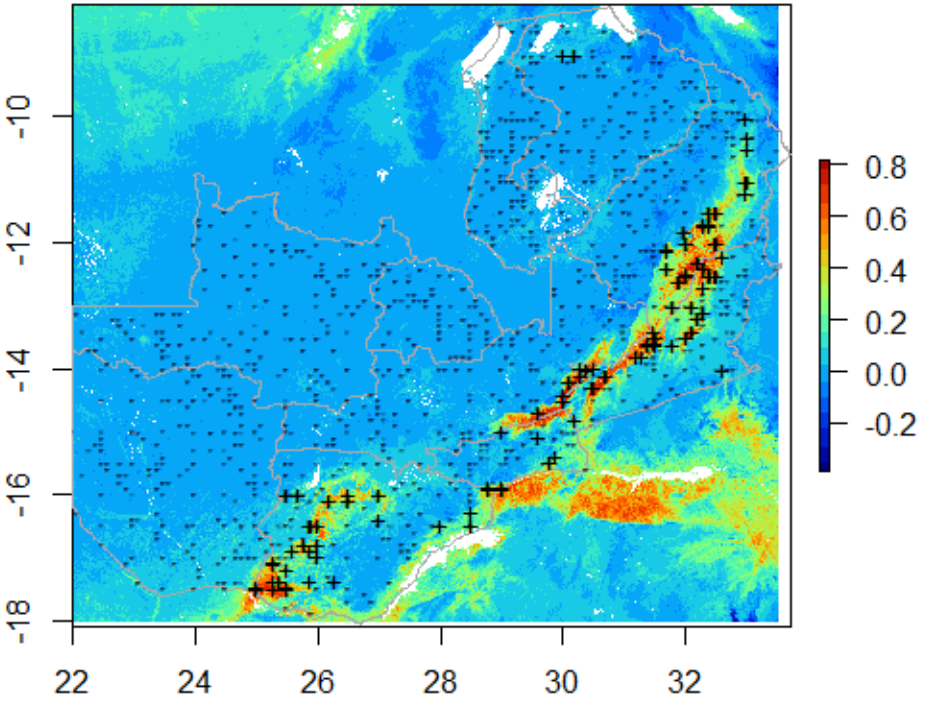
presence/absence Brachystegia spiciformis



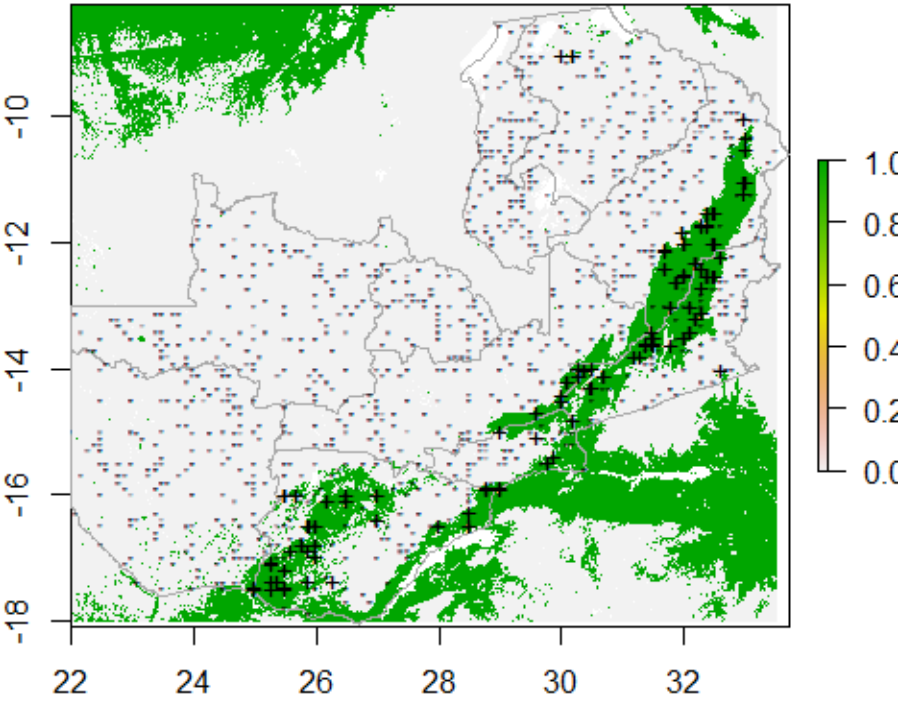

Models average for Burkea africana
-8
-10
-12
-14
-16
-18
22
24
26
28
30
32
0.8
0.6
0.4
0.2
0.0

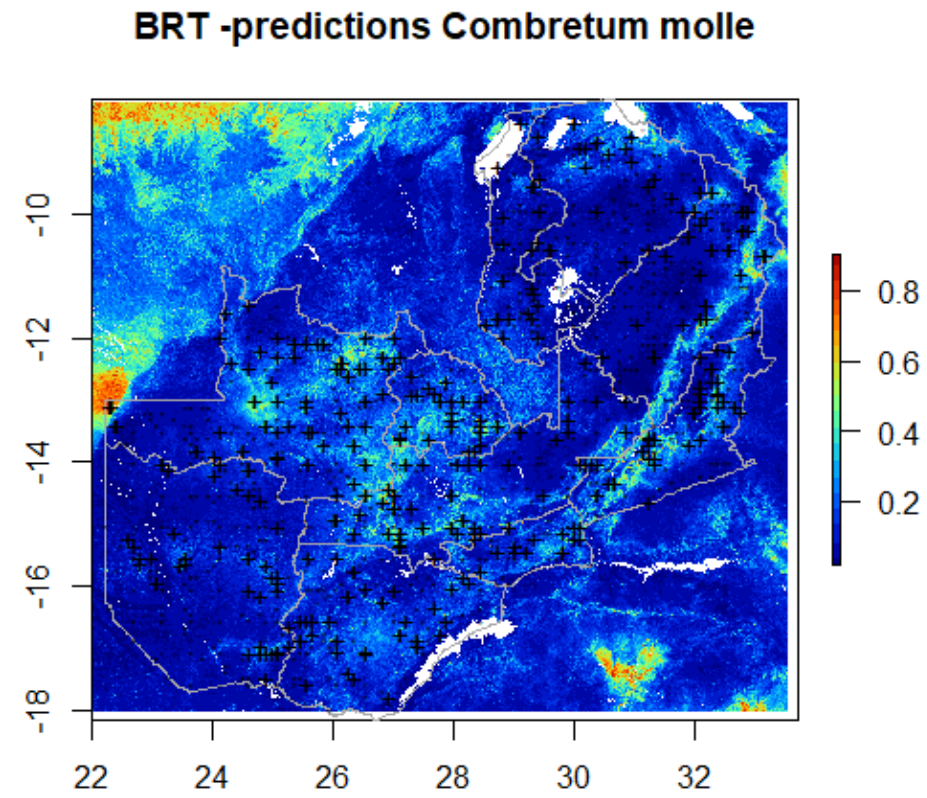

presence/absence Burkea africana
-8
-10
-12
-14
-16
-18
22
24
26
28
30
32
1.0
0.8
0.6
0.4
0.2
0.0

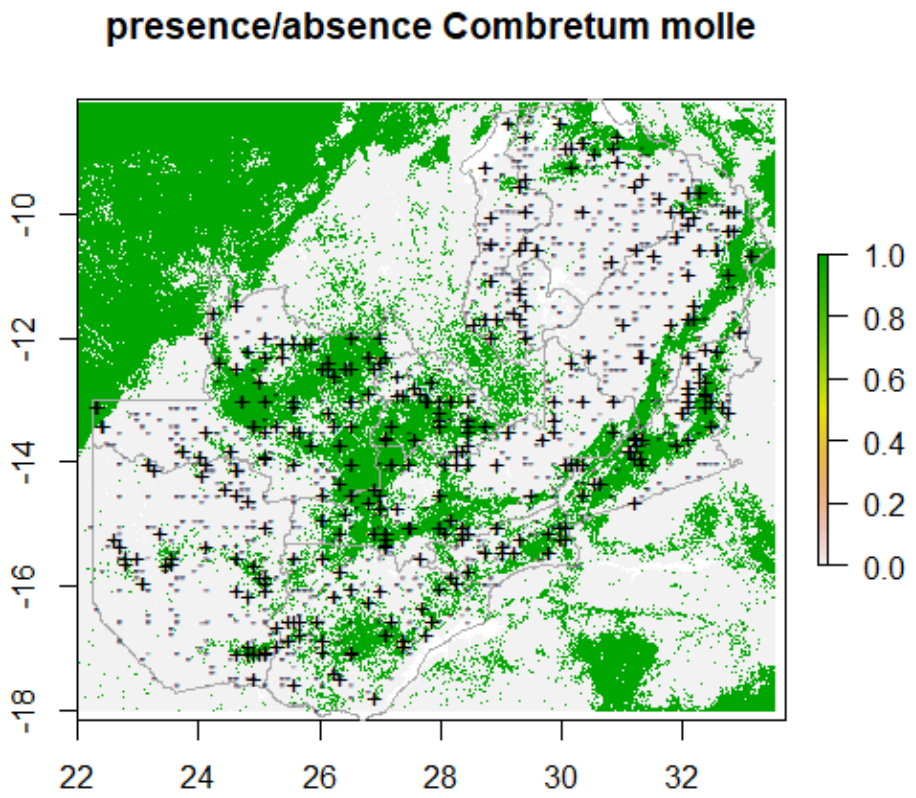
Models average for Colophospermum mopane



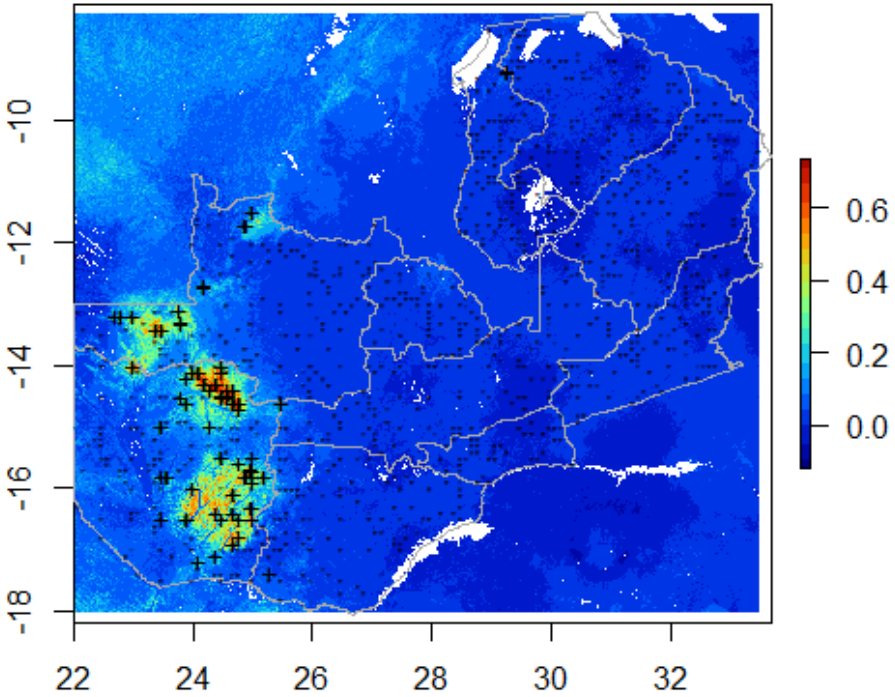
presence/absence Colophospermum mopane



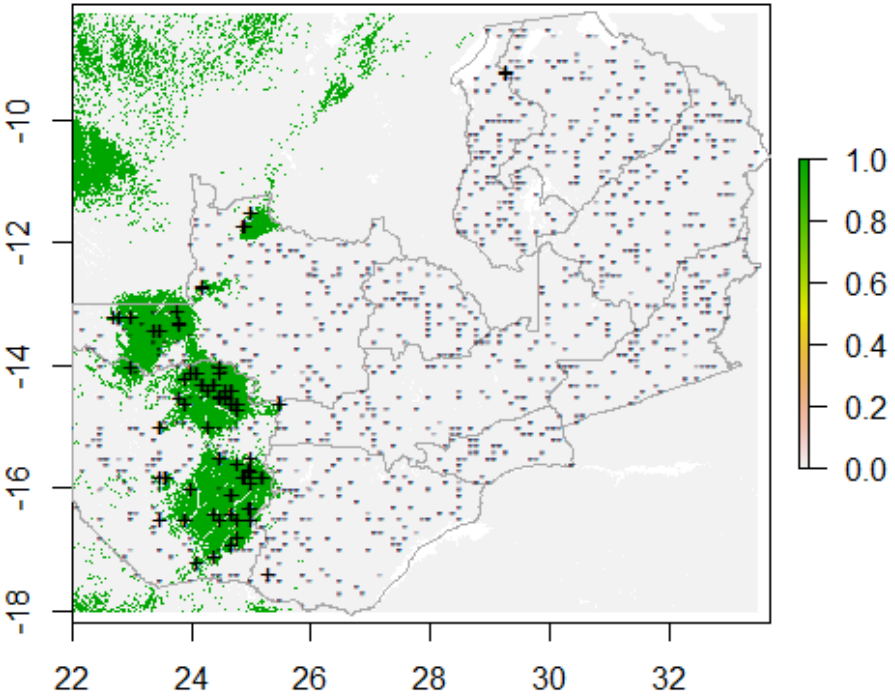

BRT -predictions Combretum molle
-10
-12
-14
-16
-18
22
24
26
28
30
32
0.8
0.6
0.4
0.2


presence/absence Combretum molle
-10
-12
-14
-16
-18
22
24
26
28
30
32
1.0
0.8
0.6
0.4
0.2
0.0

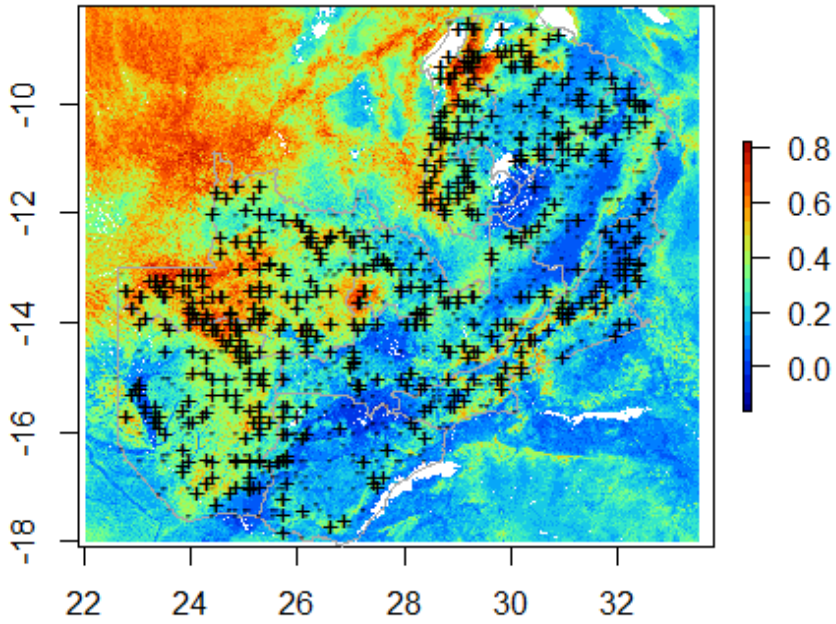
Models average for Cryptosepalum exfoliatum



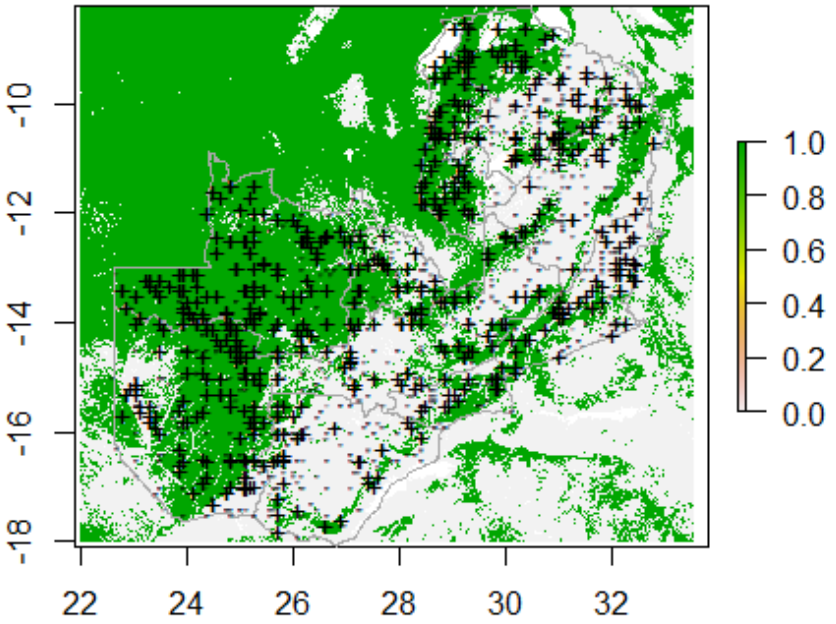
presence/absence Cryptosepalum exfoliatum



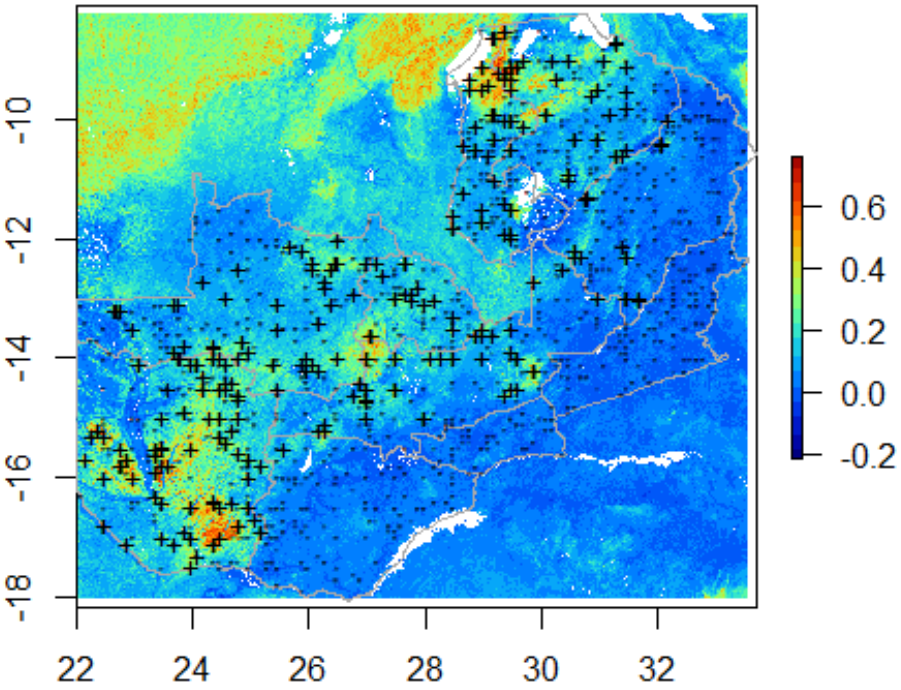
Models average for Diplorhynchus condylocarpon



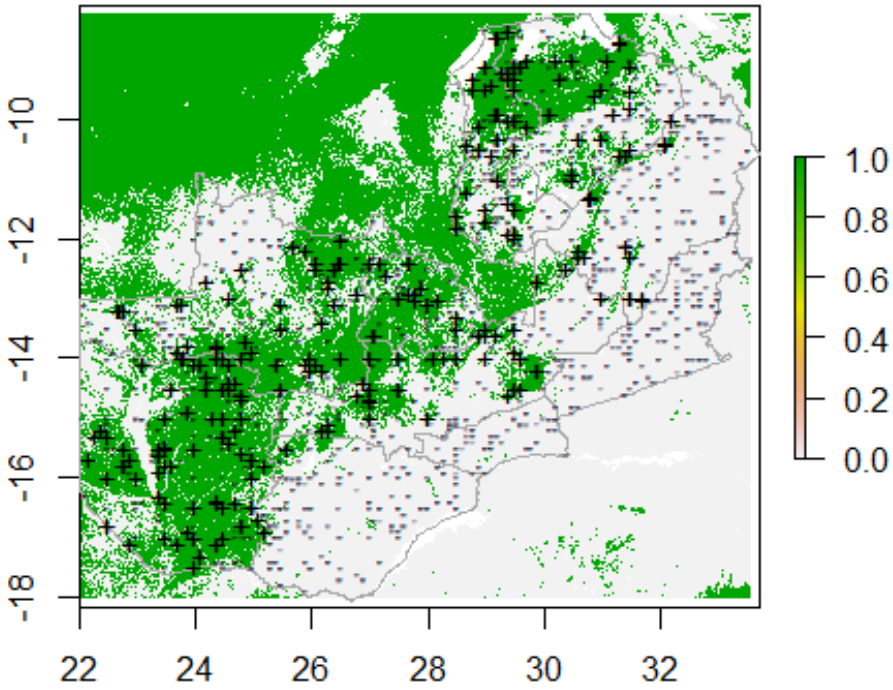
presence/absence Diplorhynchus condylocarpon



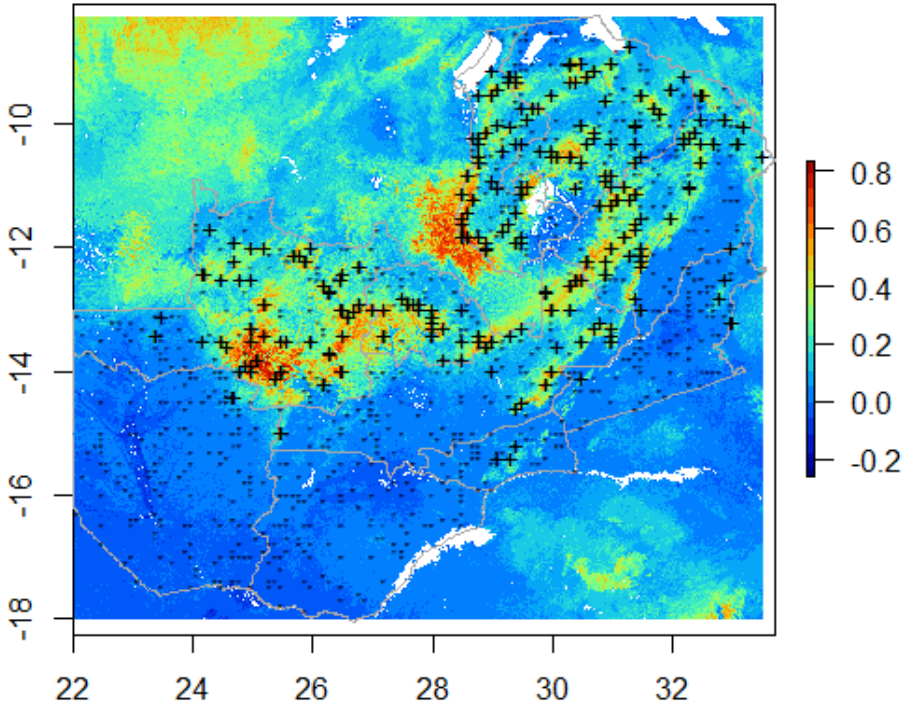
Models average for Erythrophleum africanum



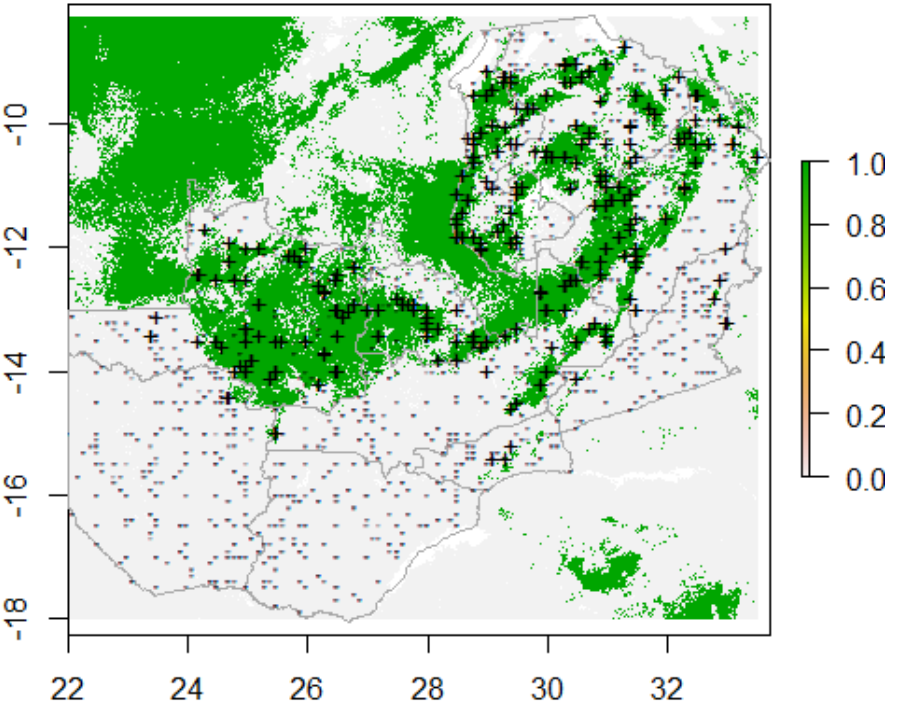
presence/absence Erythrophleum africanum



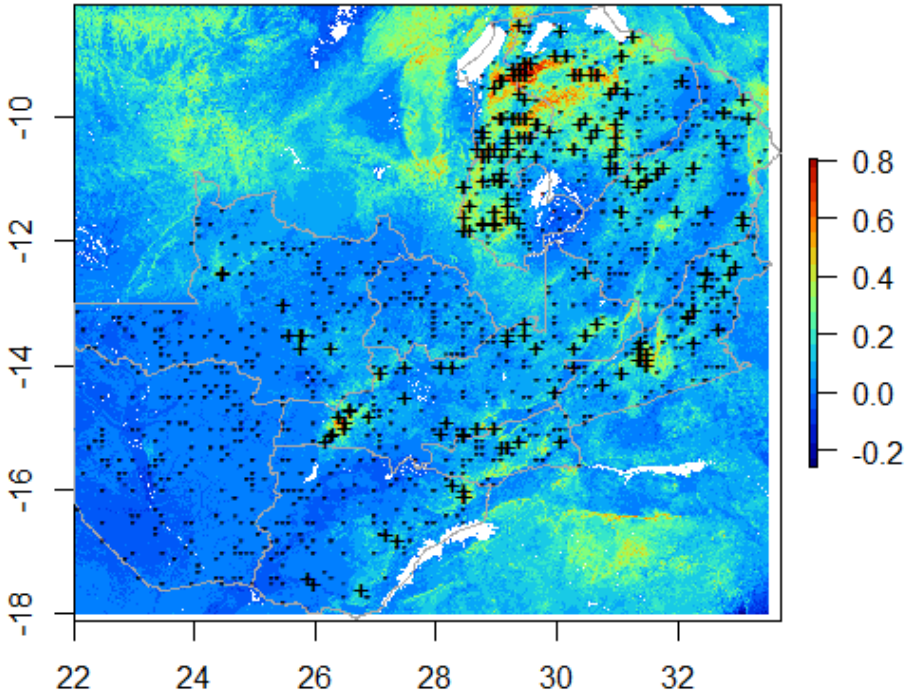
Models average for Isoberlinia angolensis



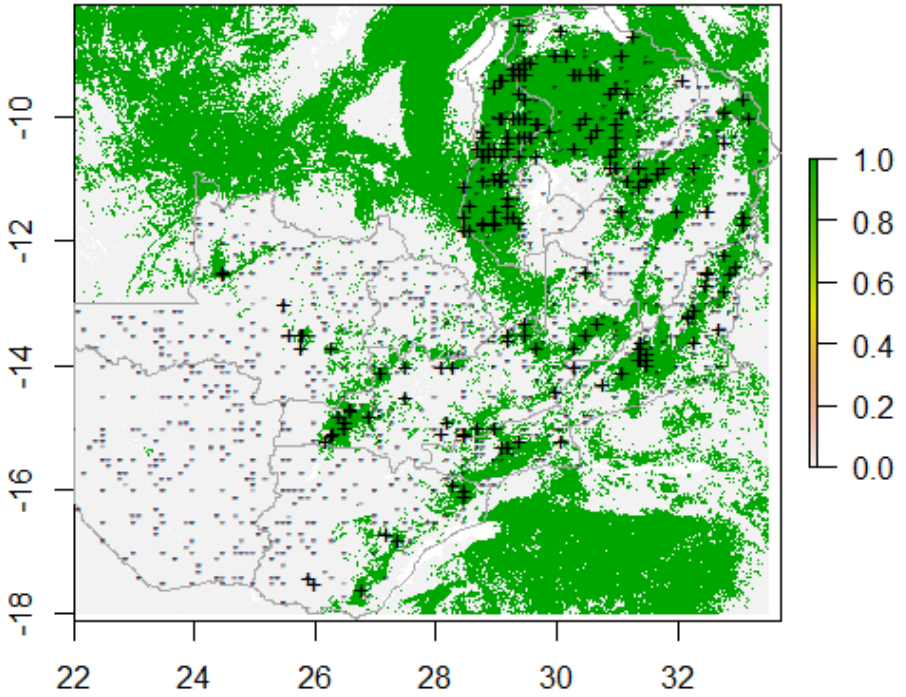
presence/absence Isoberlinia angolensis



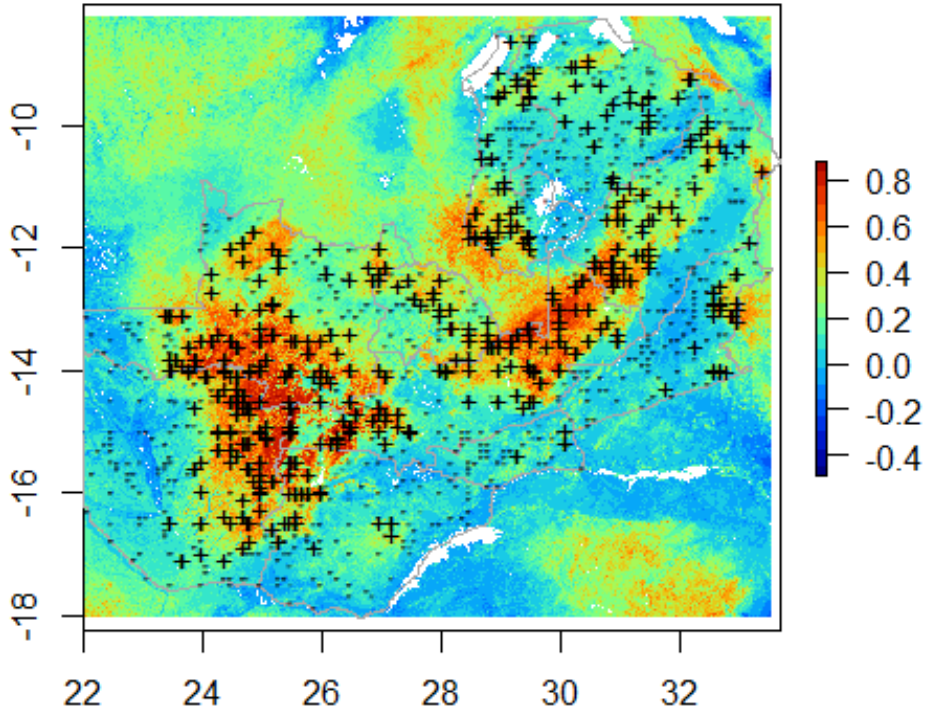
Models average for Julbernardia globiflora



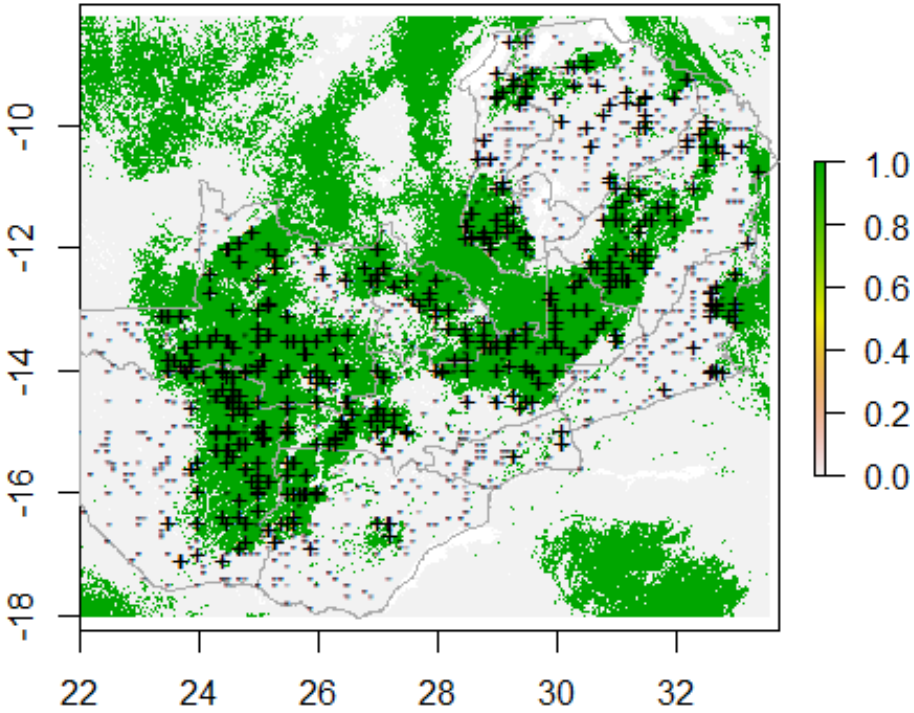
presence/absence Julbernardia globiflora

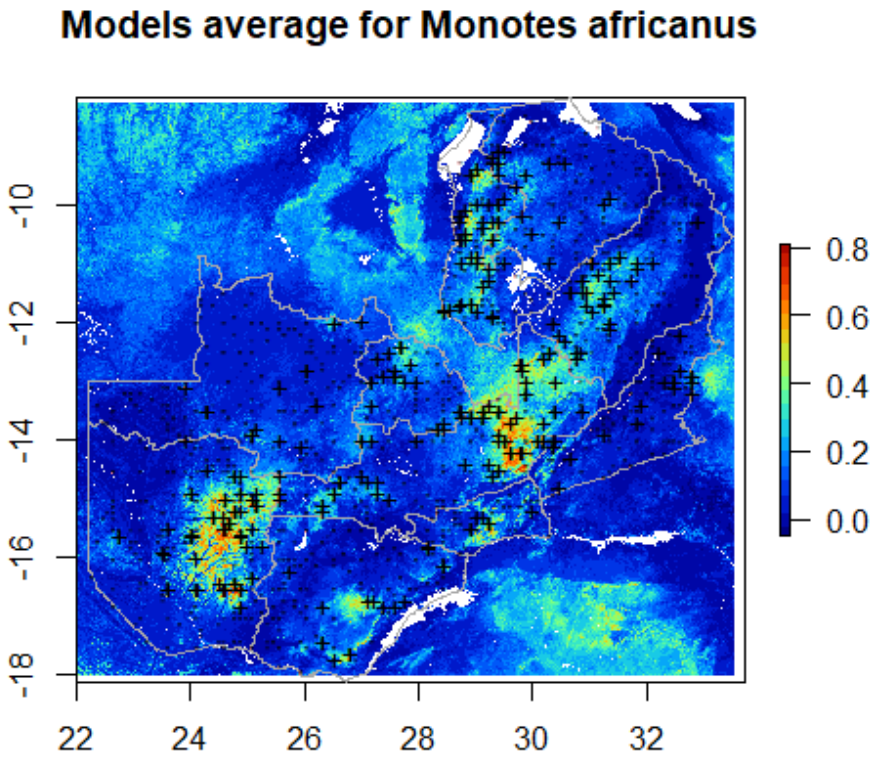


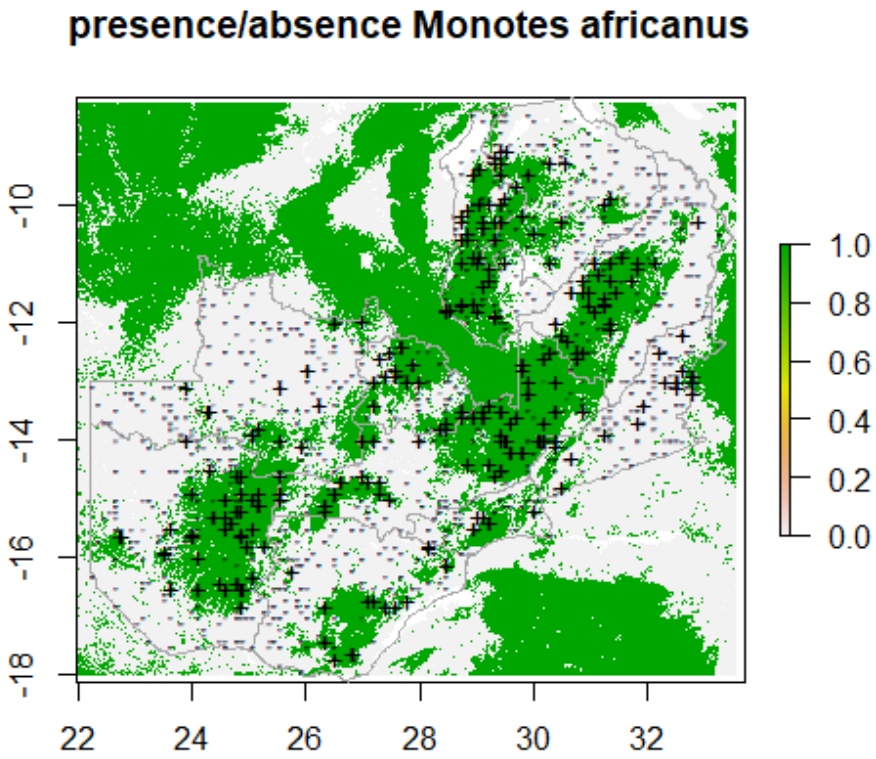
Models average for Julbernardia paniculata



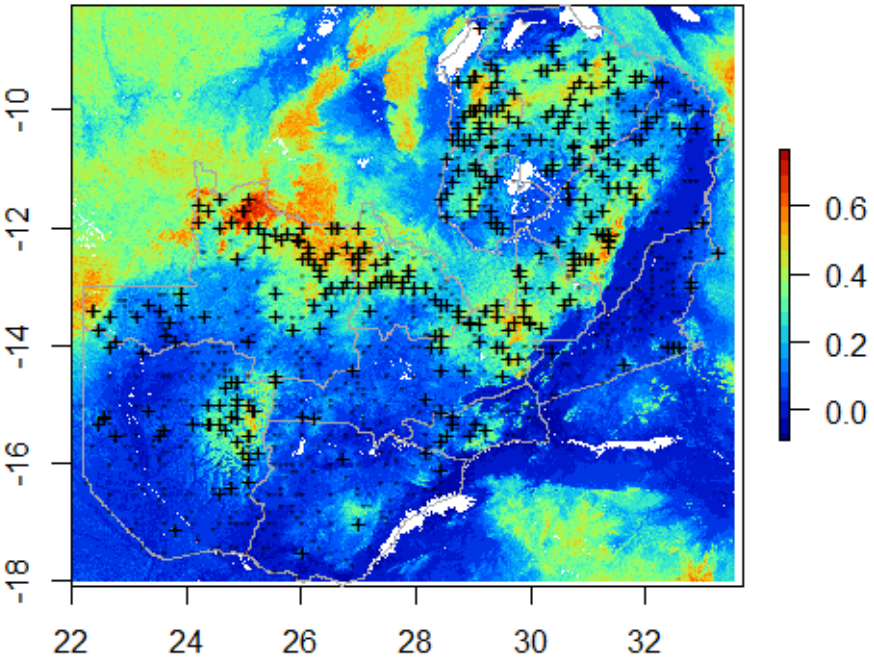
presence/absence Julbernardia paniculata



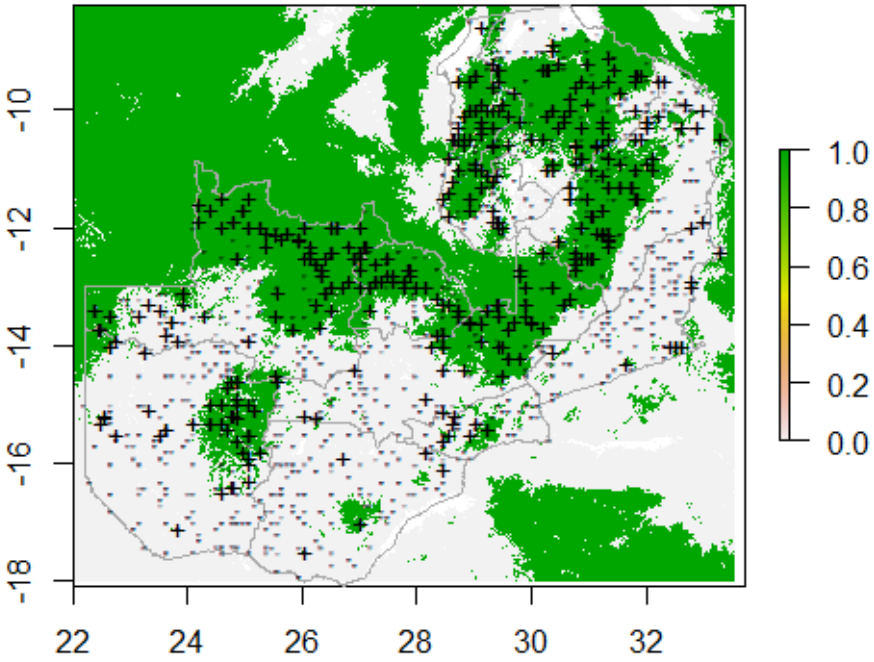

Models average for Monotes africanus
-10
-12
-14
-16
-18
22
24
26
28
30
32
0.8
0.6
0.4
0.2
0.0


presence/absence Monotes africanus
-10
-12
-14
-16
-18
22
24
26
28
30
32
1.0
0.8
0.6
0.4
0.2
0.0

Models average for Parinari curatellifolia



presence/absence Parinari curatellifolia



Next steps for this study…

- Identify key predictors for each species
- Model species distribution for those of special interest in consultation with FD
- Look at the distribution of stumps

Future work and collaboration

Capacity to generate outputs from ILUA and FLES data sets and fulfill research needs:

- Supply and demand in charcoal production
  - Detect charcoal sites with remote sensing and develop better algorithms tailored to dry forests and woodlands
  - Look at the relationship between livelihoods, charcoal, and forest diversity & carbon stocks
  - Test policy-relevant scenarios of charcoal consumption into the future.

Future work and collaboration

Provide in-house capacity-building based on these analyses:

- Statistical and spatial analysis workshops using ILUA data aimed to FD staff using open source software

Apply for research grants to complement activities developed by FD where need is, in collaboration with FD personnel

- Different funding opportunities depending on the focus

Acknowledgements

- Zambia Forestry Department
  - Director Ignatius Makumba, Kalebi Mashuta, Mindenda Pande, Bwalya Chendauka, Abel Siampale, Keddy Mbindo, Noah Zimba, Freddie Siangulube, and other support staff
- FAO Zambia – involved in ILUA project
  - Jonathan Wesley Roberts and other support staff
- Financial support of the Food and Agriculture Organization to the JP (WHRC) and the funding of NASA Applied Sciences Program – USAID SERVIR Project Grant No. NNX12AL27G, and the TNC NatureNet postdoctoral program and the Atkinson Center for a Sustainable Future
- Alain Paquette from the Center of Forest Research, Melanie Desrochers, Lauri Vesa, Brendan Rogers as well as Scott Goetz and Nadine Laporte