Newcastle University
UK | Malaysia | Singapore

How to monitor biodiversity/natural capital in human-modified tropical landscapes

Dr Marion Pfeifer, SNES, Newcastle University. Talk @CAVElab_UGent, 29/11/2019

Tropical landscapes

Sabah, Malaysia

Jimma Highlands, Ethiopia

Around Mt Elgon, Kenya

Kilombero Valley, Tanzania

…. Inside protected areas


Sabah, Malaysia


Jimma Highlands, Ethiopia


On Mt Elgon, Kenya


Kilombero Valley, Tanzania

What does it mean for biodiversity?

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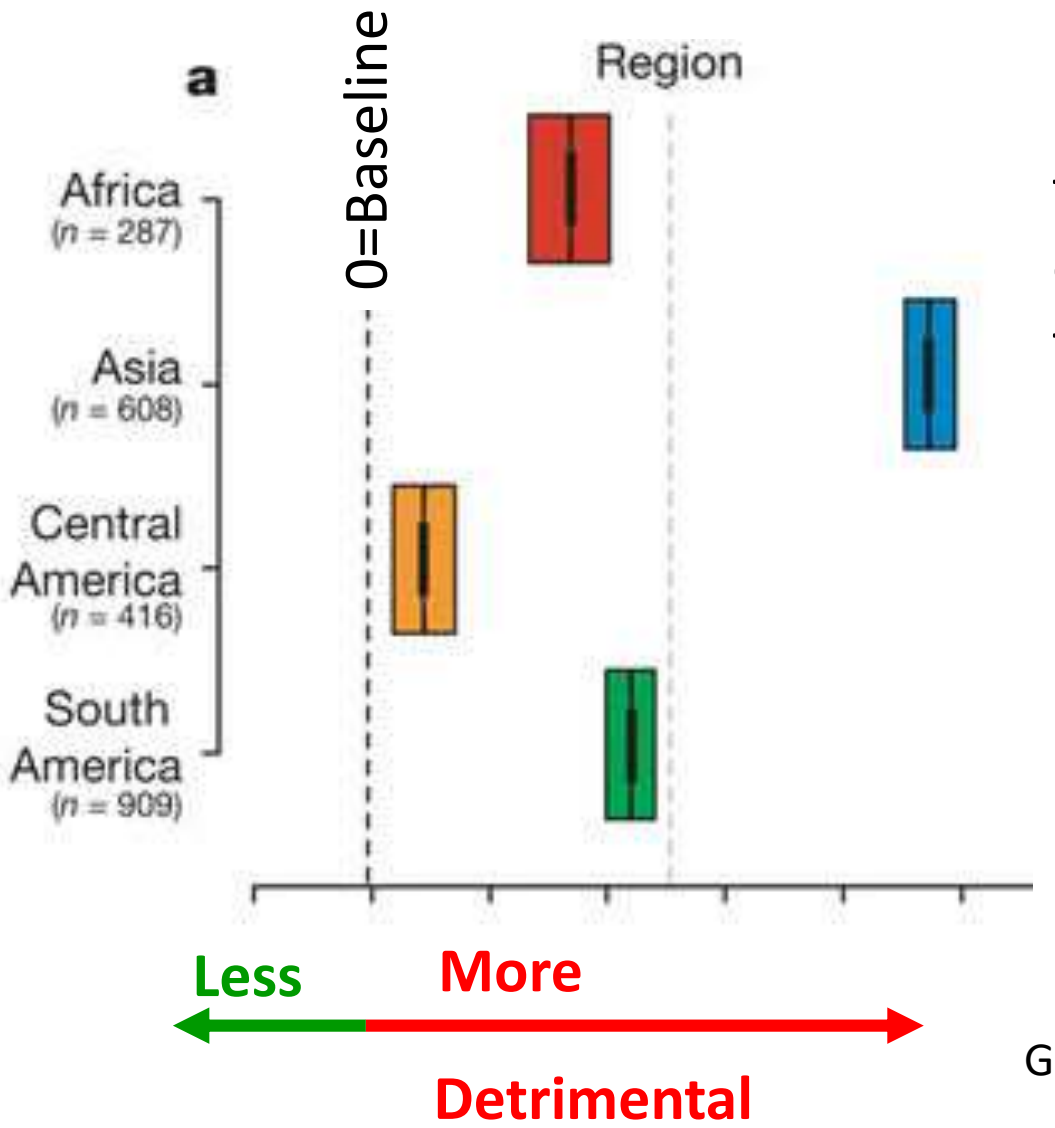
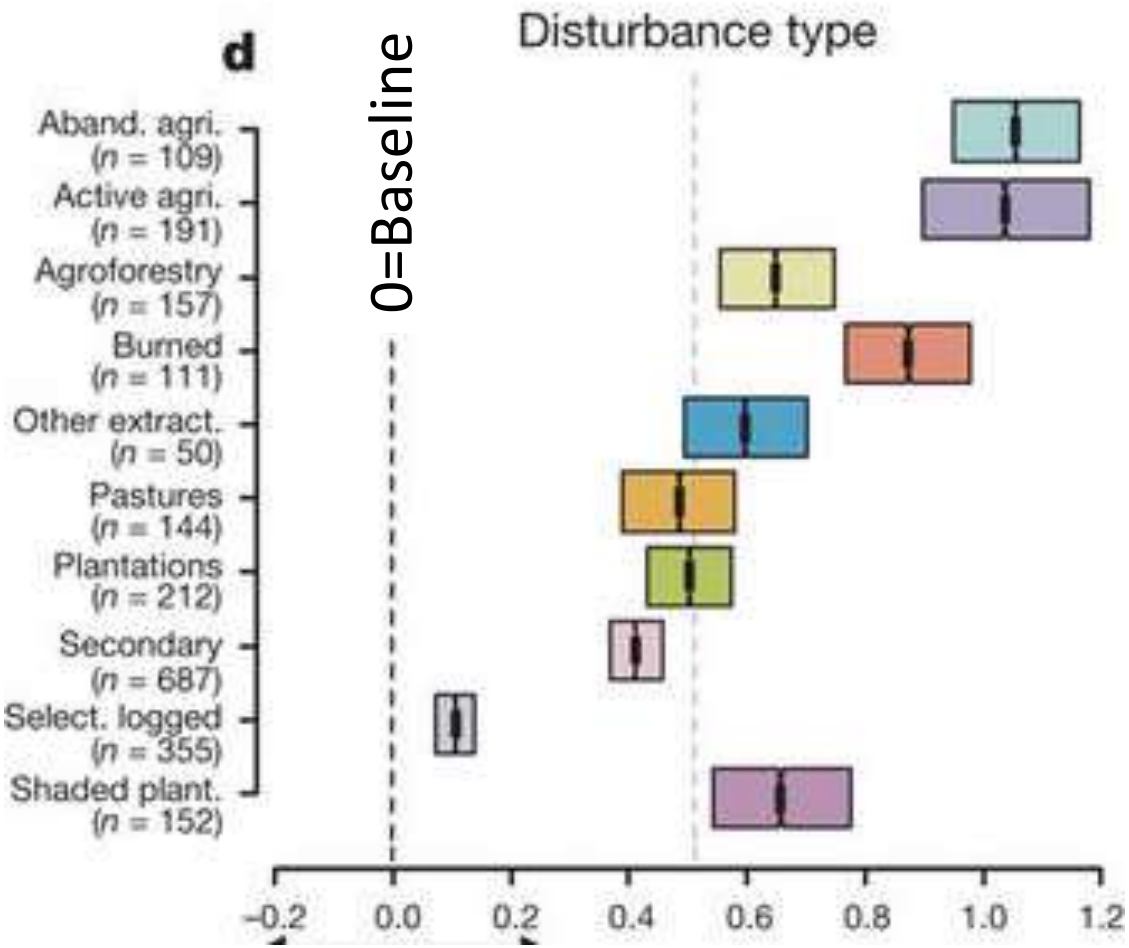


Human activities reduce biodiversity, concentrated in tropical forests, with the effect size varying by region, taxonomic group, response metric and disturbance type

Gibson et al. 2011 ***Nature*** 478, 378-381

What does it mean for biodiversity?



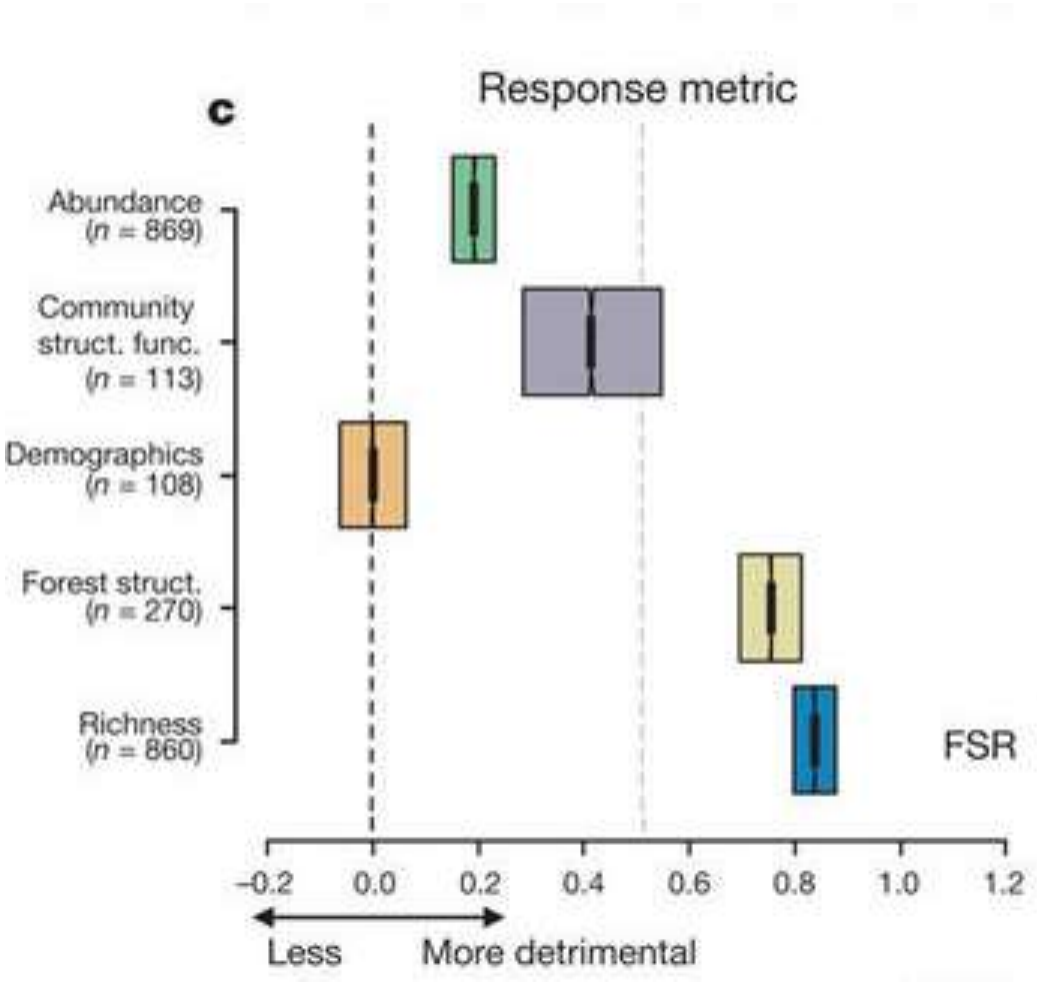
Less More

Detrimental

Agricultural land-use classes have a much greater impact than agroforestry systems and plantations

Gibson et al. 2011 ***Nature*** 478, 378-381

What does it mean for biodiversity?



Richness was markedly more sensitive to human disturbance than species abundance

Gibson et al. 2011 ***Nature*** 478, 378-381

What about natural capital?

Ecosystem functions: habitat, biological or system properties or processes of ecosystems

Ecosystem services: benefits human populations drive – directly or indirectly – from ecosystem functions

Costanza et al. 1997 ***Nature*** 387, 253 - 260

What about natural capital?

Capital: stocks of material or information that exists at a point in time and generates a flow of ecosystem services. The human use of this flow of services may or may not leave the original capital stock intact.

Natural capital: e.g. trees, water, soil nutrients and ecosystems

Costanza et al. 1997 ***Nature*** 387, 253 - 260

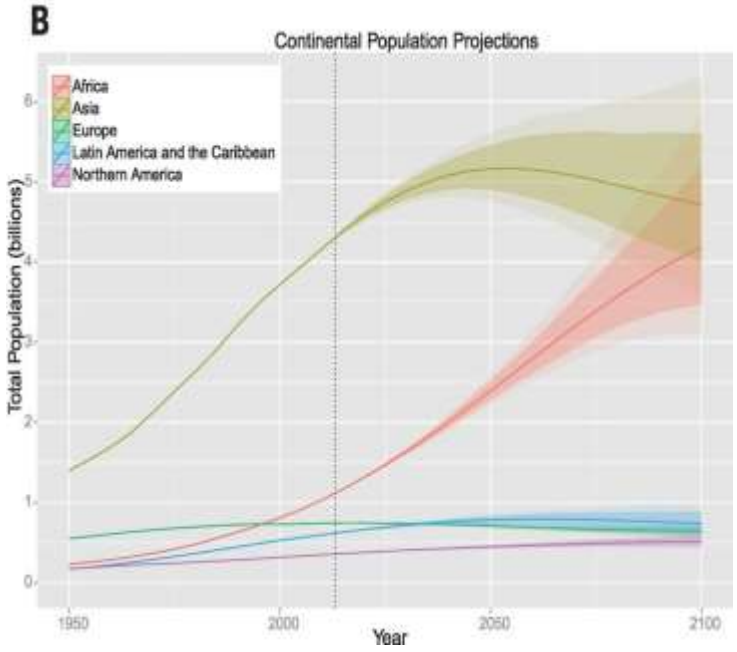
What about natural capital?

Natural capital: beneficial ('good') species ?



What about the 'bad species'

Monitor for management



There is an 80% probability that world population, now 7.2 billion people, will increase to between 9.6 billion and 12.3 billion in 2100.

Gerland et al. 2014 ***Science*** 346, 234-237

	2000	2050
N [MT]	$87 * 10^6$	$236 * 10^6$
P [MT]	$34.3* 10^6$	$83.7 * 10^6$
Cropland [ha]	$1.54 * 10^9$	$1.89 * 10^9$
Pasture land [ha]	$3.47 * 10^9$	$4.01 * 10^6$
Irrigated land [ha]	$280 * 10^6$	$529 * 10^6$
Pesticide, produced [MT]	$3.75 * 10^6$	$10.1 * 10^6$

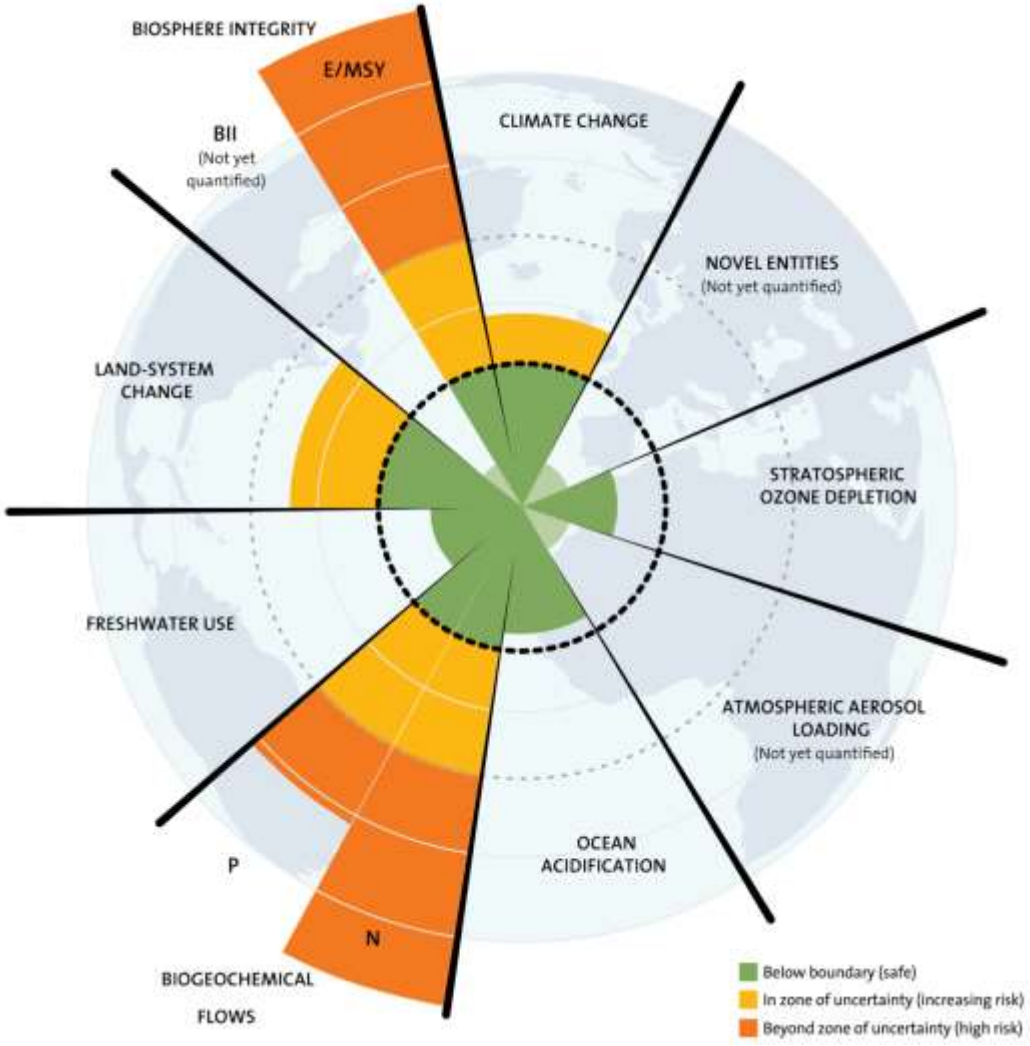
The loss of ecosystems to cropland and pasture in developing countries by 2050 would be about half of all suitable remaining land

Tilman et al. 2001 ***Science*** 346, 234-237

Monitor for management

The planetary boundaries concept presents a set of nine planetary boundaries within which humanity can continue to develop and thrive for generations to come

(a ‘safe operating space for humanity’)



Monitor for management

Sustainable resource use: *The principle of sustainability implies the use of resources at rates that do not exceed the capacity of Earth to replace them. By definition, dependency on non-renewable inputs is unsustainable, even if in the short term it is necessary as part of a trajectory toward sustainability (Godfray et al. 2010 Science 327)*

Supply of natural capital ('capacity')

Demand for natural capital ('footprint')

Aichi Biodiversity targets

Strategic Goals A – E (*shortened considerably* ☺): Address causes of biodiversity loss, reduce pressure and promote sustainable use, improve status of biodiversity, enhance benefits from biodiversity, enhance implementation through participation and capacity training

Newcastle University

Sustainable Development Goals

A set of 17 goals agreed in 2015 to end poverty, protect the planet and ensure prosperity of a new sustainable development agenda

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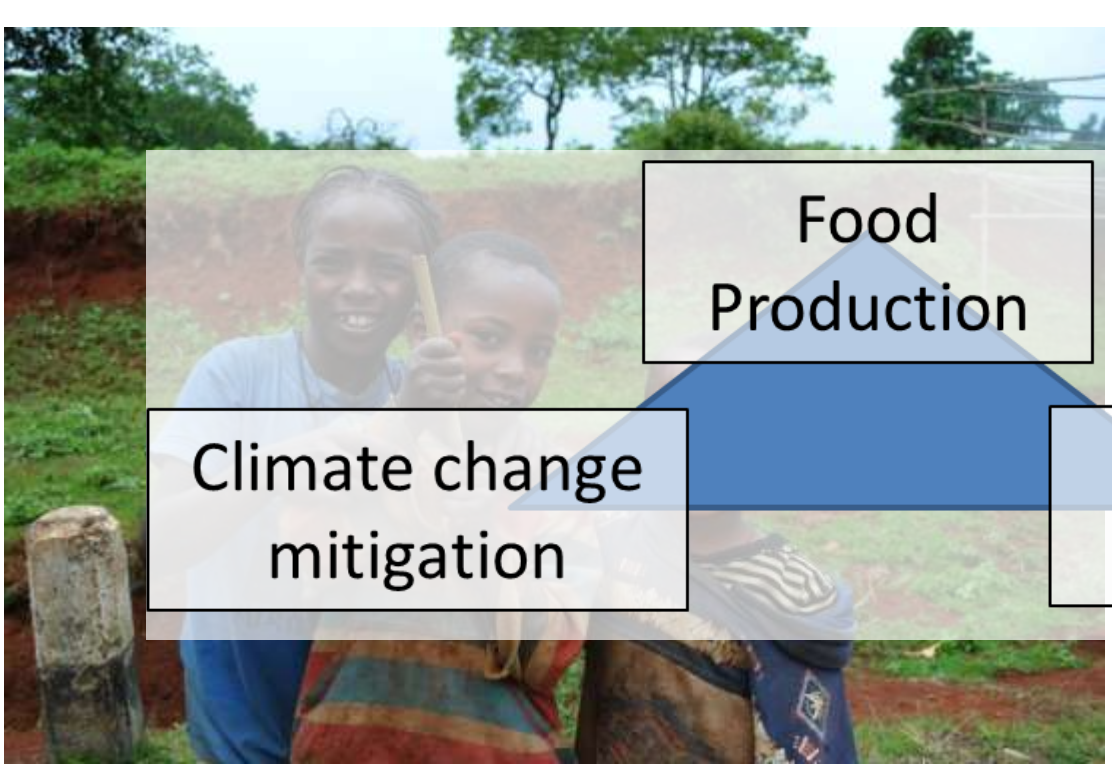
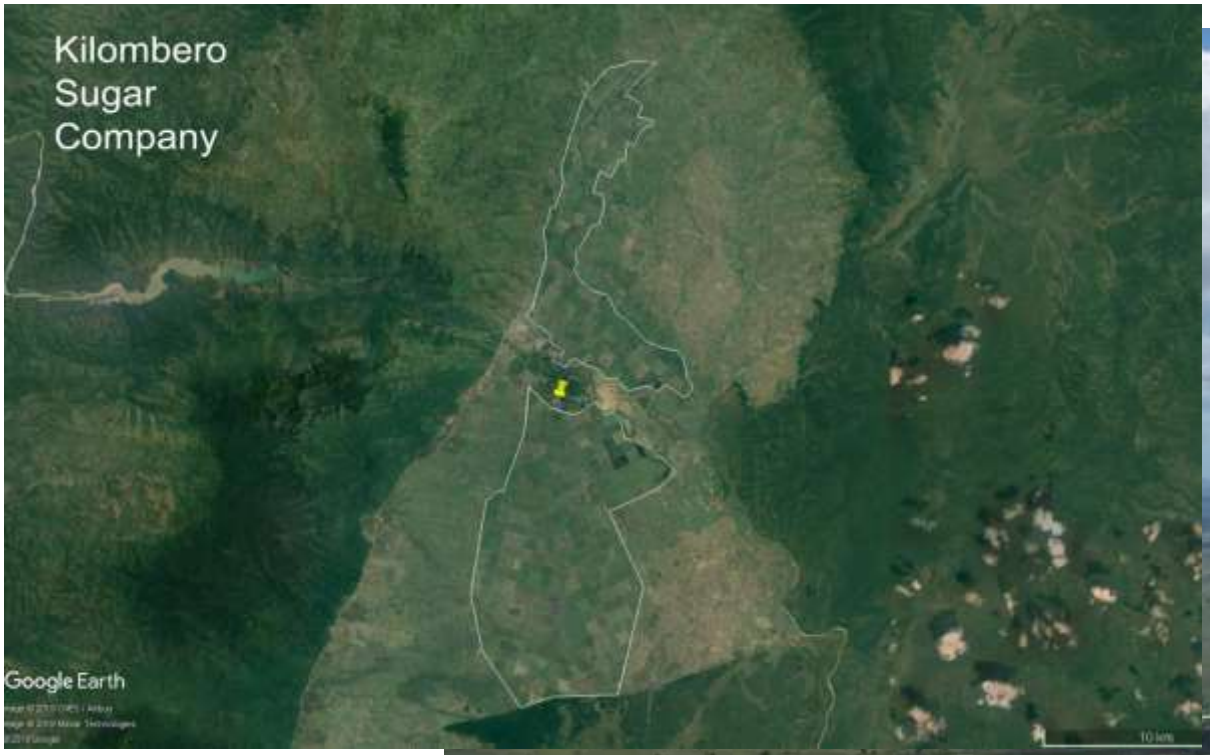


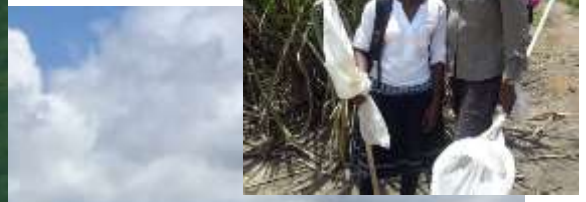
Monitor for management

So, how can we do this?

https://www.winrock.org/happy-world-water-day/

How can we do this at relevant spatial and temporal scales?





How can we do this at relevant spatial and temporal scales?

Essential Biodiversity Variables (EBVs)

i.e. ‘essential measurements to capture major dimensions of biodiversity change, complementary to one another and to other environmental change observation initiatives’ (Pereira et al. 2013 ***Science*** 339, 277-278)

Criteria for Essential Biodiversity Variables

An ideal EBV should be

- able to capture critical scales and dimensions of biodiversity
- biological
- a state variable (in general)
- sensitive to change
- ecosystem agnostic (to the degree possible)
- technically feasible, economically viable and sustainable in time

Remote Sensing is listed as a key tool in the concept of Essential Biodiversity variables

Does it work? Will it work?

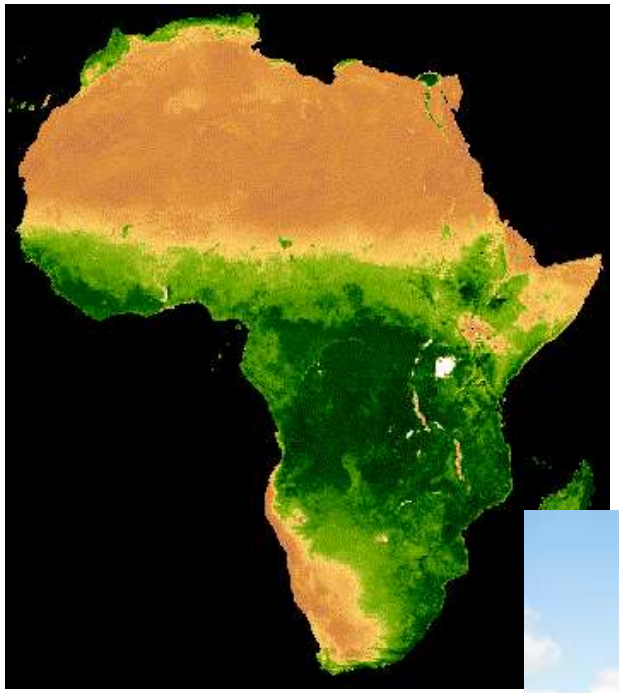
When sensing tropical human-modified landscapes remotely, how effectively can we (currently & realistically) monitor progress towards Aichi and SDG Targets

Genetic composition, Species traits, Abundance, Community composition, Ecosystem function, Ecosystem structure

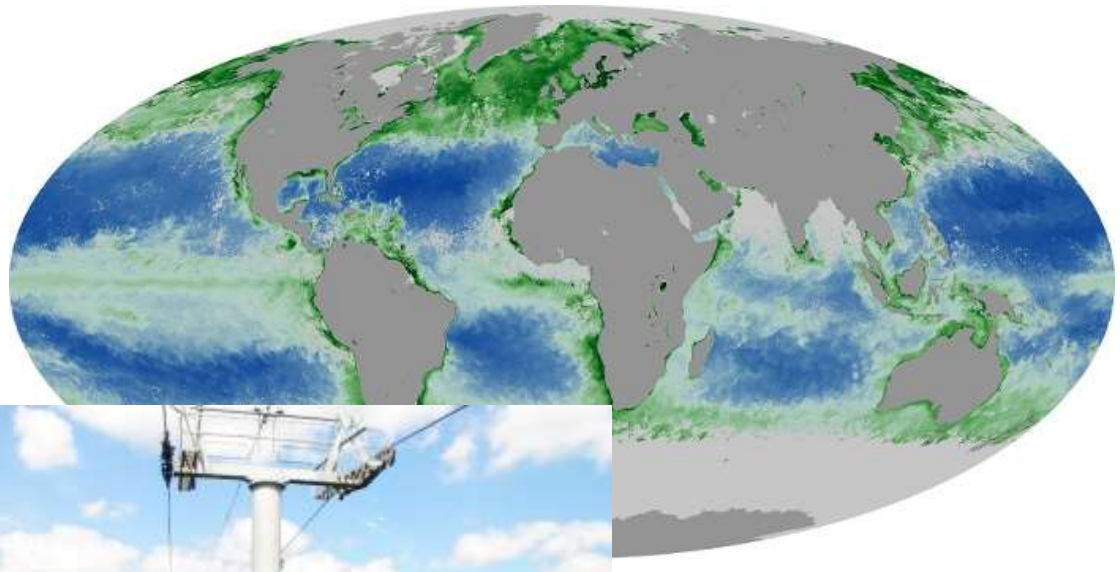
Net Primary Productivity, Secondary productivity, Nutrient regimes & disturbance

Habitat structure including in 3D, ecosystem extent & fragmentation, ecosystem functional types composition

There are some seriously cool maps out there



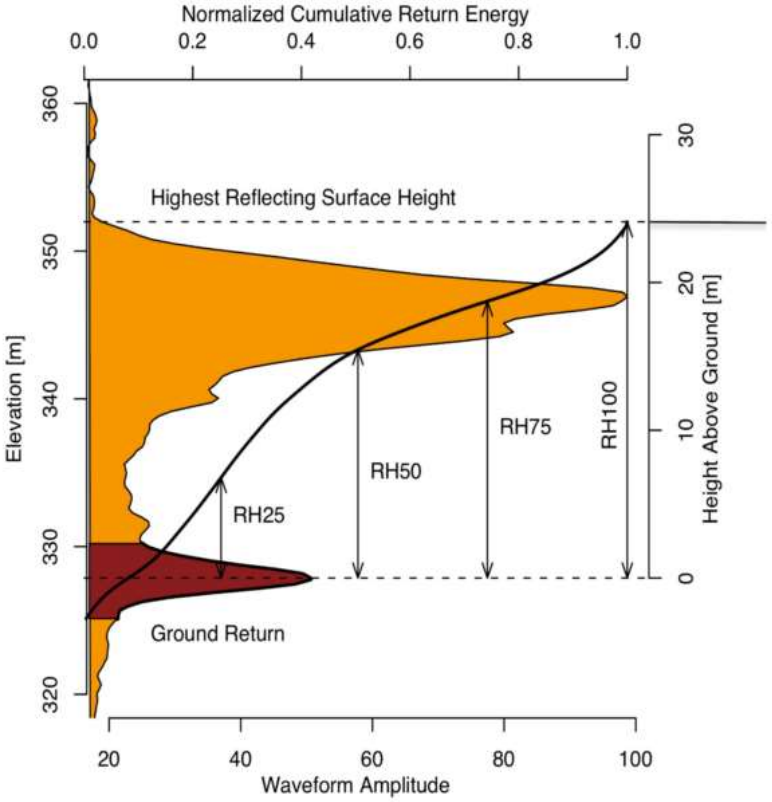
NASA MODIS EVI

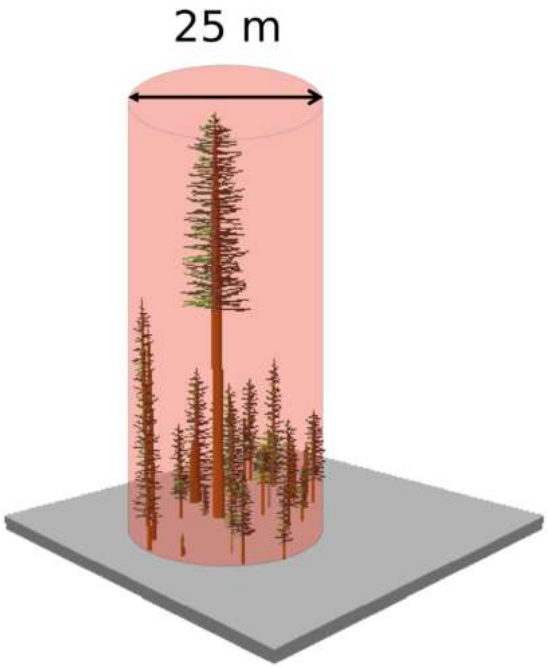


hlorophyll

Are they at the right spatial scales?

EBVs concept

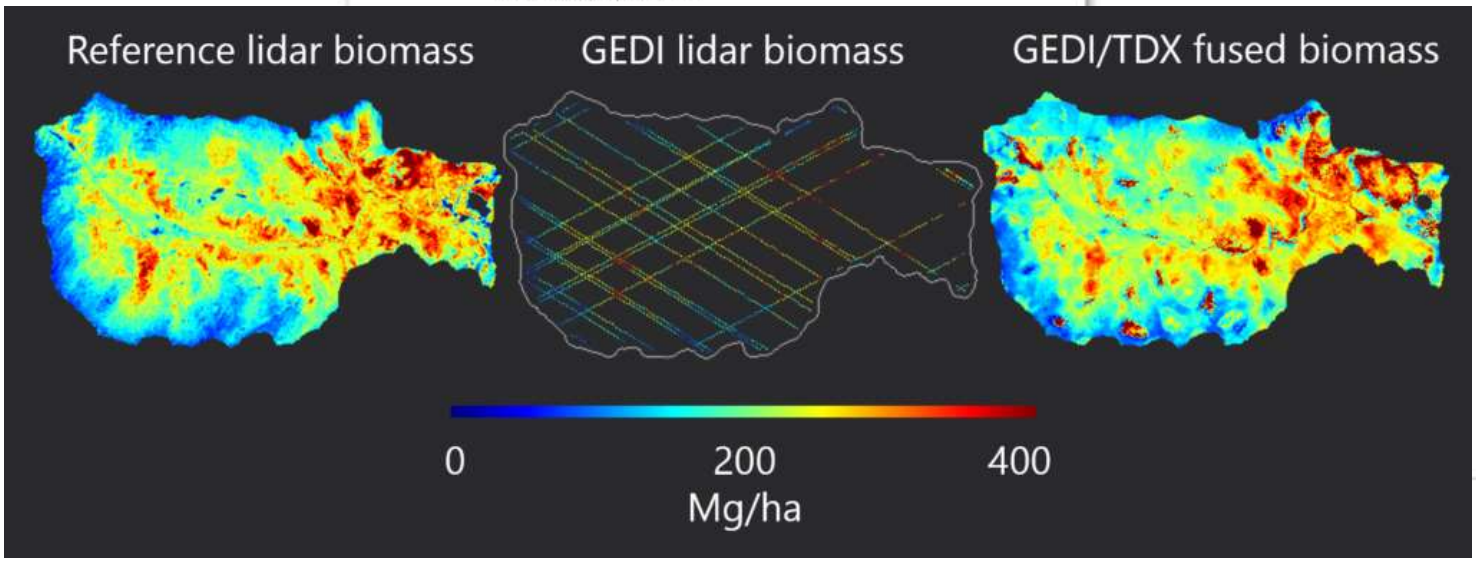




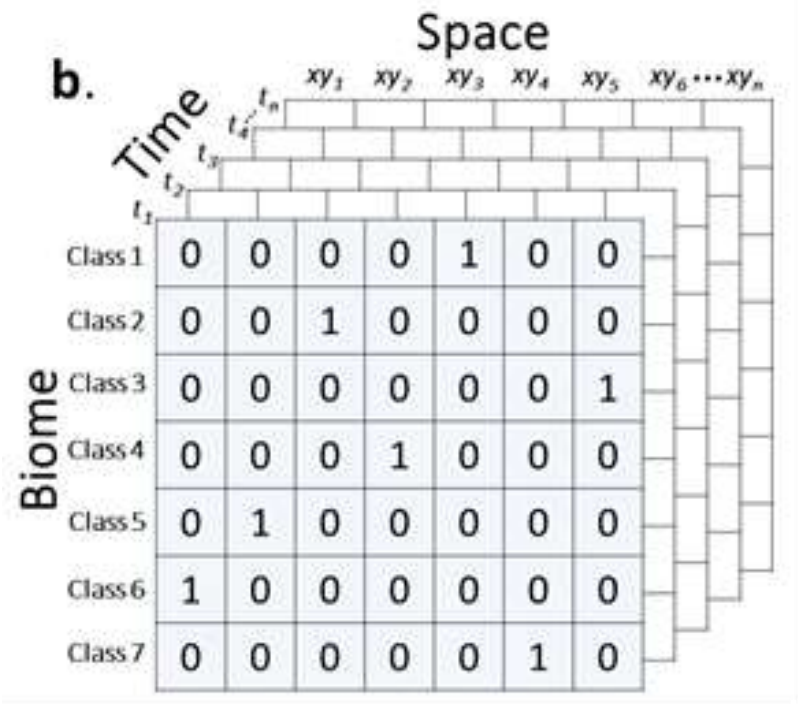
creation
(ATBDs).

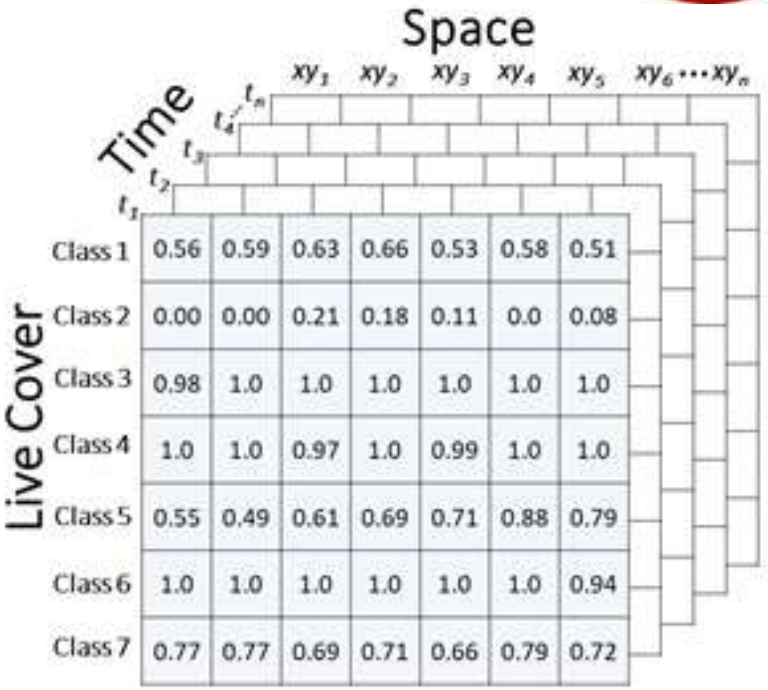
ATBD			
L1A-2A			
L1B			
L2B			
L3			
L4A			
L4B			
Demonst products	model outputs	George Hurtt	Grid size: Variable
Demonstrative products	Enhanced height/biomass using fusion with TanDEM-X	Lola Fatoyinbo Seung-Kuk Lee	Grid size: Variable
Demonstrative products	Enhanced height/biomass and biomass change using fusion with Landsat	Matt Hansen Chenquan Huang	Grid size: Variable
Demonstrative products	Biodiversity/habitat model outputs	Scott Goetz Patrick Jantz	Grid size: Variable

EBVs concept



The Working Group's progress

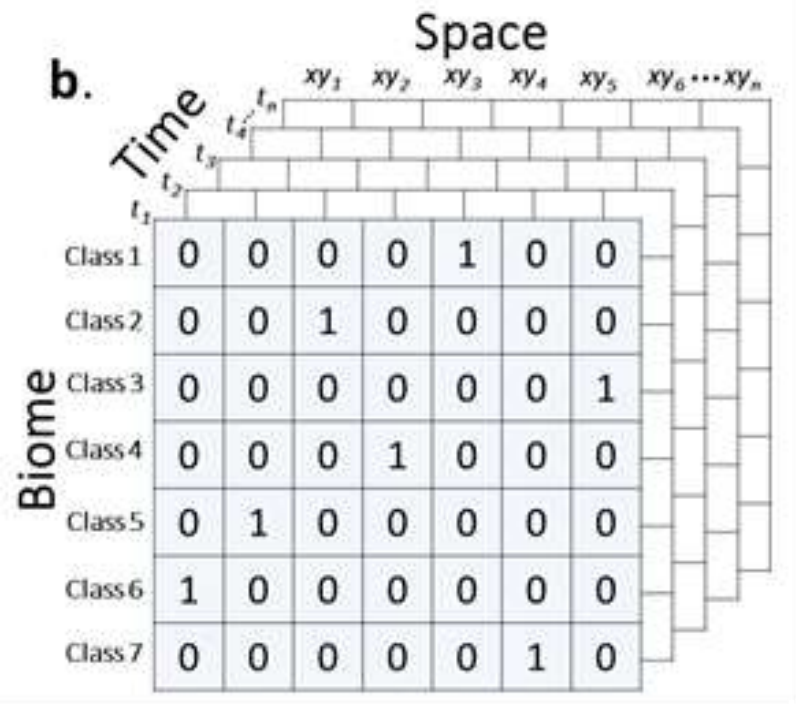


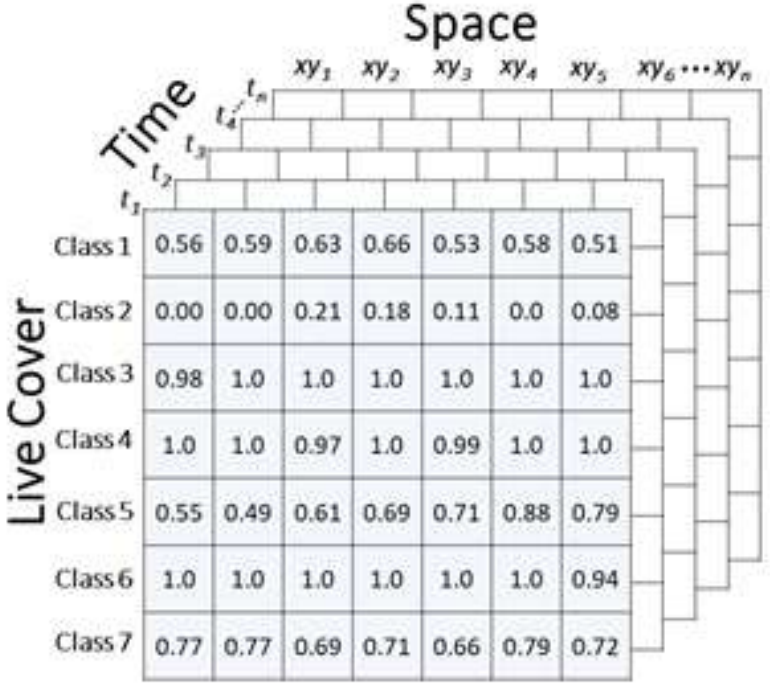


The EBV data model conceptualizes EBV Data Products as 3-D "data cubes

Gary Geller et al. GEOBON Working Group , October 2019

The Working Group's progress





How do you get the species in?

Can we link EO metrics to species richness or abundance in tropical landscapes?

How do you get the species in?

How do you get the species in?

Do we have a common understanding of what an EBV is and should be able to do?



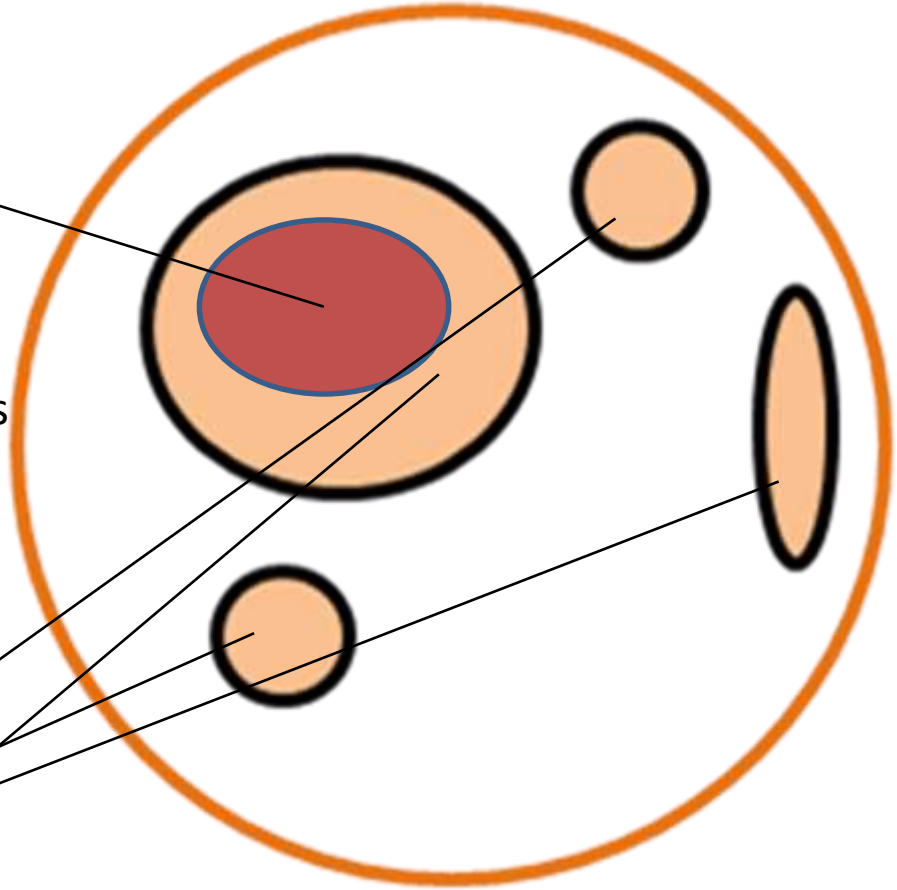

satellite remote sensing based variables that meet requirements of EBVs according to Pettorelli et al. 2016

Ecosystem structure	Ecosystem function
Fractional cover	fAPAR
Forest cover	LAI
Land cover	Vegetation phenology
Vegetation height	Phytoplancton
Biomass	Soil moisture
	Fire disturbance
	Inundation

Not necessarily straightforward

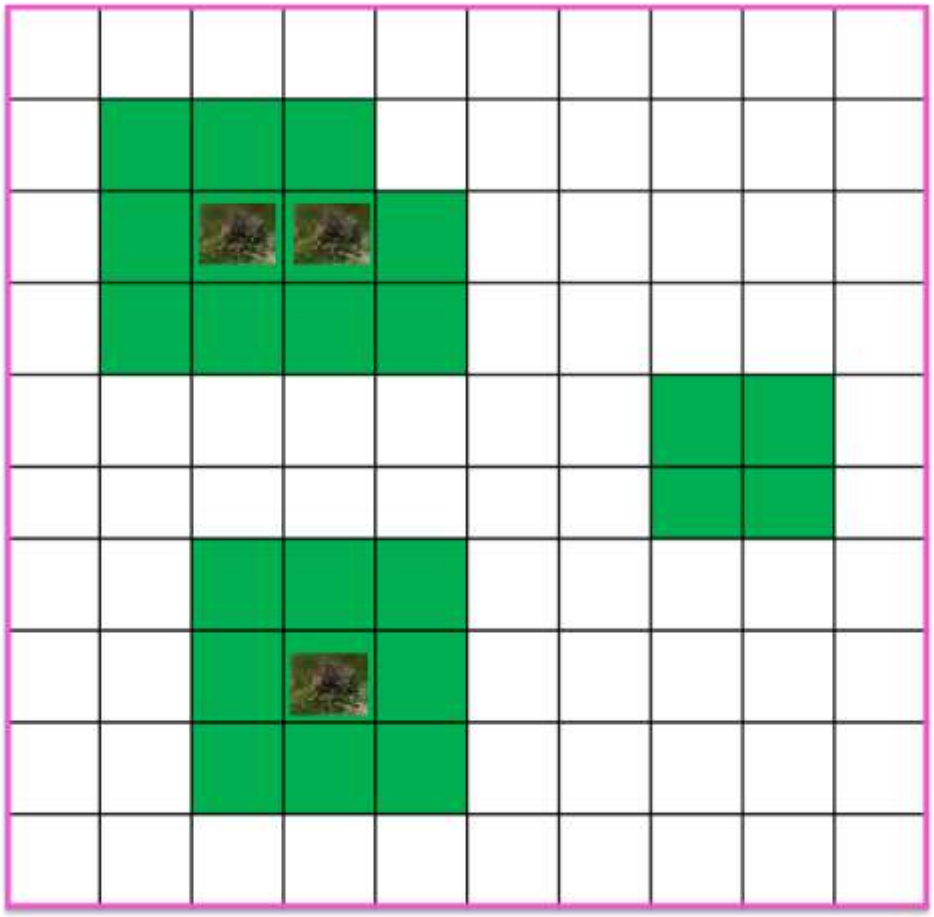
Species show different dependencies on habitat quality variation

Tupaia longipes: core forest species



Muntiacus muntjak*:* forest species

Species' habitat use & scales



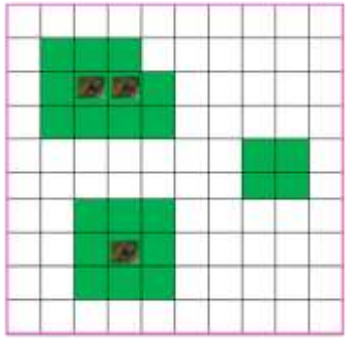
1000 m NDVI pixel

An edge sensitive beetle that likes forests

Total beetle N in pixel: 3

Total NDVI of pixel: 0.4

Species' habitat use & scales

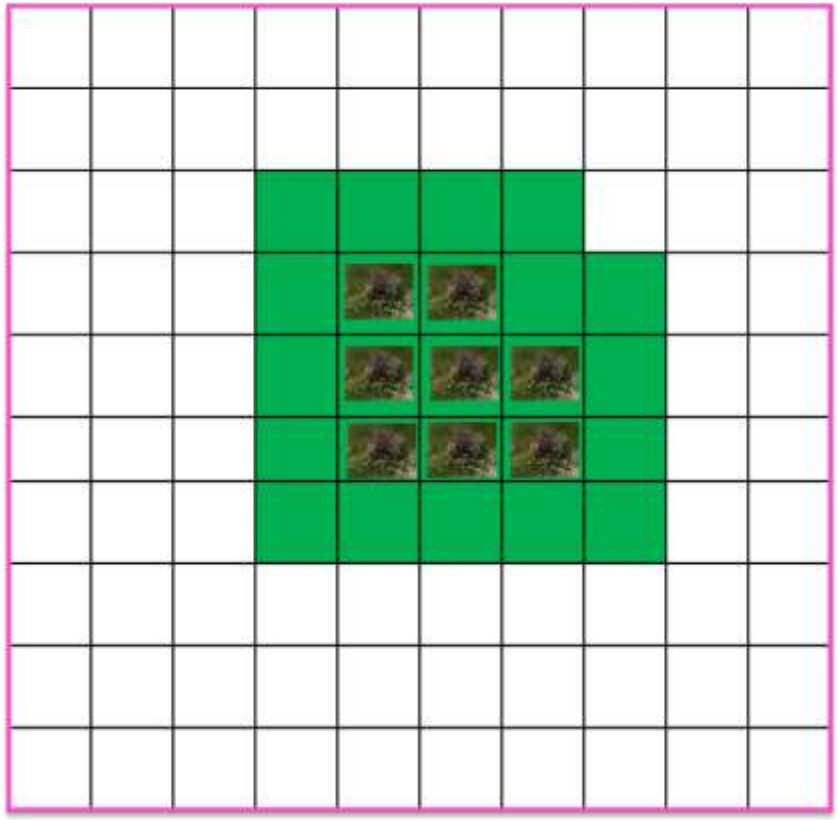


1000 m NDVI pixel

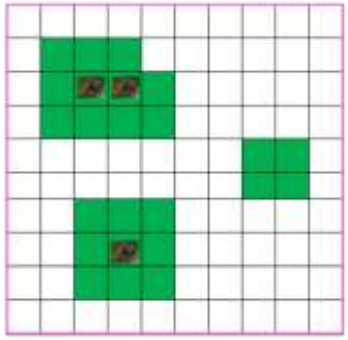
An edge sensitive beetle that likes forests

Total beetle N in pixel: 3
Total NDVI of pixel: 0.4

Total beetle N pixel: 8
Total NDVI of pixel: 0.4



Species' habitat use & scales



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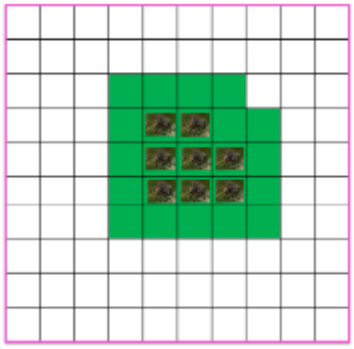
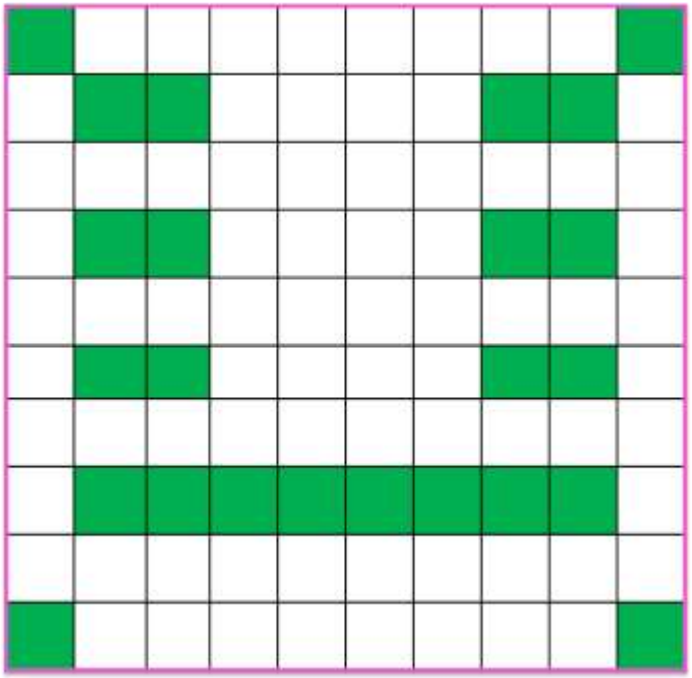


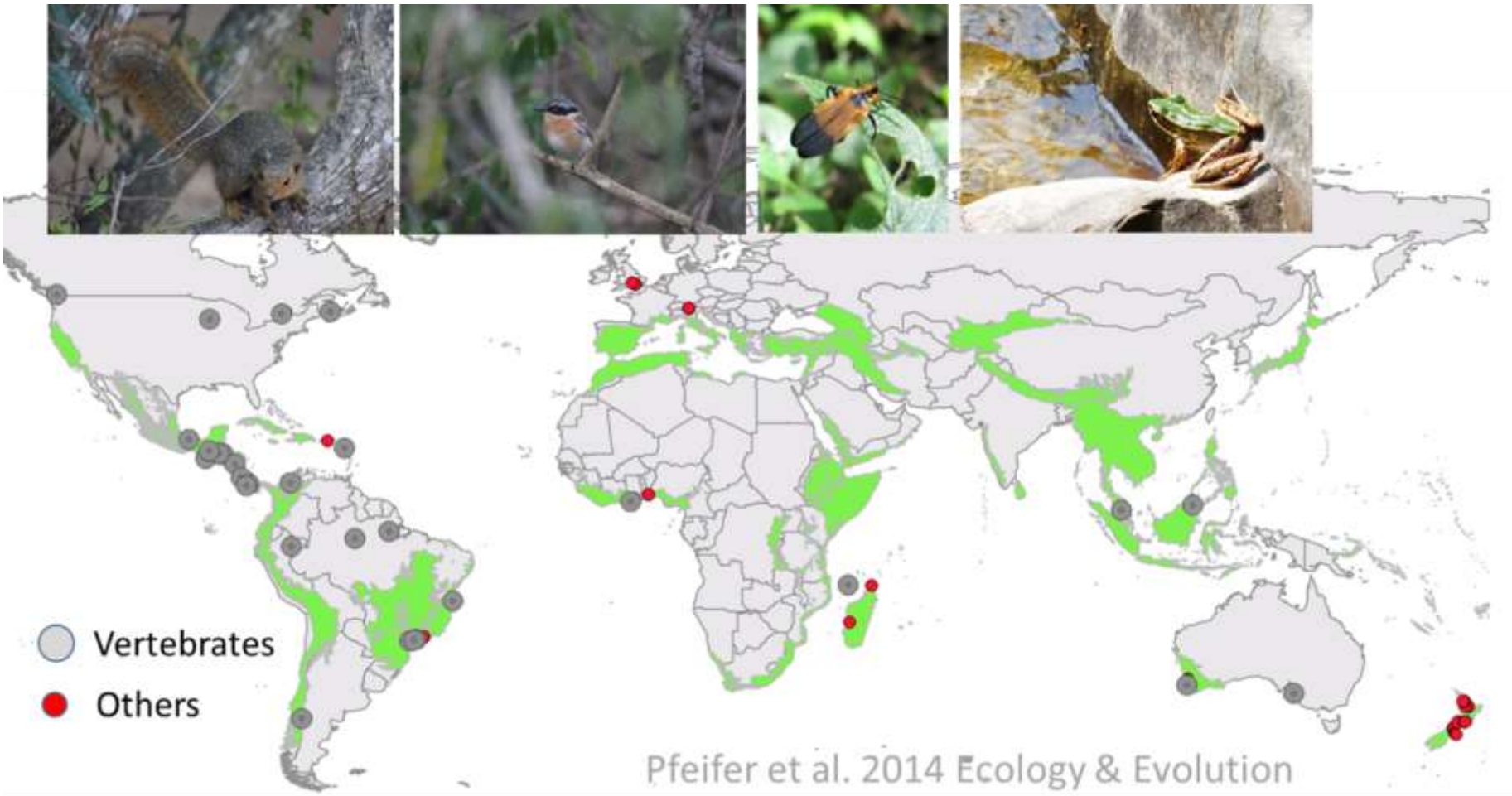
Total beetle N pixel: 8
Total NDVI of pixel: 0.4



1000 m NDVI pixel

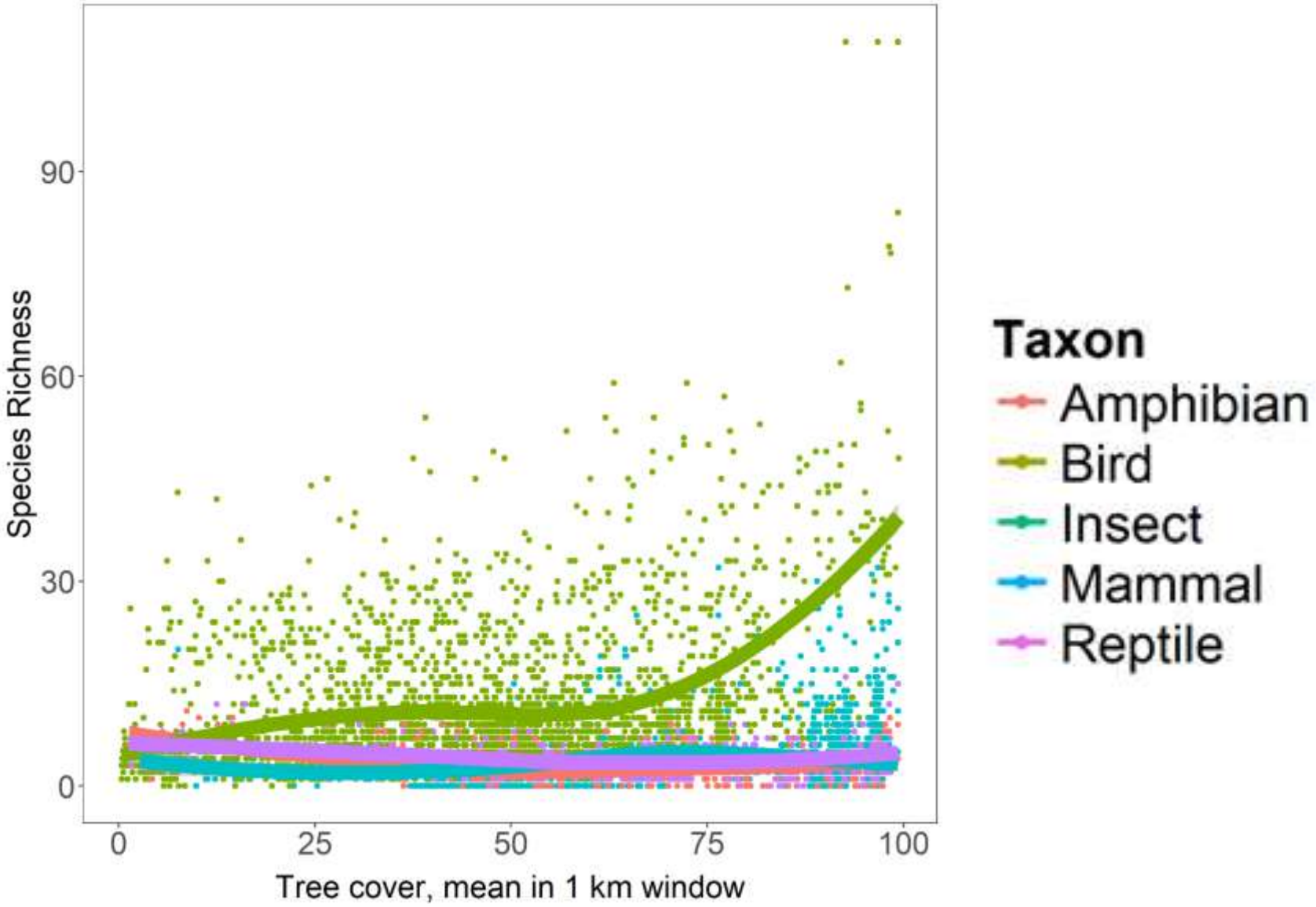
Total beetle N pixel: 0
Total NDVI of pixel: 0.4

This does matter for our ability to monitor biodiversity/natural capital

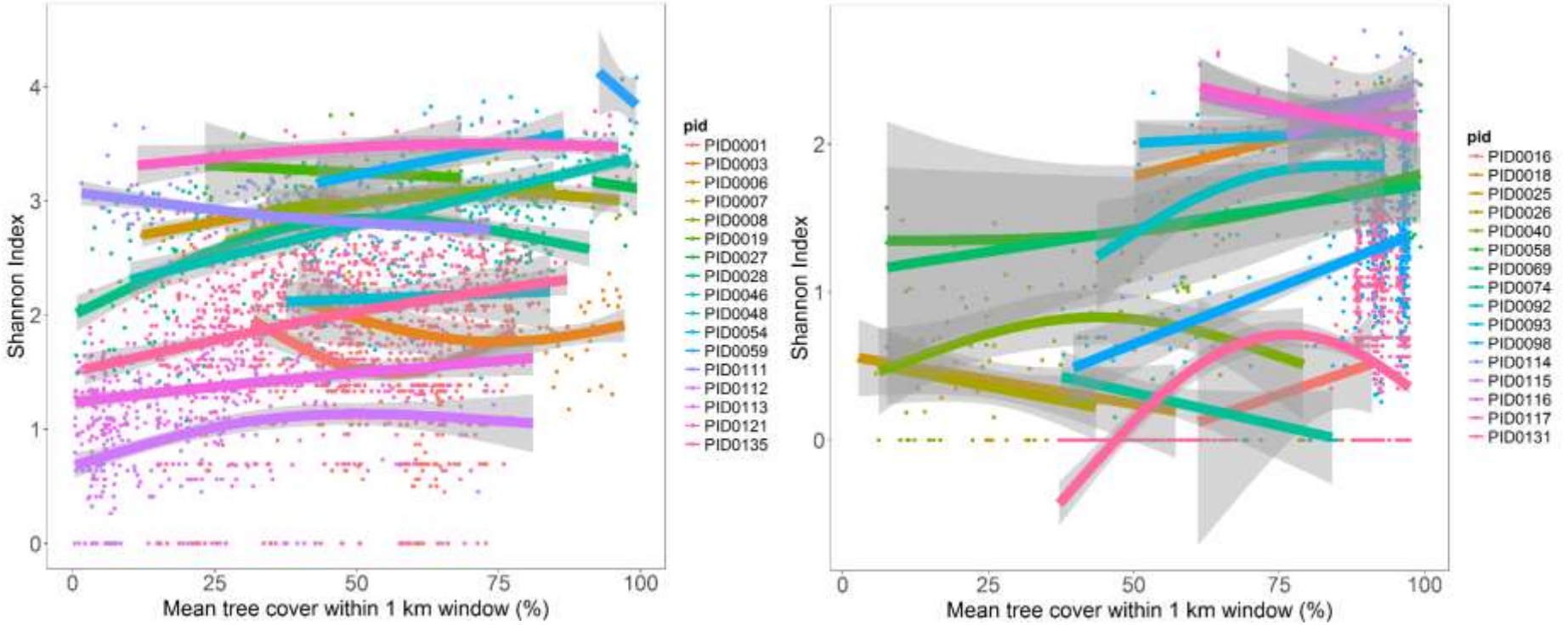


Global scale tests using the BIOFRAG database

This does matter for our ability to monitor biodiversity/natural capital



Species vary – a lot



Where are going wrong?

Key challenges:

1. **Sampling bias**

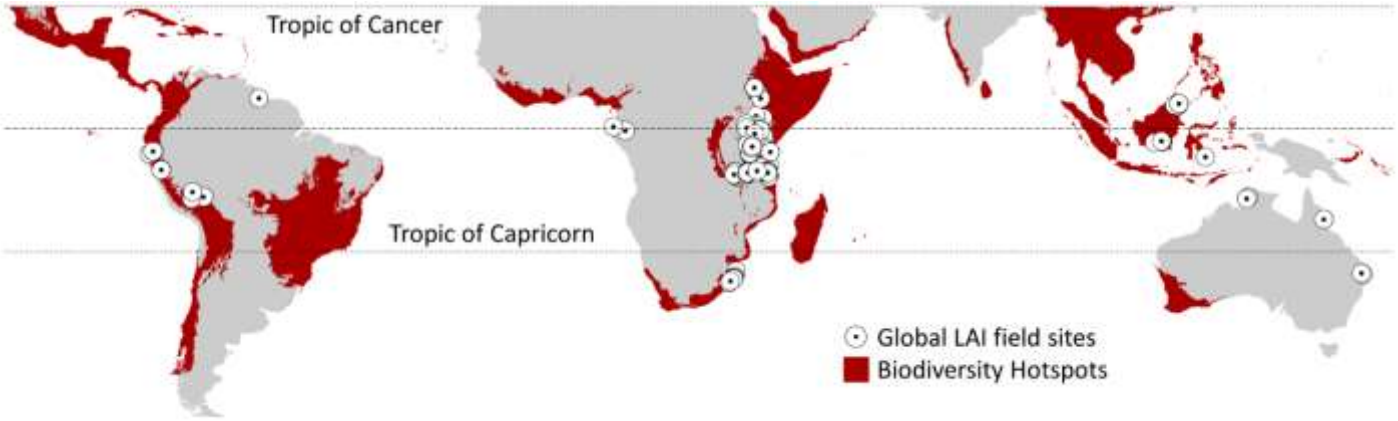
Using the landscape discussed in Pfeifer et al 2018 *PeerJ*

Where are going wrong?

Key challenges:

1. **Sampling bias** skews the view of how species use landscapes
2. **Habitat quality**



Pfeifer et al. 2018 ***Forest Ecosystems***

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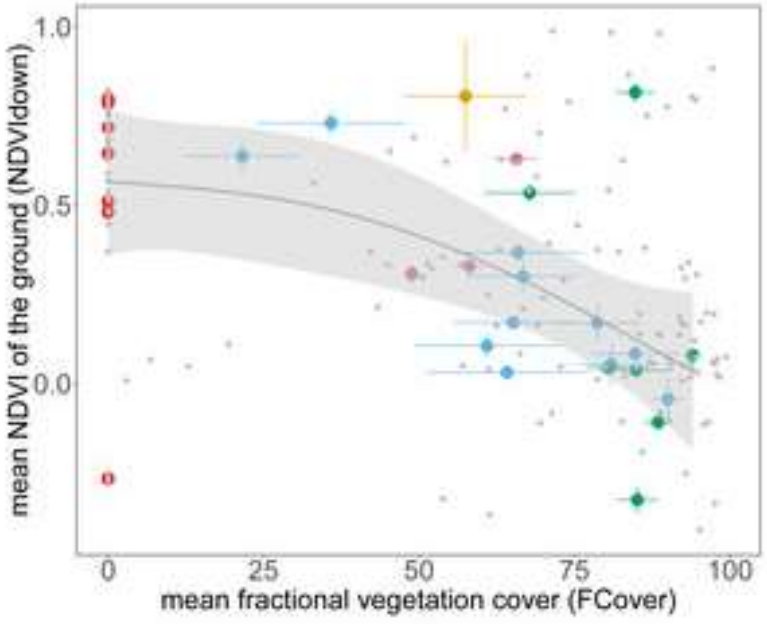
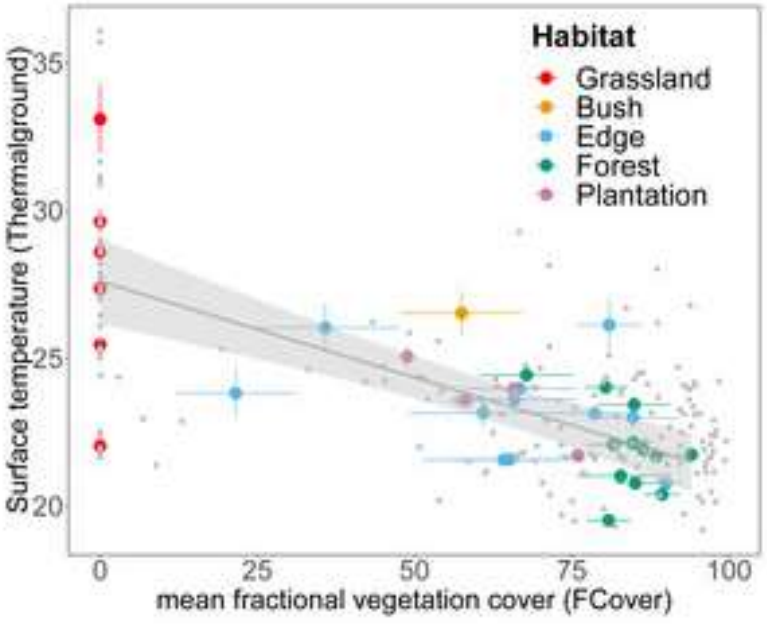
Pfeifer et al 2018 *PeerJ*



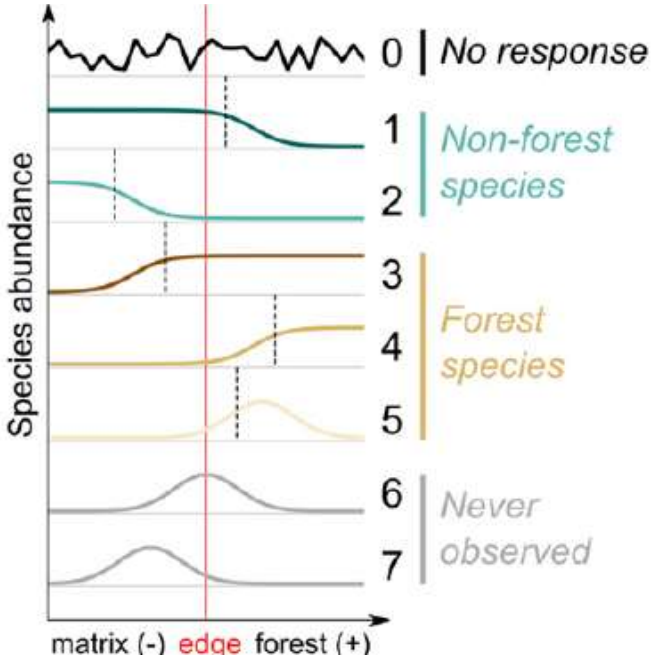


Where are going wrong?

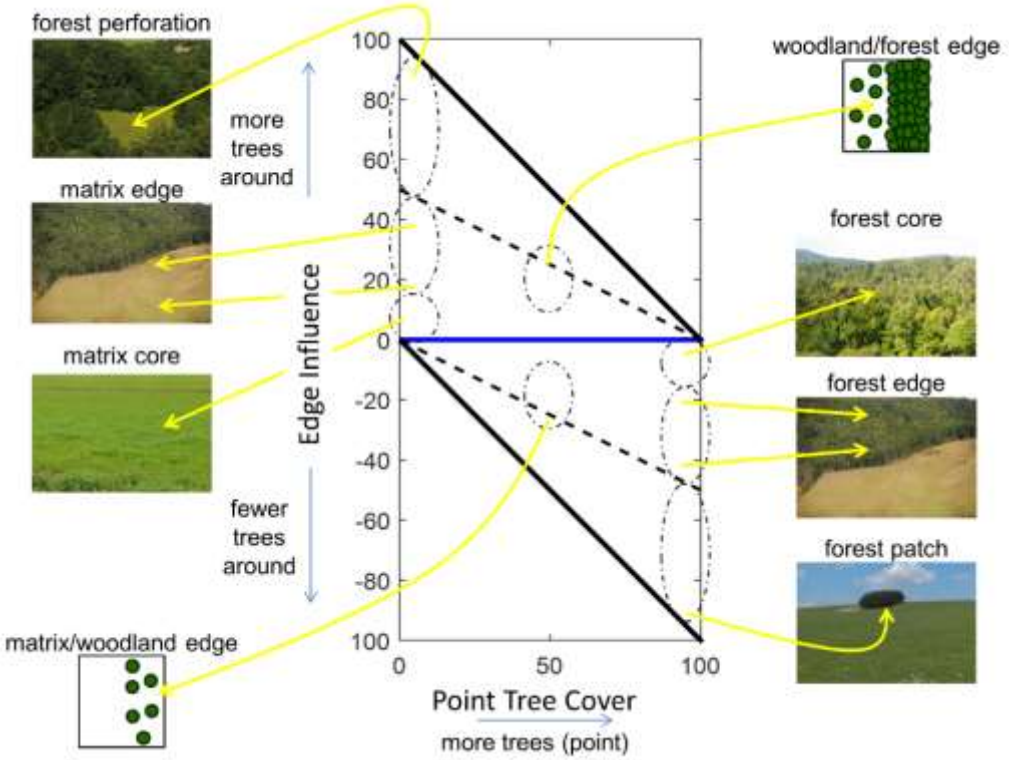
Key challenges:

1. **Sampling bias** skews the view of how species use landscapes
2. **Habitat quality:** is an ubiquitous term
3. **Species vary in their responses**

Pfeifer et al. 2017 *Nature*



Schneider–Maunory et al. 2016 *Biol Conserv*



Predicting species responses is possible

South Africa – coastal forests

N = 153 bird species	
High NDVI Core (‘Forest core’)	N = 23
High NDVI Edge (‘Forest edge’)	N = 10
Low NDVI Core (‘Matrix core’)	N = 8
Low NDVI Edge (‘Matrix edge’)	N = 2
High NDVI no preference	N = 8
Generalist	N = 17
Too rare	N = 80
Unknown:	N = 6

Batis capensis

High NDVI core

Zosterops pallidus

High NDVI edge

BIOFRAG software
https://github.com/VeroL/BioFrag/releases

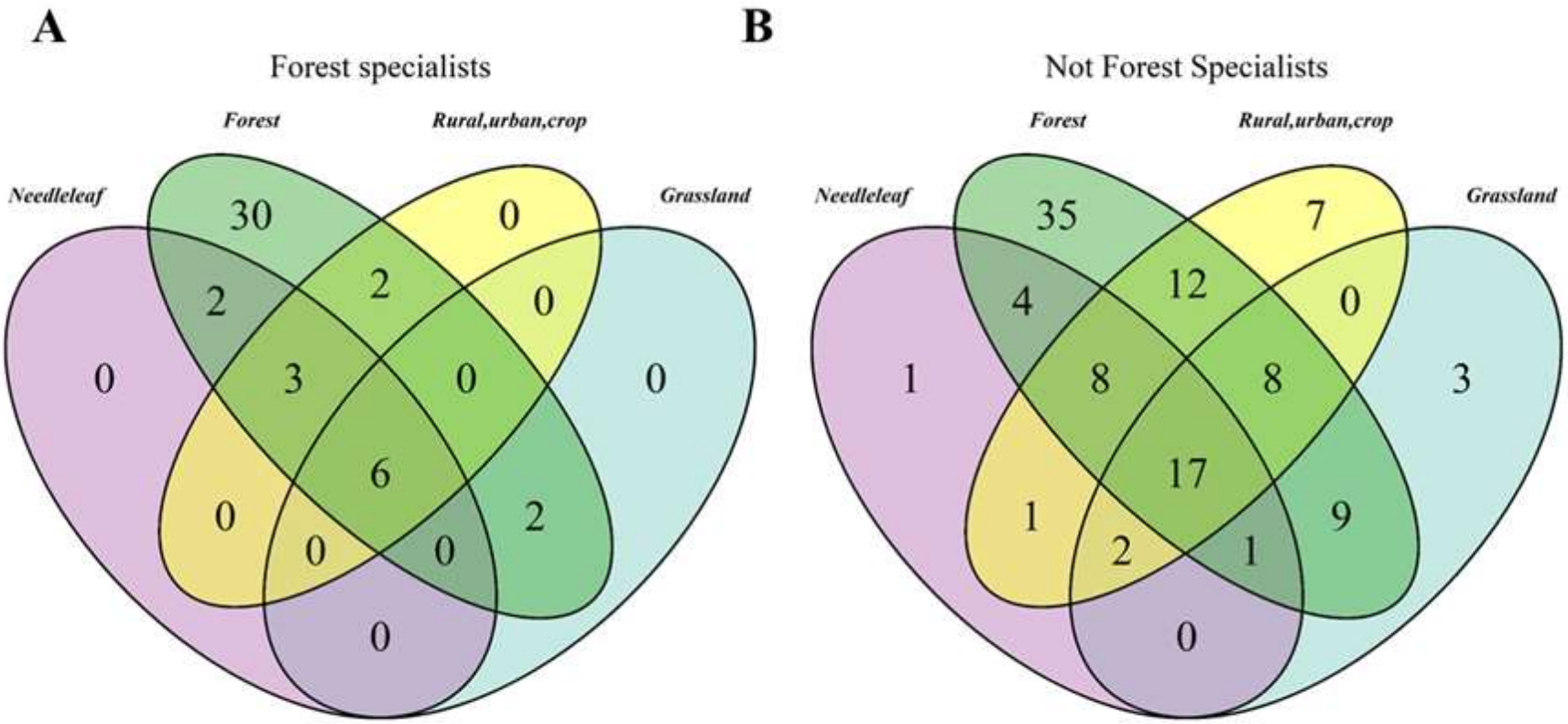
Getting the data to do this prediction right is essential

Plan your sampling before you sample. Bowler et al. To Be

MEE.

ampling designs on the
dscape, with green
alid forest regions and
eas. Each sampling
of 45 sample sites
crosses

Species use resources in the landscape



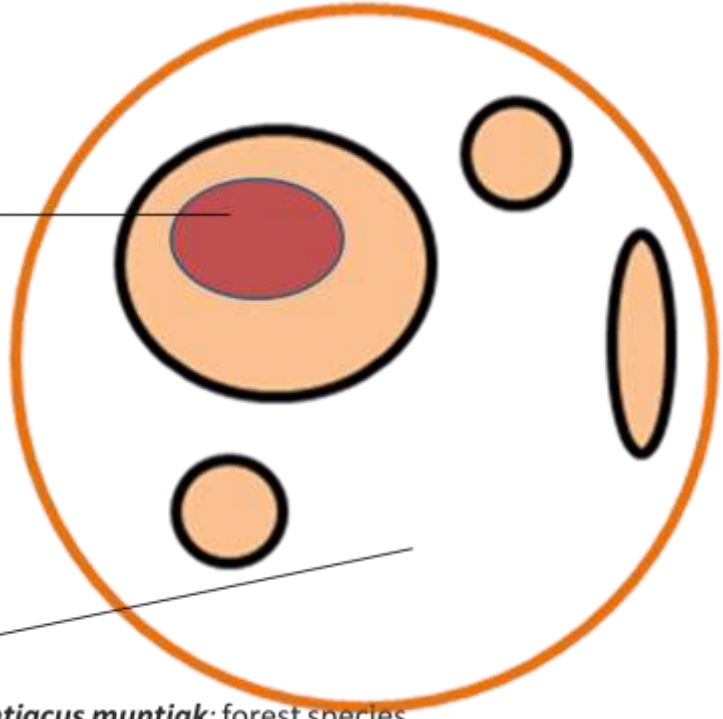
Pfeifer et al., For submission to PNAS

And we haven't even yet accounted for processes and functions

Biodiversity

⇩

Tupaia longipes: core forest species



Muntiacus muntjak: forest species

Species functions -> Species regulated ecosystem services?

Natural Capital

The Agrisys Tanzania Project

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Mammal/bird ectoparasite

2ndary Aphid Parasitoid

Insect feeding bird/mammal

Leaf miner parasitoid

Aphid Parasitoid

Insect seed feeder parasitoid

Leaf feeding bird/mammal

Pollinator

Leaf eating insect

Leaf miner

Scale insect

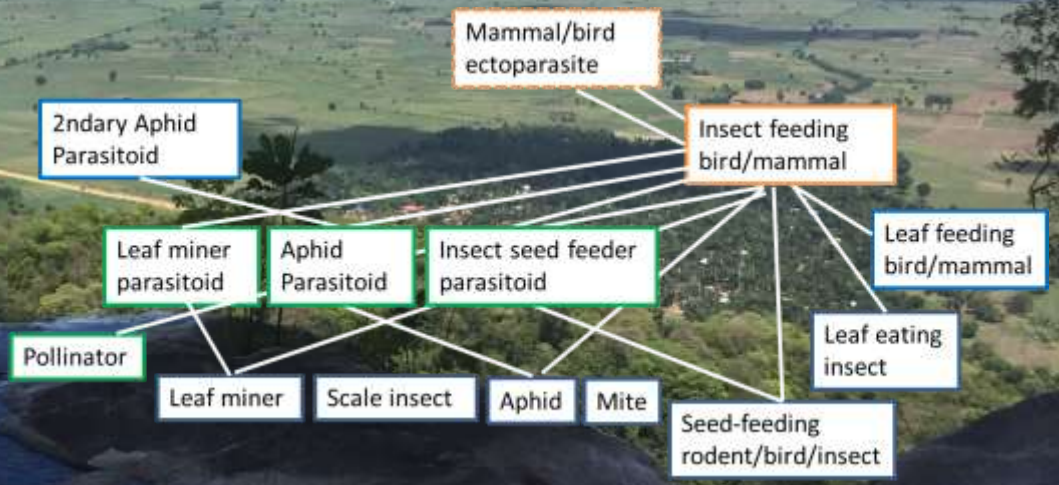
Aphid

Mite

Seed-feeding rodent/bird/insect

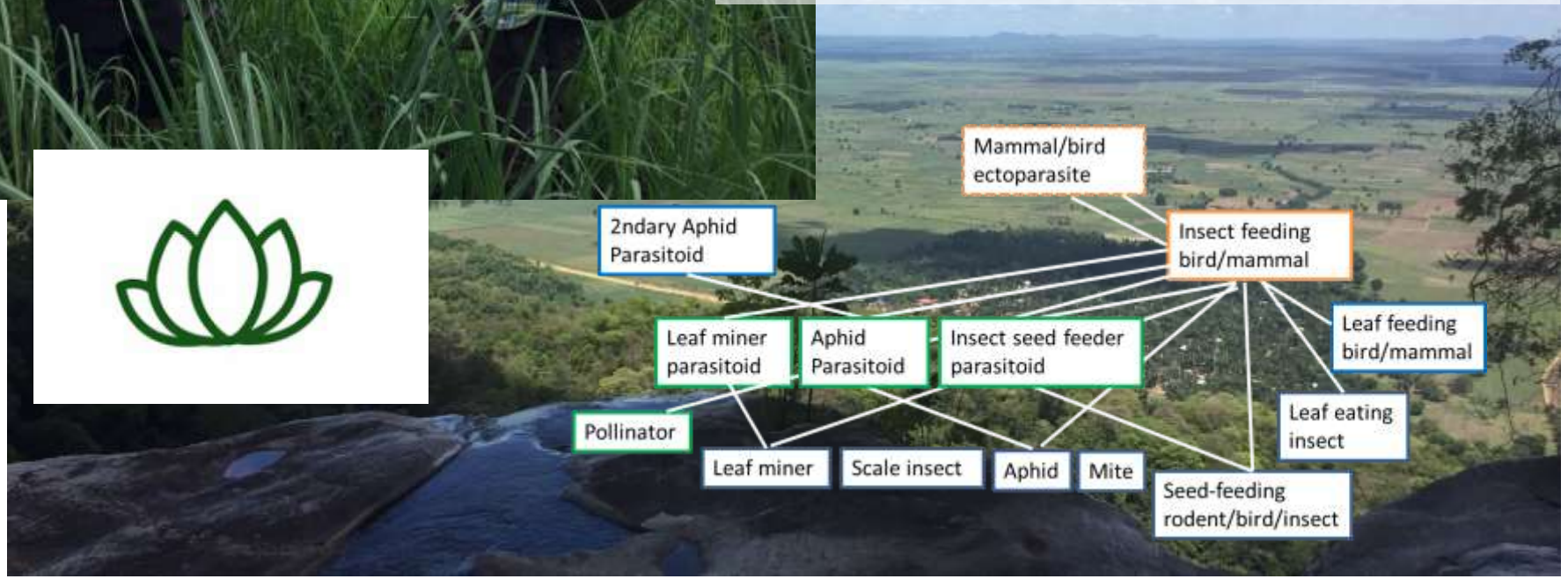
The Agrisys Tanzania Project

Hypothesis 1: Crop yields on the farm are higher when crops are located more closely to (semi-)natural habitats (benefits from pollination/pest control species outweigh crop damage through pests)



The Agrisys Tanzania Project

Human wellbeing includes the dimensions of basic materials for a good life, security, health, social relations and freedom of choice and action, considering all aspects of a person's experience of life



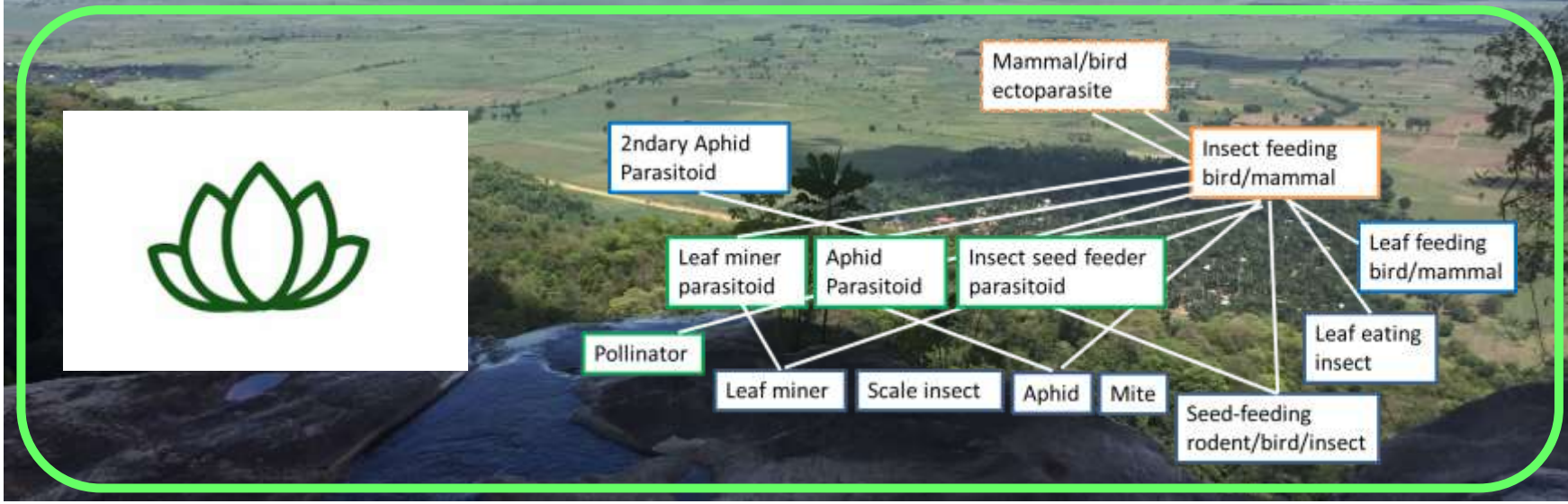
The Agrisys Tanzania Project

Hypothesis 4: Small-holder farms recognise natural and semi-natural habitats as beneficial for improved well-being

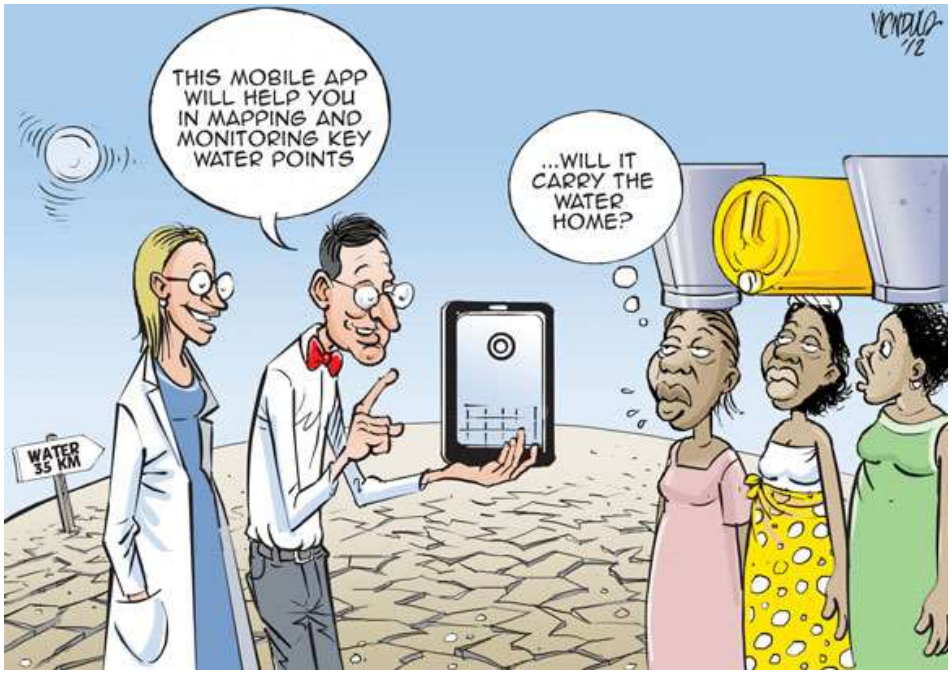
'Trees are not great as crops don't grow well under them'

'We don't know what the insects do, so we try to kill them all'

'There is a lot of research here but we never benefit'



Where next?



Responding to the needs identified by the communities affected

Hypothesis 8: Overall mean benefits increase following a saturation curve as a function of restoration of habitats on the farm and/or in the wider landscape

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https://blogs.ncl.ac.uk/agrisystanzania/

http://force-experiment.com/

Forest Restoration & Climate Experiment

How to monitor biodiversity/natural capital in human-modified tropical landscapes?

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Agrisys Tanzania