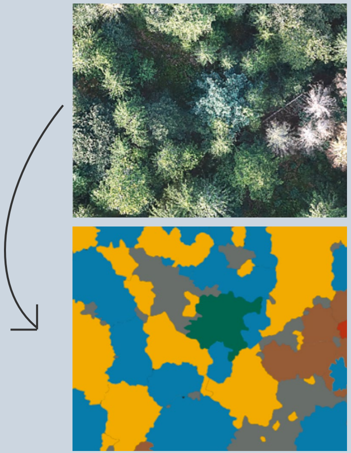
About the link between spectral variation and biodiversity

**Fabian Ewald Fassnacht*, Jana Müllerova, Luisa Conti,
Marco Malavasi, Sebastian Schmidtlein**

*presenting author

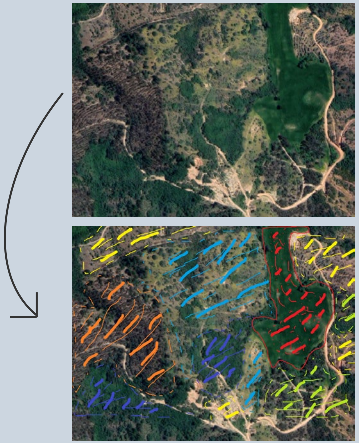

Four main approaches for mapping plant biodiversity using remote sensing (according to Wang & Gamon 2019):

Direct species mapping
(supervised species classification)



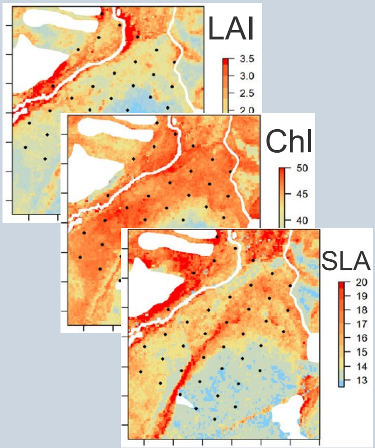
Schiefer et al. 2021

Habitat mapping
(land-cover classification)



From Google Earth

Via functional traits
(regression or VIs)



Kattenborn et al. 2017

Spectral variation-based
(regression)

VS

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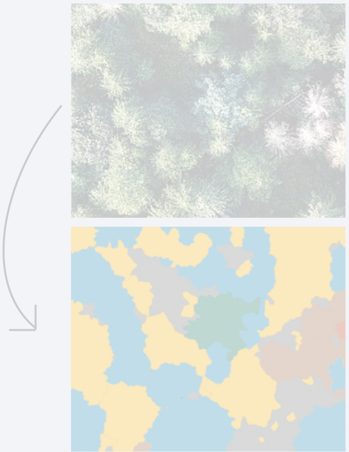

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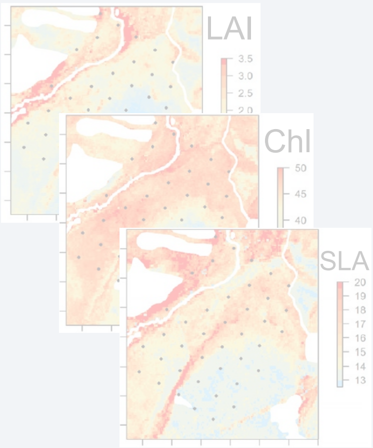

Kattenborn et al. 2017

Spectral variation-based
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VS

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The spectral variability hypothesis (SVH)

The SVH states that **the biodiversity of a given area is positively related to the spectral variation of the same area captured by an RS image**.

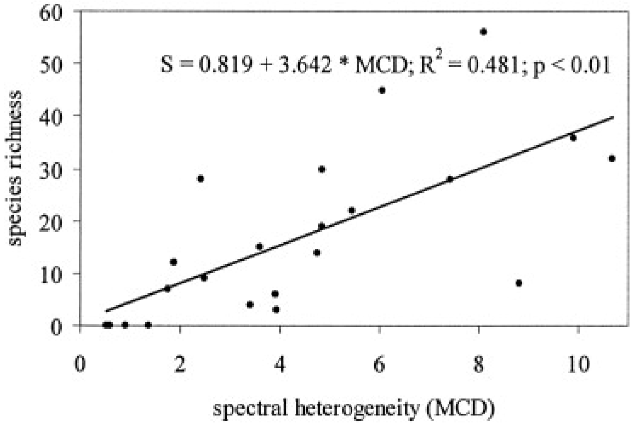
The underlying assumption is that a higher spectral variation can be interpreted as a higher variation in (number of) habitats or linked vegetation types and hence a larger number of species.

(Palmer et al. 2000, 2002)

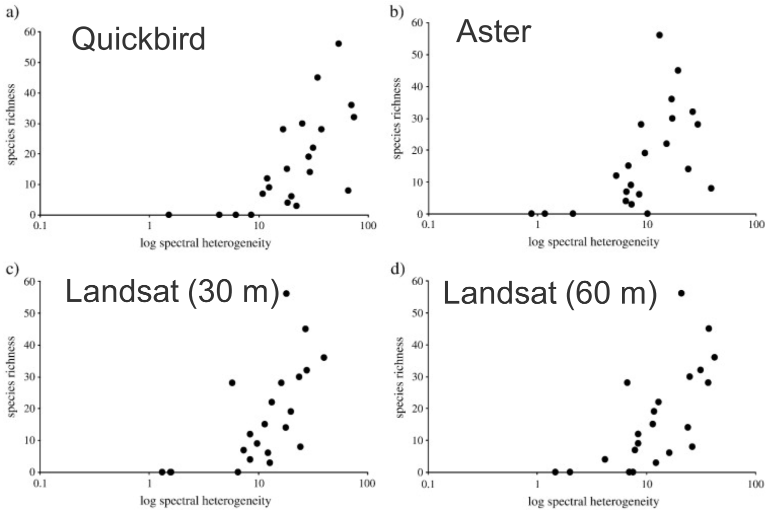
vs

The spectral variability hypothesis (SVH)

Some empirical support in earlier studies



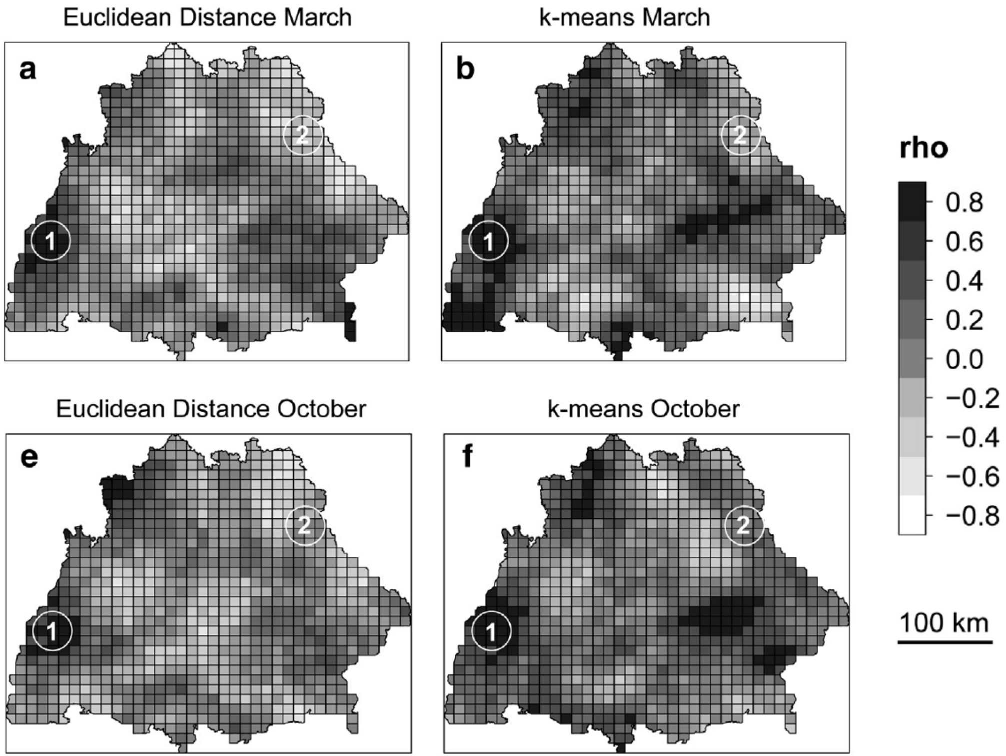
Rocchini et al. 2004



Rocchini et al. 2007

The spectral variability hypothesis (SVH)

But also doubts…



Schmidtlein & Fassnacht 2017

Objectives

Conceptually discuss and question the SVH with respect to:

- Habitat type/identity vs. number of habitats
- Spatial scale
- Phenology

Habitat type/identity vs. number of habitats

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Key problem: Not all habitats have equal amounts of species

- A single species-rich habitat may make a huge difference in terms of species numbers / biodiversity
- But at the same time little difference in spectral variation
- Hence: Habitat type is at least as important as the number of habitats

➔ A fundamental assumption of the spectral variation hypothesis is simply wrong
➔ Or well – it only holds true if habitats are nested

694000
696000
698000
700000
5354000
5352000
5350000
1
2
3
4
5
6
7
0
750
1500 m
EPSG: 32632

Scale

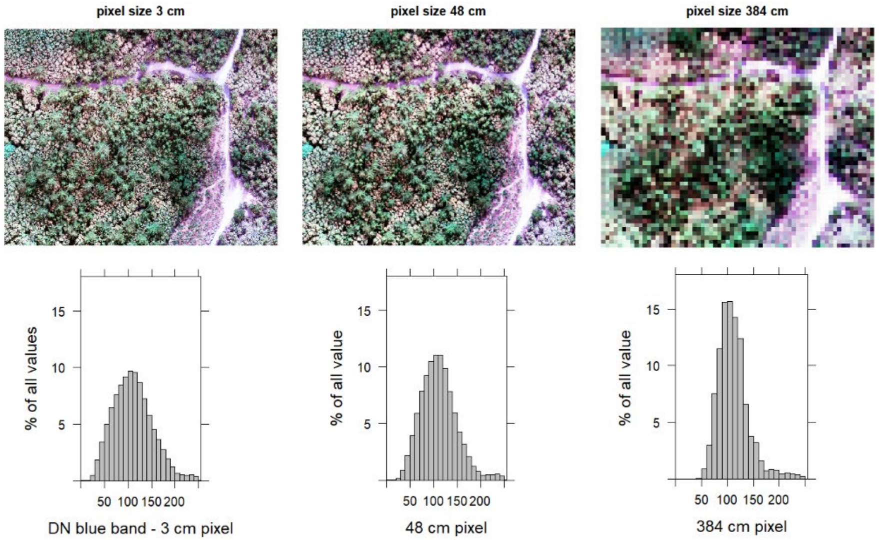
- Species ~ area relationship

  Grain => The coarser the grain, the more species in one pixel (**if areas are nested**)

  Extent => the larger the extent, the more species in the extent (**if areas are nested**)

- Spectral variability decreases with decreasing grain

Any potential link between spectral variation and plant species numbers will be affected by scale



Scale

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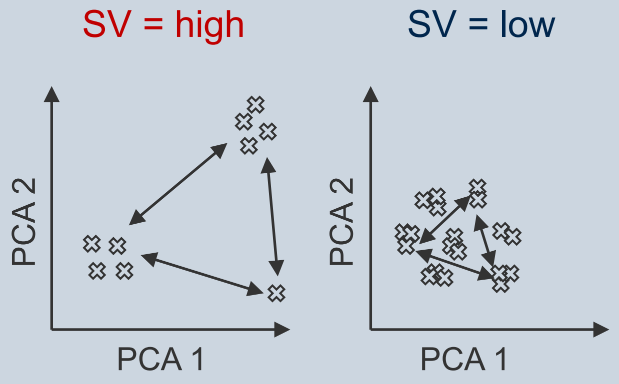
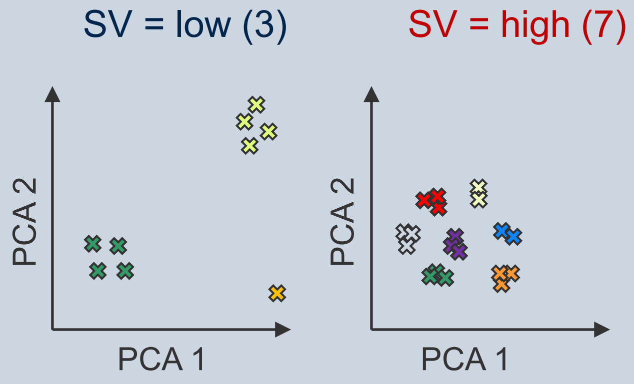
Methods

- Two approaches to define spectral variability

Distance based-metrics ➔ **Spectral contrast**
(in spectral feature space)



Clustering-based approach ➔ **Multifoldness**
(spectral-species concept)



Methods

- Field-spectrometer measurements of 20 common herbs and grasses of central Europe were used in simulation experiments
- Field-spectrometer Measurements were taken several times over the course of a growing season ➔ multi-temporal data
- Individual spectra were used to create **synthetic raster images** where each pixel was filled with a field-measured spectrum representing the species

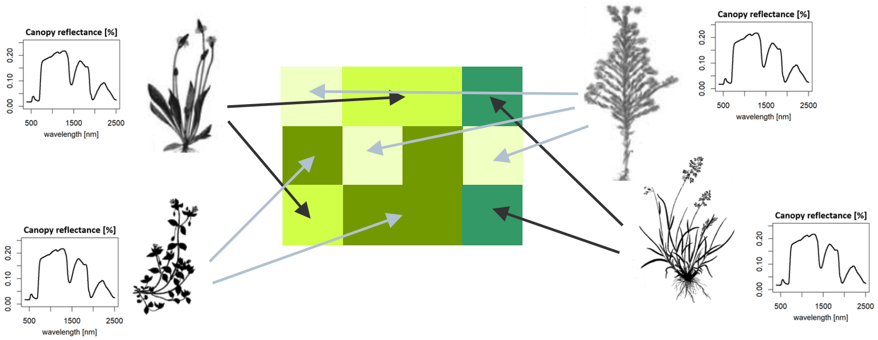
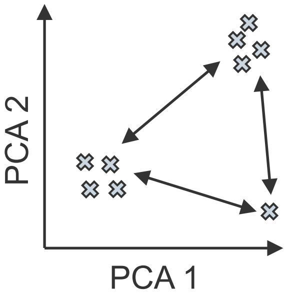
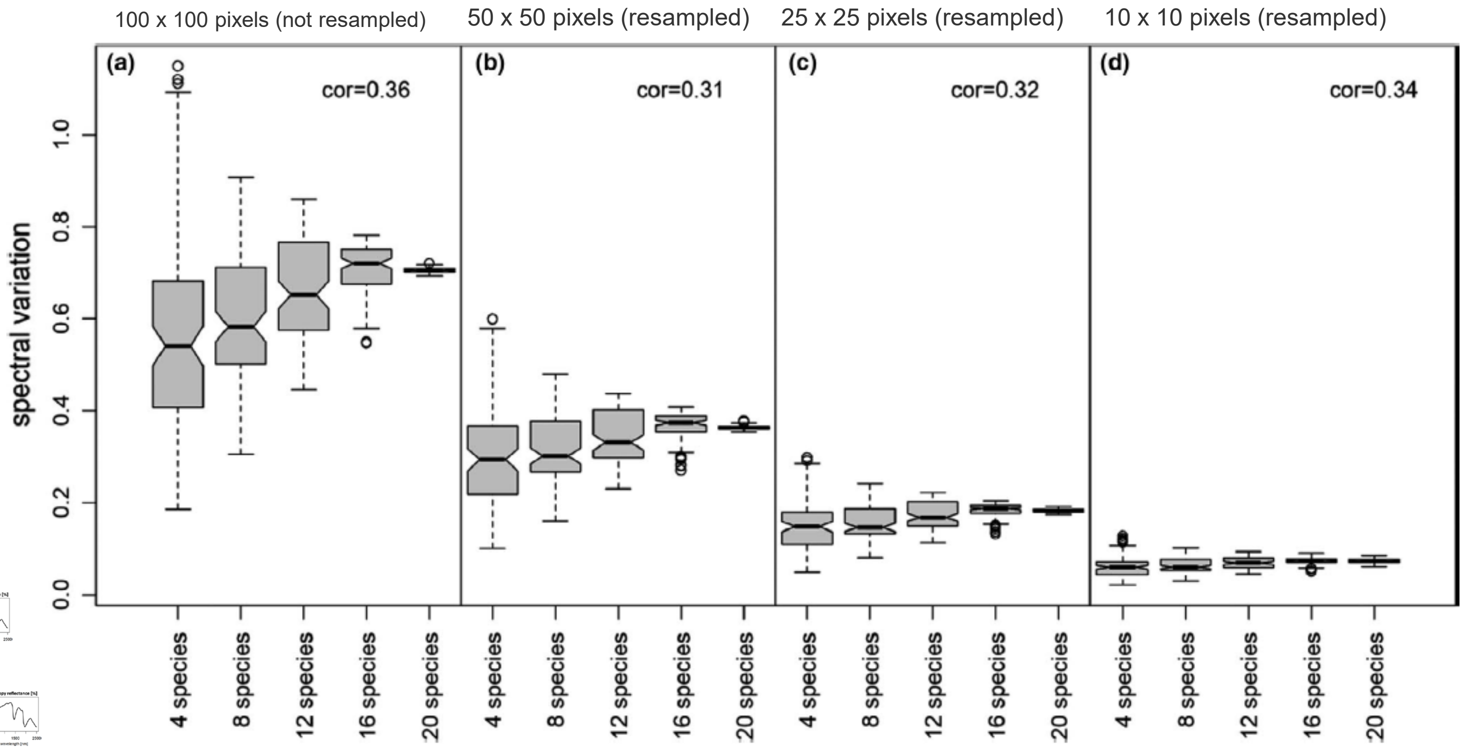


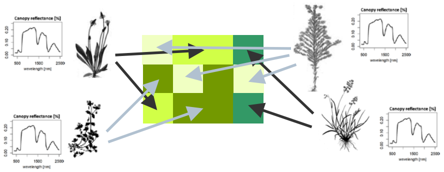
Figure by Teja Kattenborn

Scale

Contrast-based SV ~ number of species

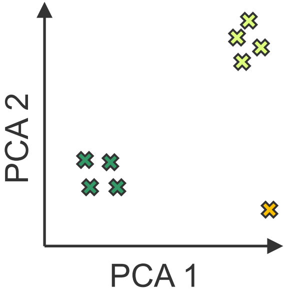


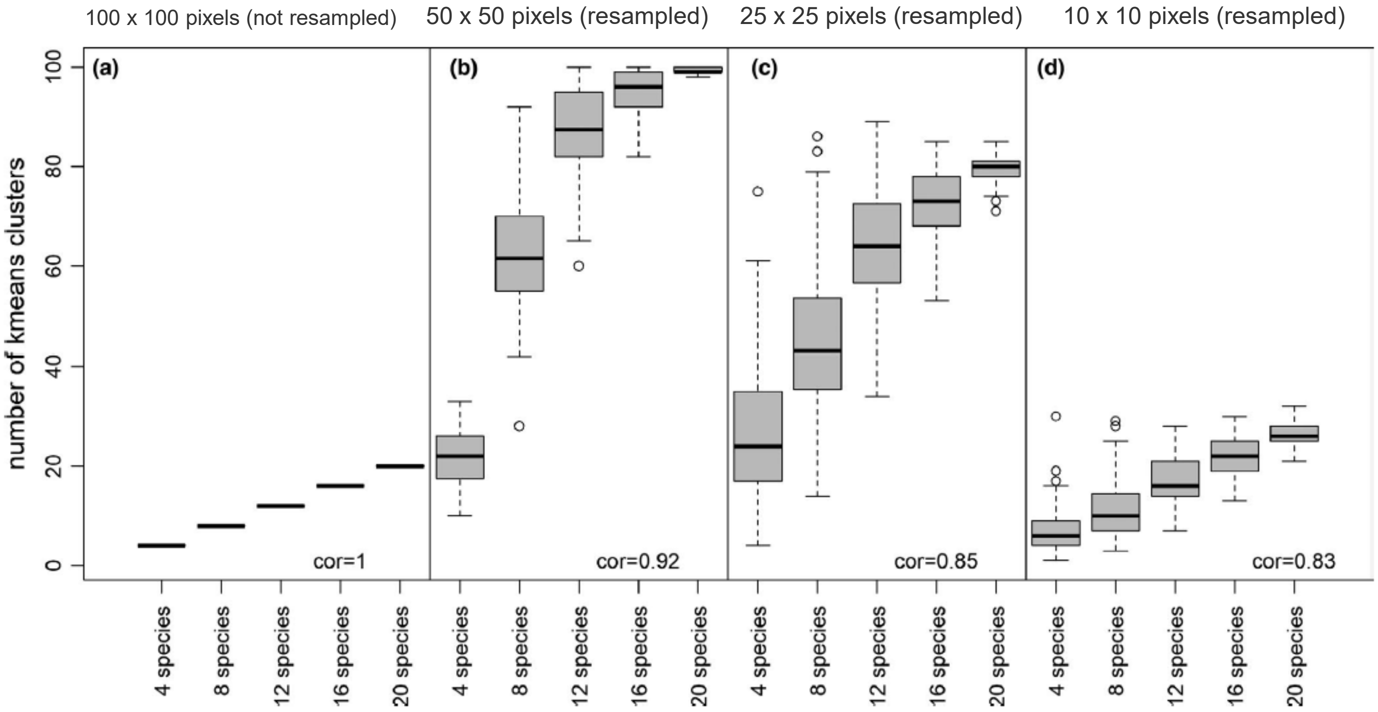


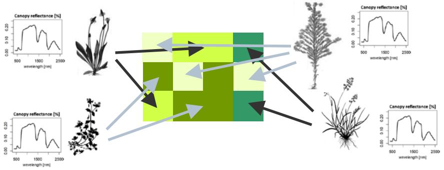


Scale

Multifoldness based SV ~ number of species

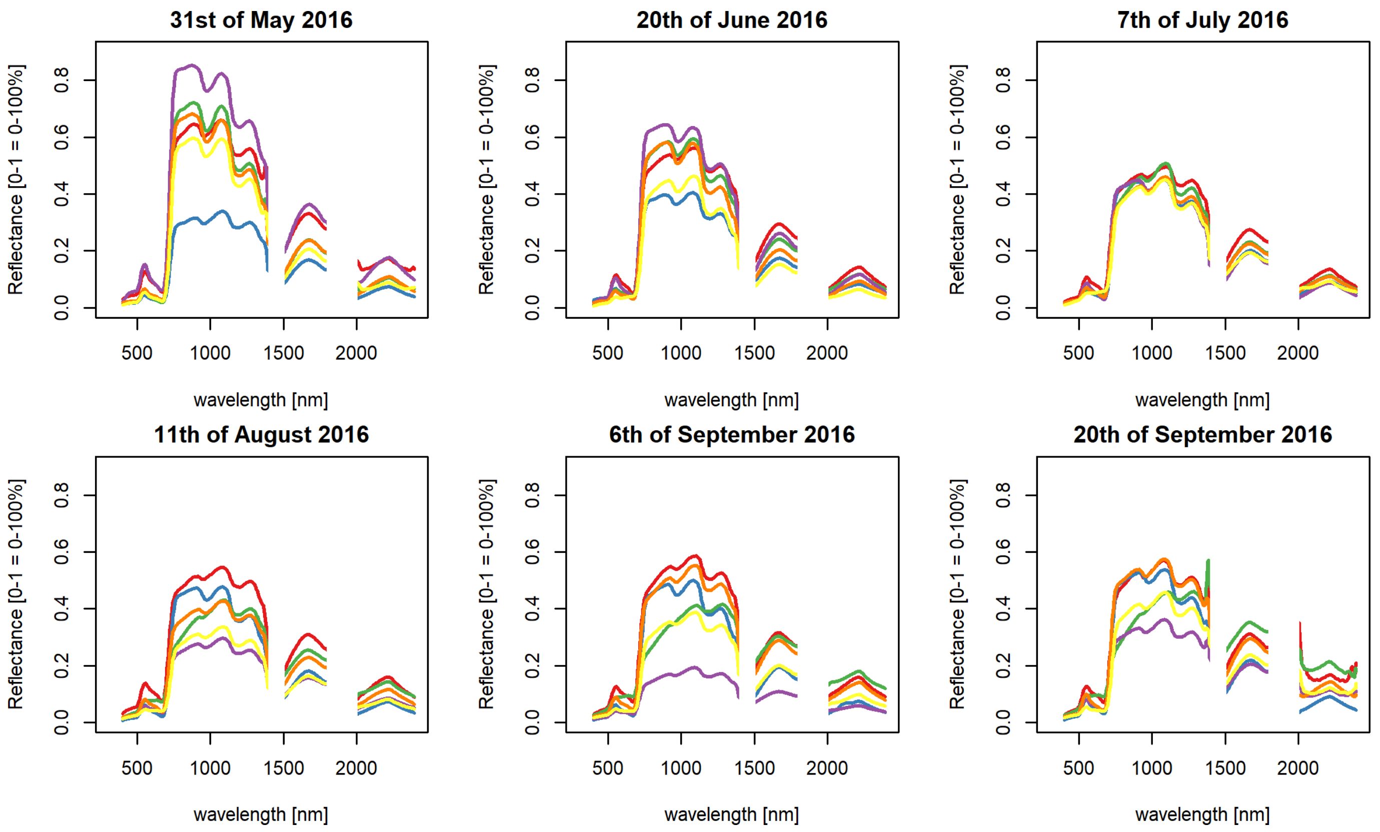






Phenology

- **Each color represents the spectrum of a single species at the date indicated above the panels**
- Spectral variability changes across the season



Phenology

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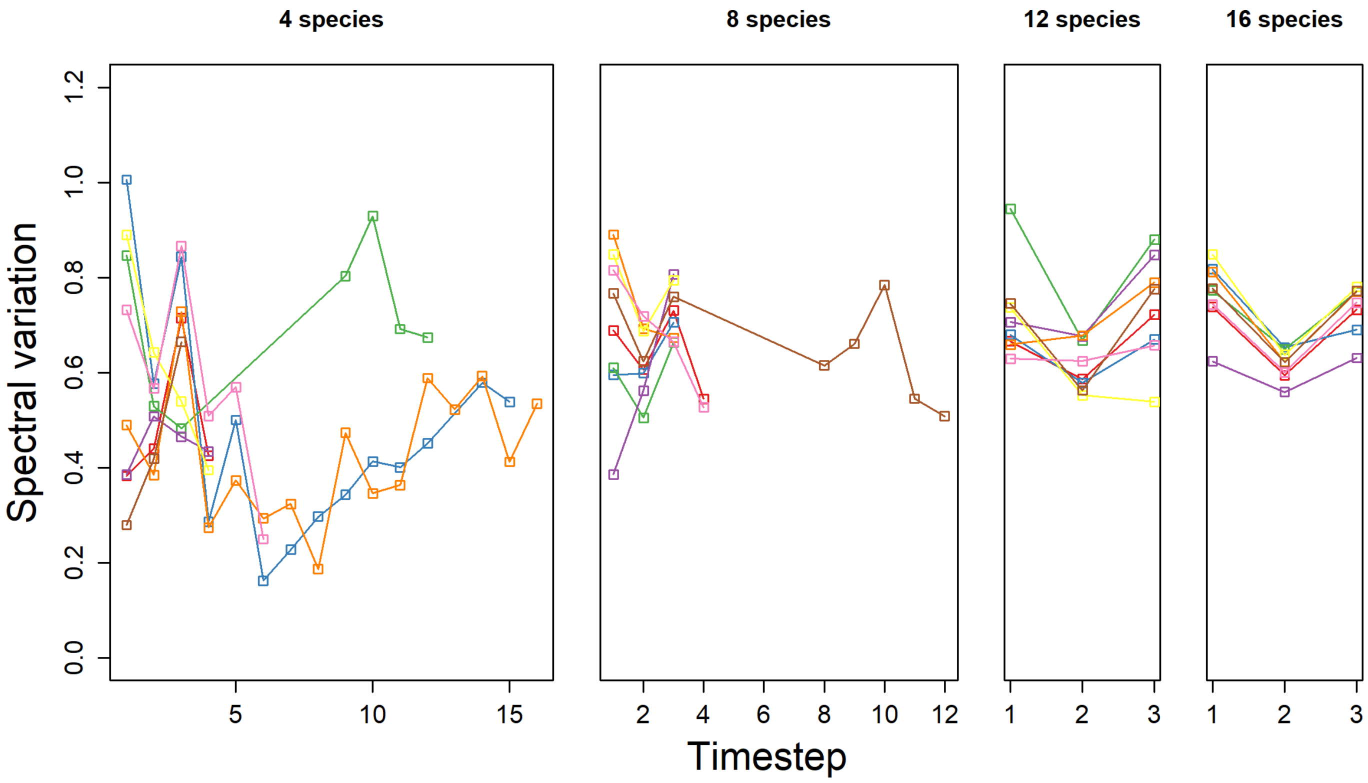
- **Each color represent a random image with a different species composition**
- No clear relation between number of species and spectral variation
- species compositions matter more than number of species



Mapping vs. Monitoring

- Most studies applying remote sensing to assess biodiversity focus on **mapping** and not on **monitoring**

- Monitoring is more important and remote sensing is likely to be more suitable for this task than for mapping

- Our suggestion:

  ➔ Map biodiversity in the field
  ➔ Use remote sensing to monitor for changes
  ➔ Change detected ➔ go to the field and check

- Essential Biodiversity Variables contribute to this task

Conclusions

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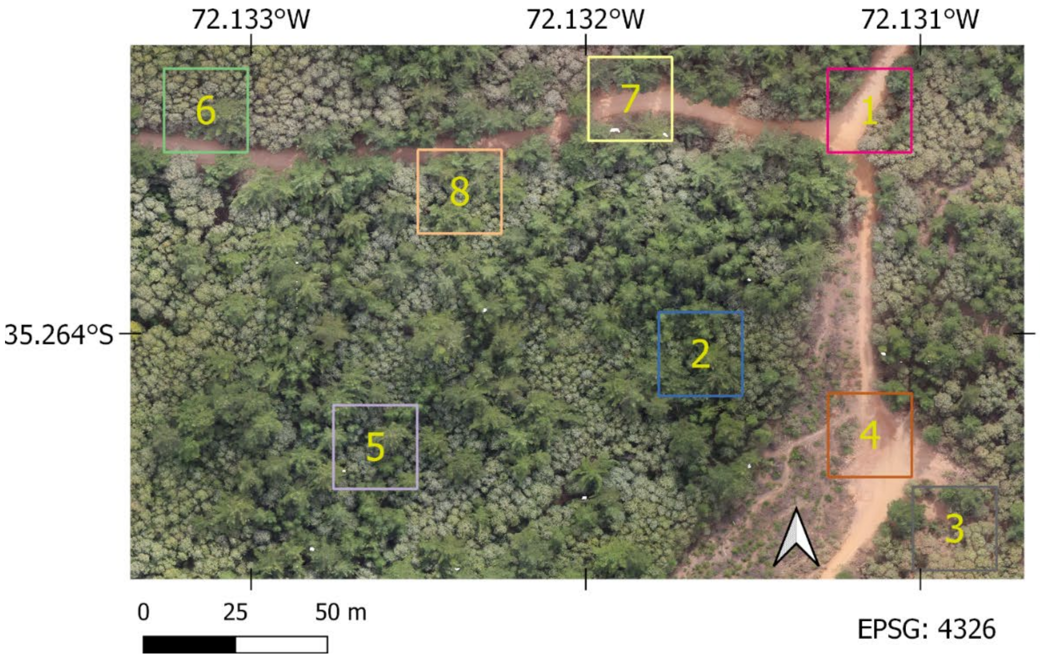
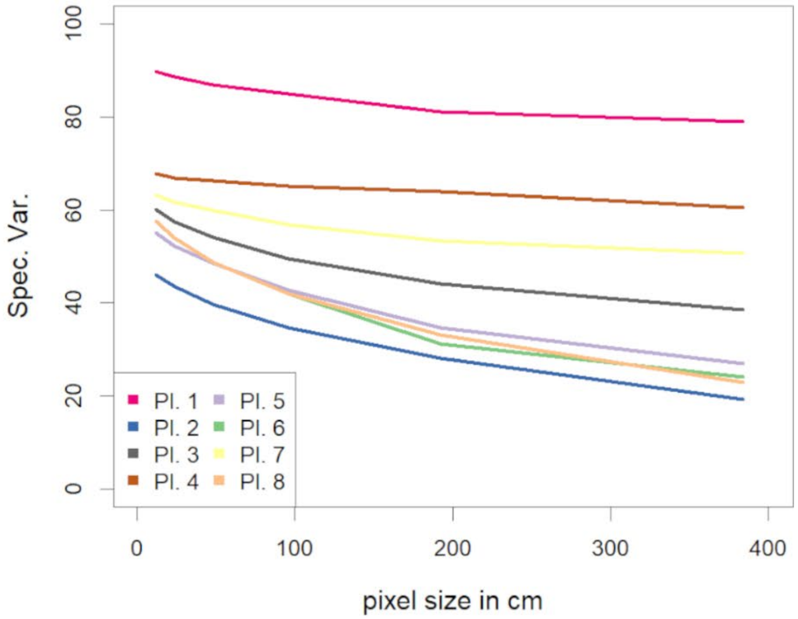
- The type of habitats is at least as important as the number of habitats
- Spectral variation is influenced by many things and is unlikely to become a reliable proxy for biodiversity in many situations
- Spectral contrast-based metrics should be avoided
- We need more research on monitoring/change detection, less on mapping
- Change detection for biodiversity is not simple (ecosystems are dynamic, the appropriate scale is unclear, …)

https://www.princeton.edu/sites/default/files/styles/half_2x/public/images/2011/10/biome_IMG_2584_575.jpg?itok=mqJikgXG

Thank you for your attention

Scale


72.133°W
72.132°W
72.131°W
35.264°S
6
7
1
8
2
4
5
3
0
25
50 m
EPSG: 4326


Spec. Var.
100
80
60
40
20
0
0
100
200
300
400
pixel size in cm
Pl. 1
Pl. 2
Pl. 3
Pl. 4
Pl. 5
Pl. 6
Pl. 7
Pl. 8