



Class-less vegetation mapping

demand, opportunities and ways towards remote sensing

data products

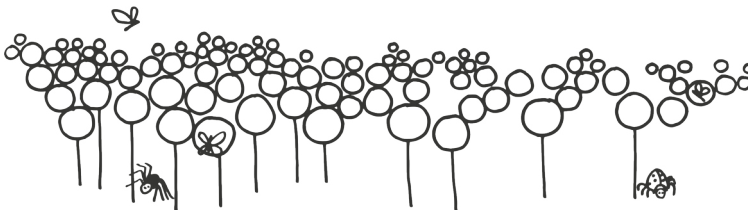


Hannes Feilhauer

Remote Sensing Centre for Earth System Research

Universität Leipzig

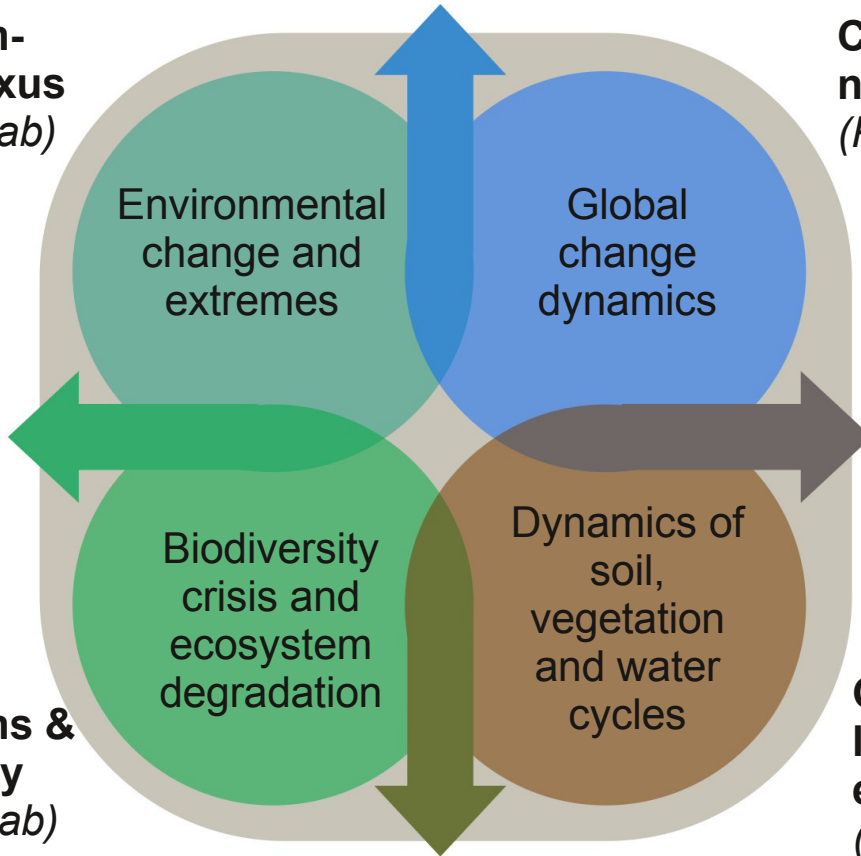
hannes.feilhauer@uni-leipzig.de





**Ecosystem-
climate nexus**
(Mahecha lab)

**Climate-water
nexus**
(Peng lab)



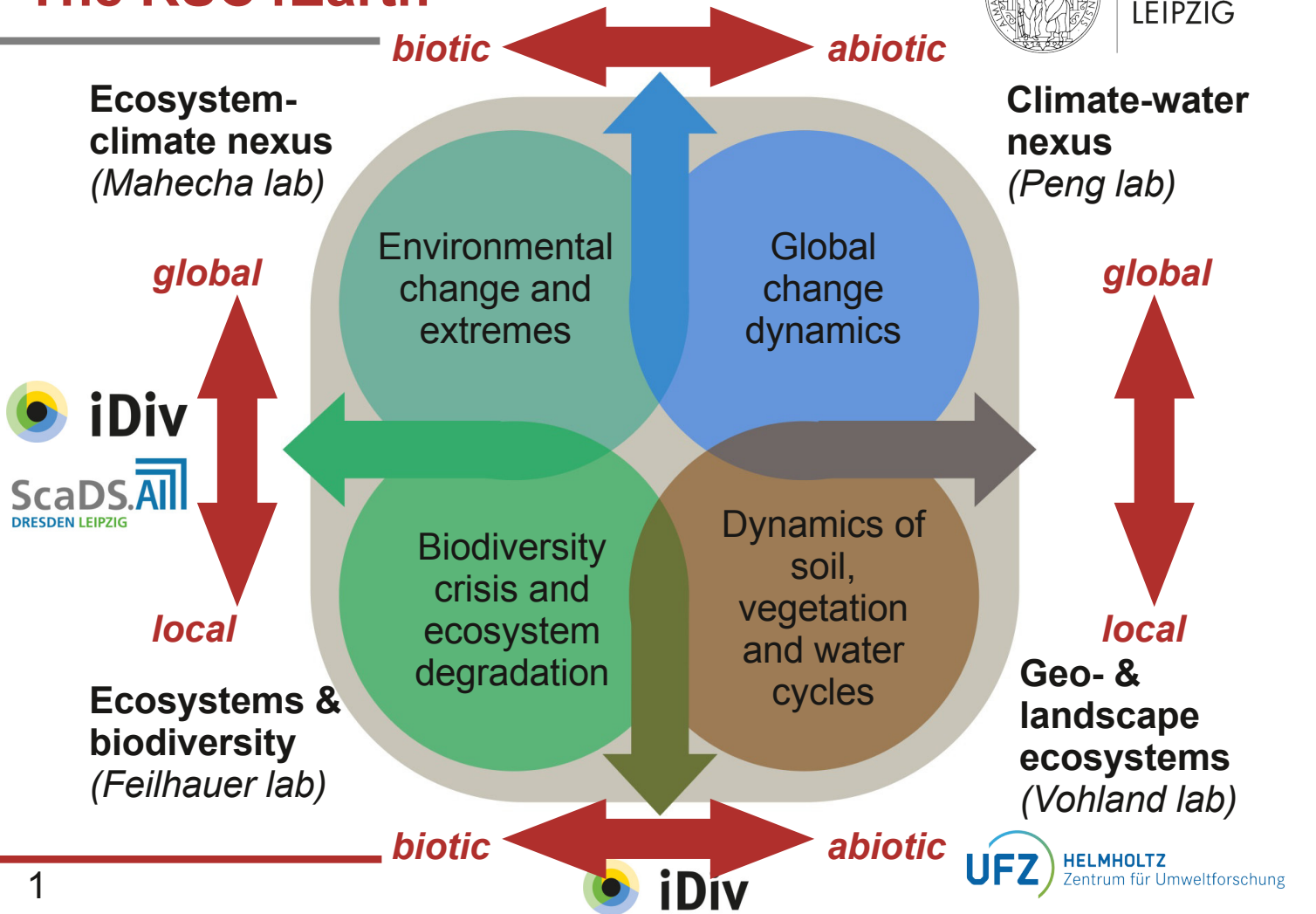
**Ecosystems &
biodiversity**
(Feilhauer lab)

**Geo- &
landscape
ecosystems**
(Vohland lab)

The RSC4Earth



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Remote Sensing Centre for Earth System Research



Leipzig is a vibrant hotspot for creativity in eastern Germany, known for its world-class research in biodiversity and ecosystem research. The [Faculty of Physics and Earth Sciences](#) at [Leipzig University](#) and the [Helmholtz Centre for Environmental Research \(UFZ\)](#) have teamed up and established the Remote Sensing Centre for Earth System Research to expand research in this area and better understand ecosystem functioning in a changing world.



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HELMHOLTZ
Zentrum für Umweltforschung

Twitter: @rsc4earth
Web: rsc4earth.de



M. Sc. Earth System Data Science and Remote Sensing

International Master Program
Starting Oct 2022

Remote sensing

- Multispectral
- Hyperspectral
- Spectroscopy
- Radar & Lidar
- Ground-truthing

Data science

- Big data
- Machine learning
- Timeseries analysis
- Geostatistics
- Data management

Earth system data science

Specialization

- Earth sciences
- Physical geography
- Biodiversity science
- Climatology
- ...

2 years
120 ECTS

Teaching in English

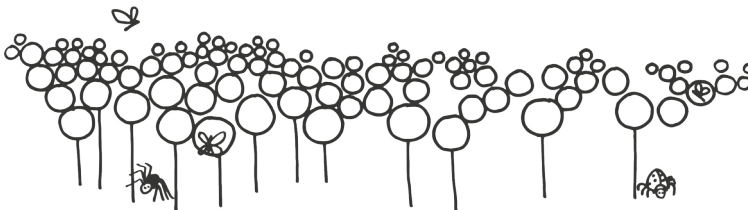
*'Facing environmental
problems with the tools
of our time'*



Class-less vegetation mapping

demand, opportunities and ways towards remote sensing

data products



COUNCIL DIRECTIVE 92/43/EEC

of 21 May 1992

on the conservation of natural habitats and of wild fauna and flora

(OJ L 206, 22.7.1992, p. 7)





COUNCIL DIRECTIVE 92/43/EEC

of 21 May 1992

on the conservation of natural habitats and of wild fauna and flora

(OJ L 206. 22.7.1992. p. 7)

91. Forests of Temperate Europe

9110 *Luzulo-Fagetum* beech forests

9120 Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercion robori-petraeae* or *Ilici-Fagenion*)

9130 *Asperulo-Fagetum* beech forests

9140 Medio-European subalpine beech woods with *Acer* and *Rumex arifolius*

9150 Medio-European limestone beech forests of the *Cephalanthero-Fagion*

9160 Sub-Atlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli*

9170 *Galio-Carpinetum* oak-hornbeam forests

9180 * *Tilio-Acerion* forests of slopes, screes and ravines



COUNCIL DIRECTIVE 92/43/EEC

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(Official Journal L 204, 22.7.1992, p. 7)

91. Forests of Temperate Regions

9110 *Luzulo-Fagetum* beech forests

9120 Atlantic acidophilous forests in the shrublayer (oak-hornbeam)

9130 *Asperulo-Fagetum* beech forests

9140 Medio-European suboceanic beech forests

9150 Medio-European littoral beech forests

9160 Sub-Atlantic and north-western European oak-hornbeam forests (*Carpinion betuli*)

9170 *Galio-Carpinetum* oak-hornbeam forests

9180 * *Tilio-Acerion* forests of slopes, screes and ravines

2. COASTAL SAND DUNES AND INLAND DUNES

21. Sea dunes of the Atlantic, North Sea and Baltic coasts

2110 Embryonic shifting dunes

2120 Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes')

2130 * Fixed coastal dunes with herbaceous vegetation ("grey dunes")

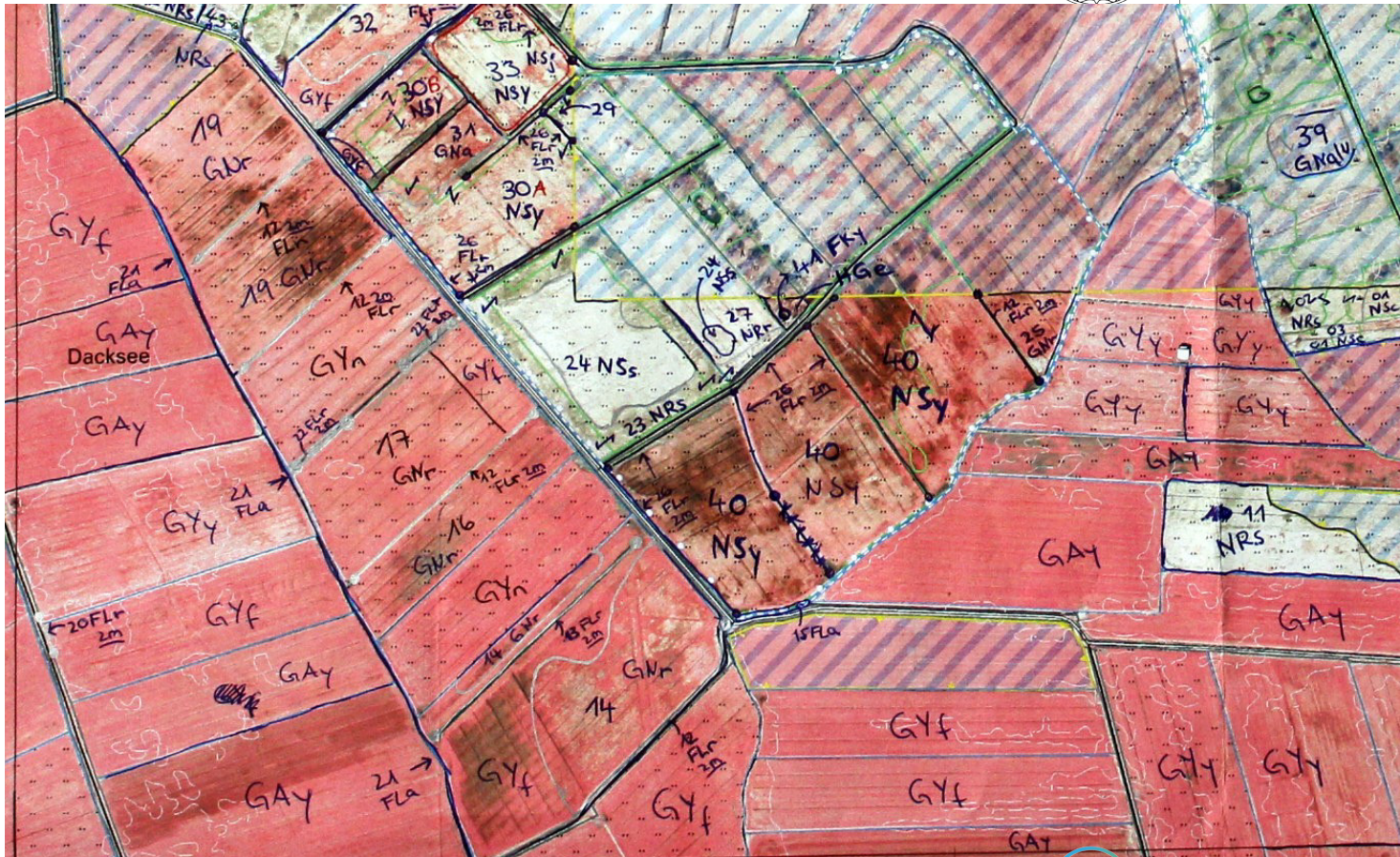
2140 * Decalcified fixed dunes with *Empetrum nigrum*

2150 * Atlantic decalcified fixed dunes (*Calluno-Ulicetea*)

2160 Dunes with *Hippophaë rhamnoides*

2170 Dunes with *Salix repens* ssp. *argentea* (*Salicion arenariae*)

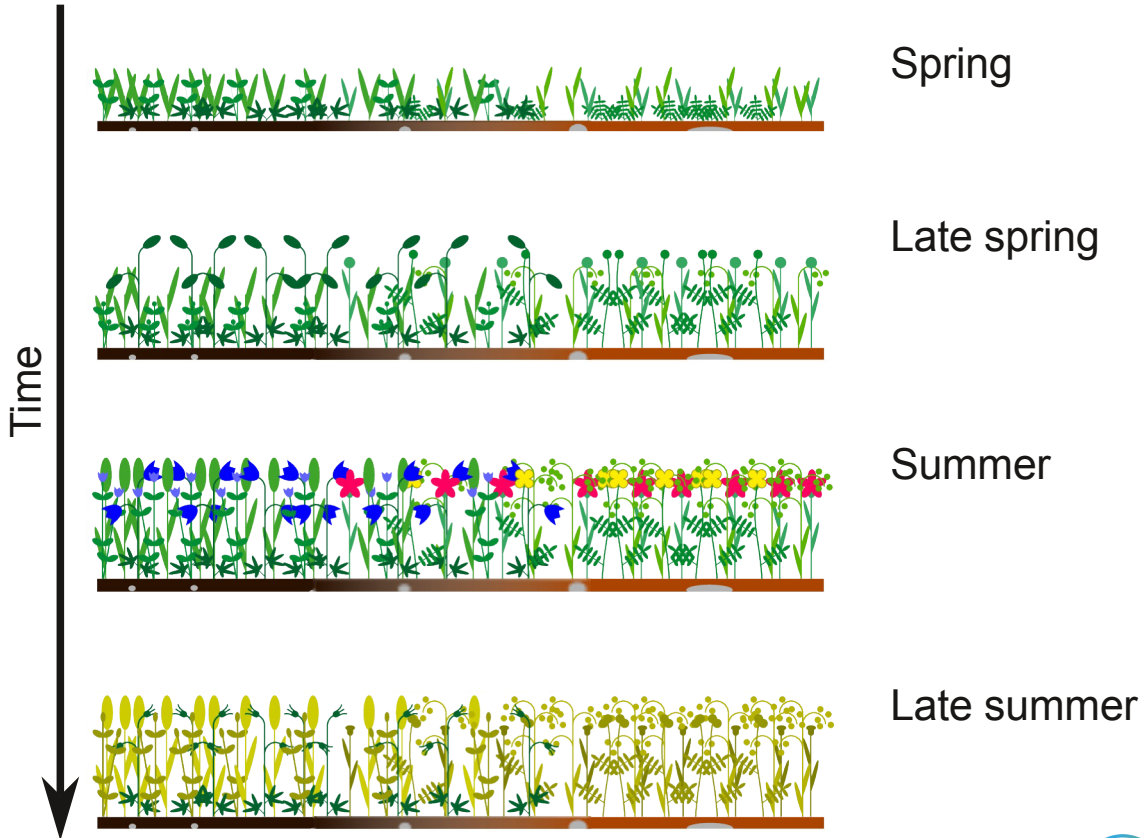
Who needs maps of species composition?



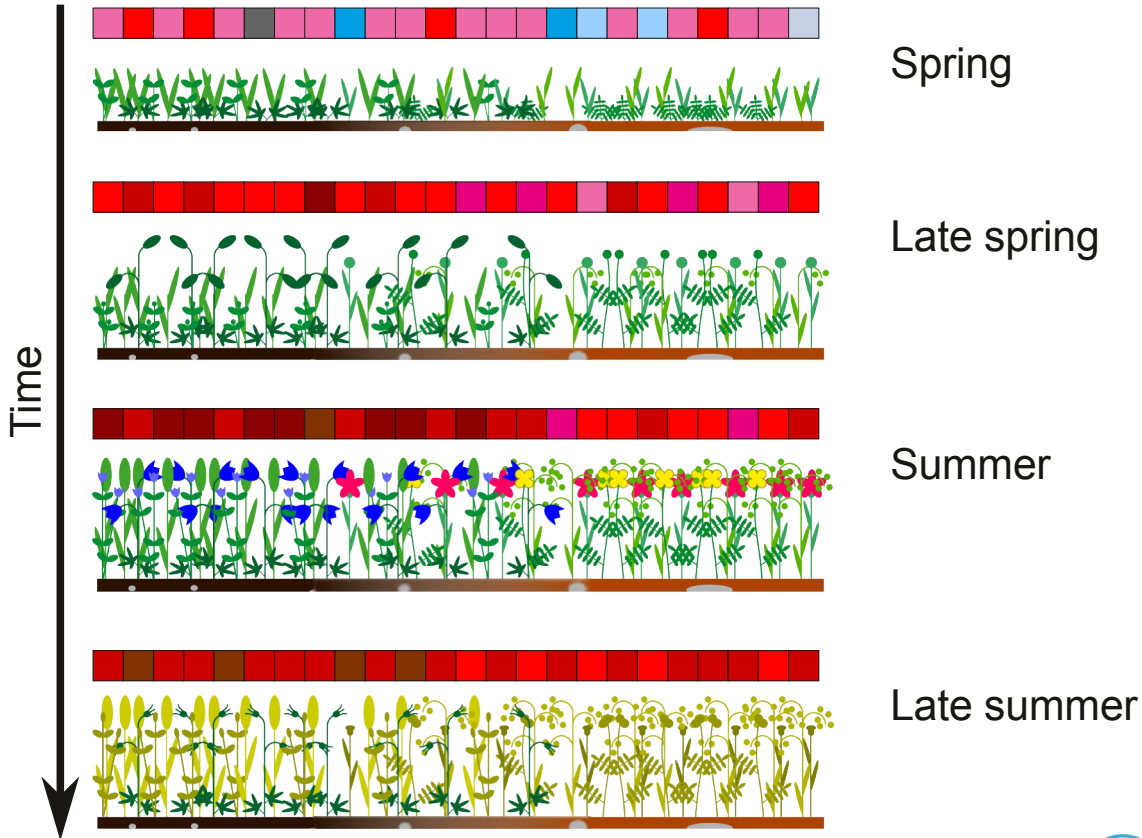
Most plants are green...



Seasonal changes

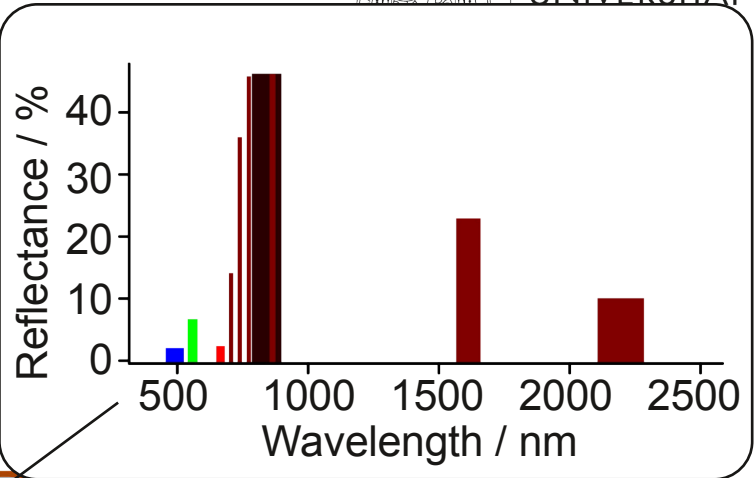
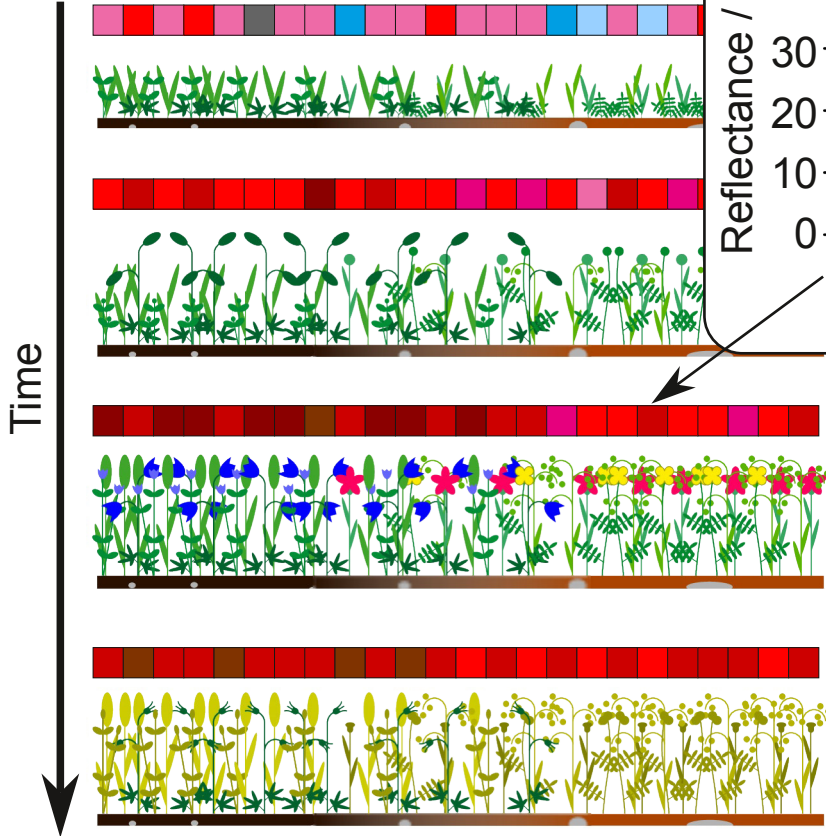


Seasonal changes



Multi-seasonal, multi-spectral data

Seasonal changes

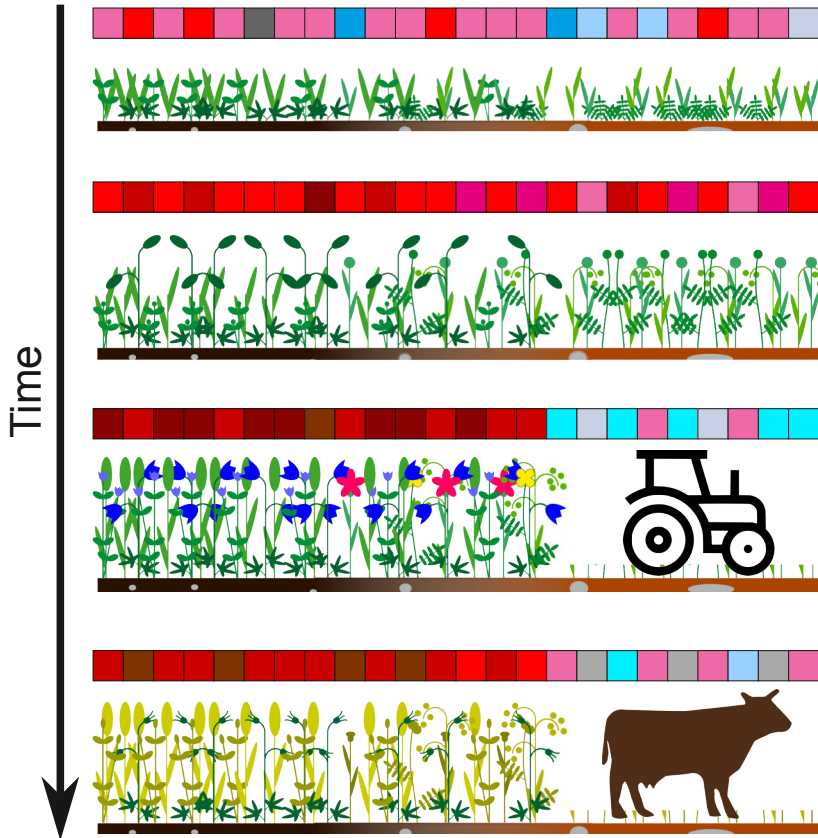


Summer

Late summer

Multi-seasonal, multi

Seasonal changes and land use



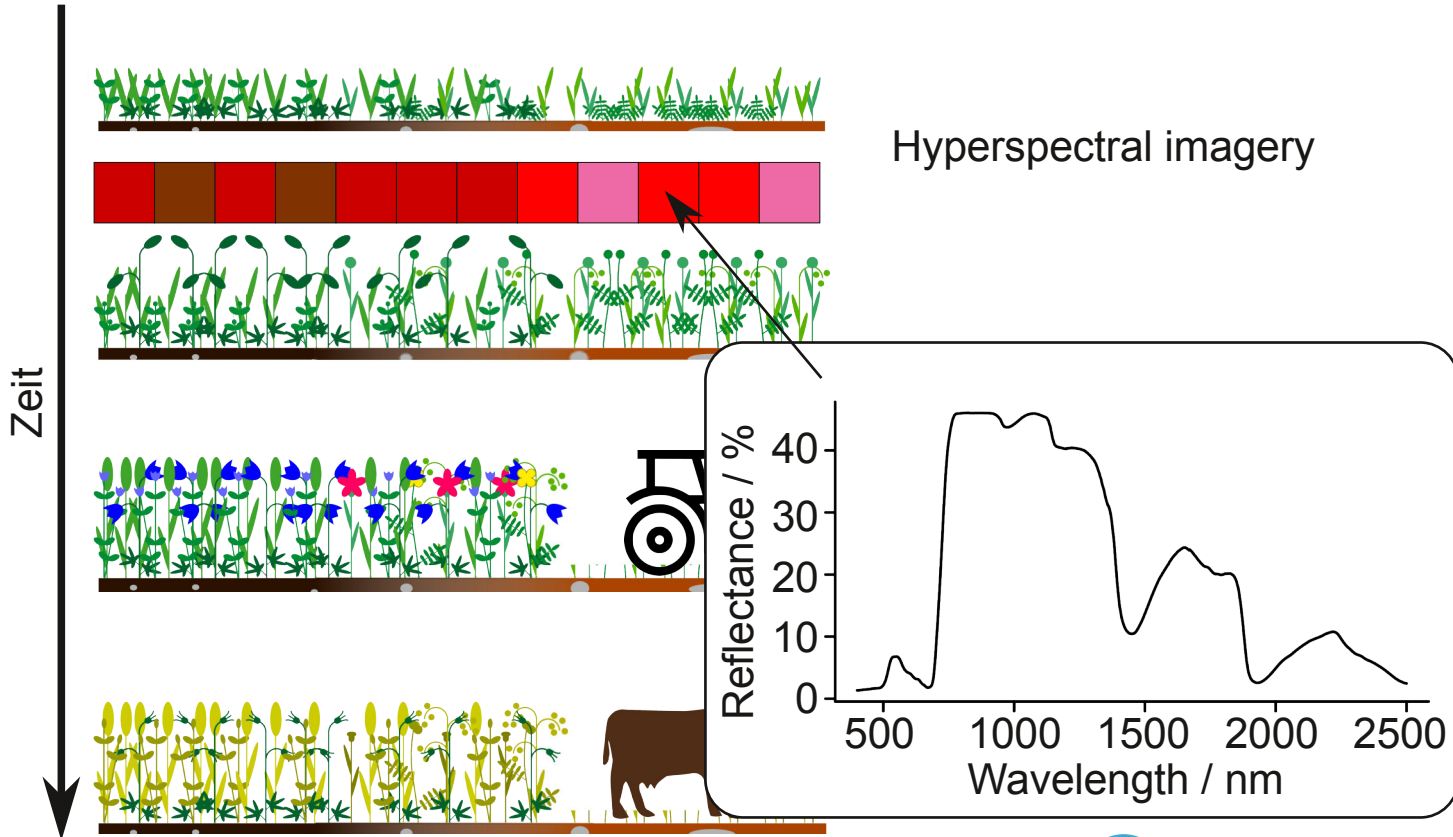
Spring

Late spring

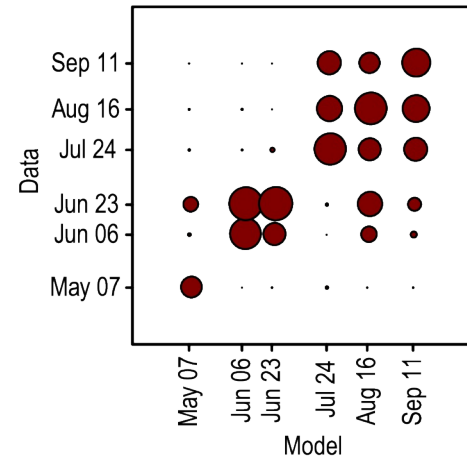
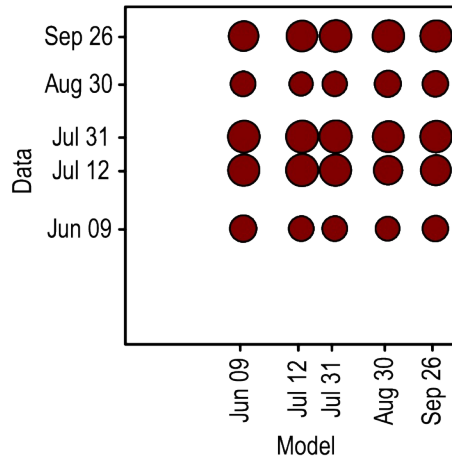
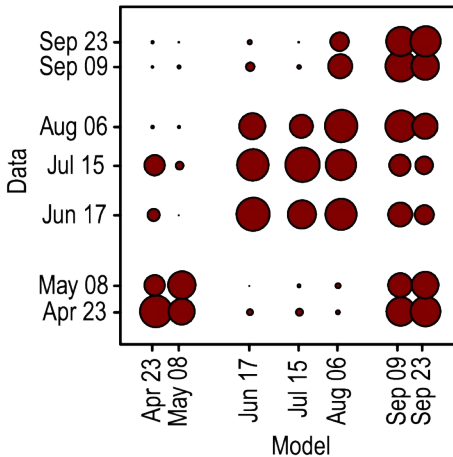
Summer

Late summer

Multi-seasonal, multi-spectral data



Transferability issues



Mean R² • 0.1 • 0.2 • 0.3 • 0.4 • 0.5 • 0.6 • 0.7 • 0.8

- **Field data are inevitable for model (re-)calibration and validation**
- Limited operationalization possibilities
 - Image data processing and normalization
 - Acquisition of *in-situ* data



- Field data are inevitable for model (re-) calibration and validation
- Limited operationalization possibilities
- Classification keys are not designed for remote sensing applications



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Int J Appl Earth Obs Geoinformation

journal homepage: www.elsevier.com/locate/jag



Adapting a Natura 2000 field guideline for a remote sensing-based assessment of heathland conservation status



Johannes Schmidt^{a,*}, Fabian Ewald Fassnacht^a, Christophe Neff^a, Angela Lausch^b, Birgit Kleinschmit^c, Michael Förster^c, Sebastian Schmidlein^a

- Field data are inevitable for model (re-) calibration and validation
- Limited operationalization possibilities
- Classification keys are not designed for remote sensing applications



What justifies the additional effort?

- Field data are inevitable for model (re-)calibration and validation
- Limited operationalization possibilities
- Classification keys are not designed for remote sensing applications



What justifies the additional effort?

- mapping of (really) remote and inaccessible areas



- **Field data are inevitable for model (re-)calibration and validation**
- Limited operationalization possibilities
- Classification keys are not designed for remote sensing applications



What justifies the additional effort?

- mapping of (really) remote and inaccessible areas
- **mapping of vegetation patterns that cannot be reliably assessed in conventional surveys**

Where to draw the line?



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Where to draw the line?



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Mapping gradual transitions



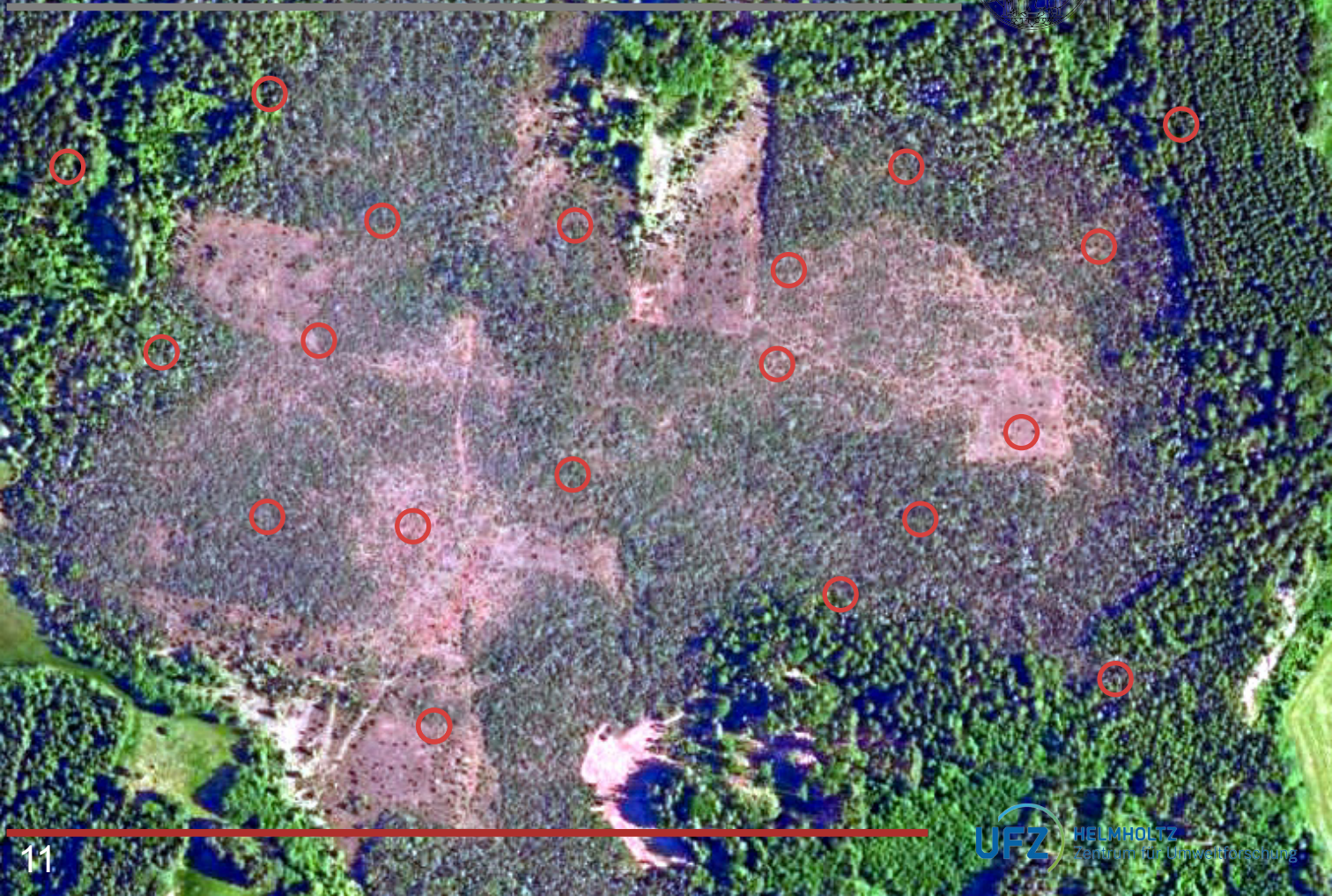
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Mapping gradual transitions



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Vegetation records



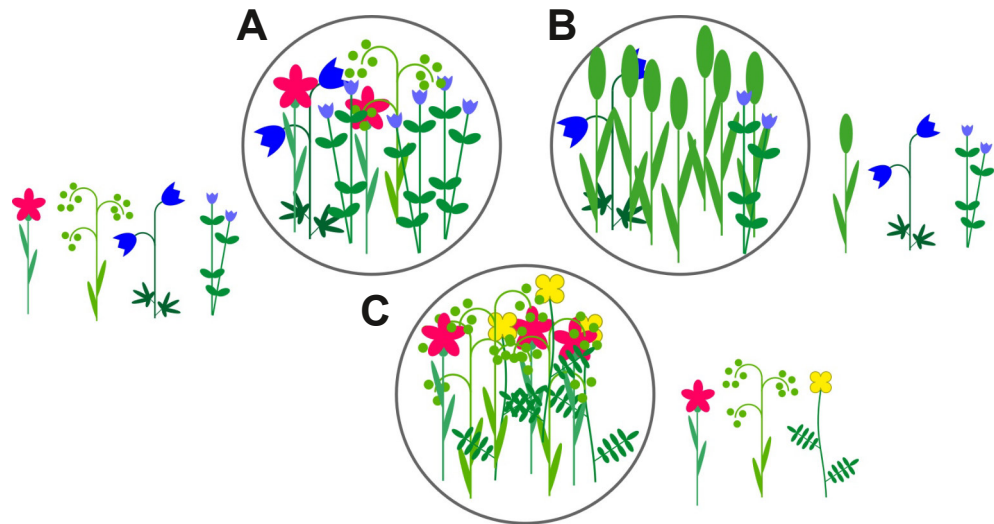
	<i>Primula.farinosa</i>	<i>Tofieldia.calyculata</i>	<i>Potentilla.erecta</i>	<i>Schoenus.ferrugineus</i>	<i>Ranunculus.bulbosus</i>	<i>Molinia.caerulea</i>	<i>Succisa.pratensis</i>	<i>Carex.flacca</i>	<i>Polygala.amarella</i>	<i>Eriophorum.latifolium</i>
p001	3	1	3	20	10	8	8	2	2	1
p002	5	1	3	25	0	3	0	3	1	0
p003	5	2	5	15	2	5	7	2	1	5
p004	0	0	4	0	0	5	4	5	2	0
p005	0	0	5	0	0	4	4	5	1	0
p006	2	0	2	0	0	0	15	3	2	0
p007	0	0	0	2	0	0	0	0	0	0
p008	0	0	5	10	0	0	0	2	2	0
p009	1	0	7	8	0	0	0	25	2	0
p010	0	0	6	0	0	0	0	25	2	0
p011	0	0	0	0	0	3	0	5	0	0
p012	3	0	3	0	0	20	0	15	1	1
p013	0	0	3	0	3	5	0	3	2	0
p014	0	0	3	0	0	3	0	0	3	0

Mapping gradual transitions



Grasleiten



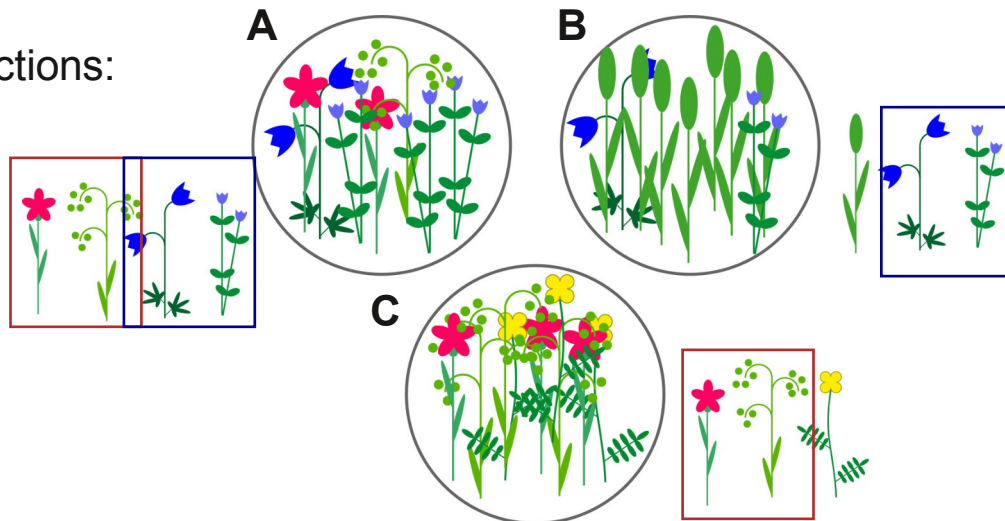


A/B: 2 common species
A/C: 2 common species
B/C: 0 common species

or, including cover fractions:

Dissimilarity

	A	B
B	0.750	
C	0.625	1.000



A/B: 2 common species

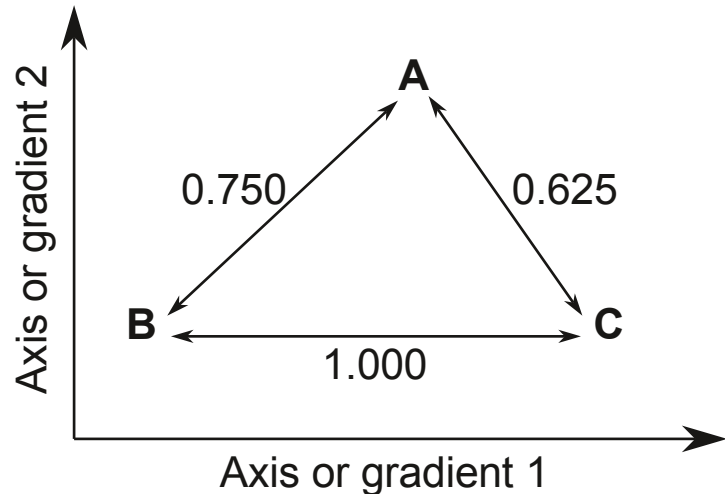
A/C: 2 common species

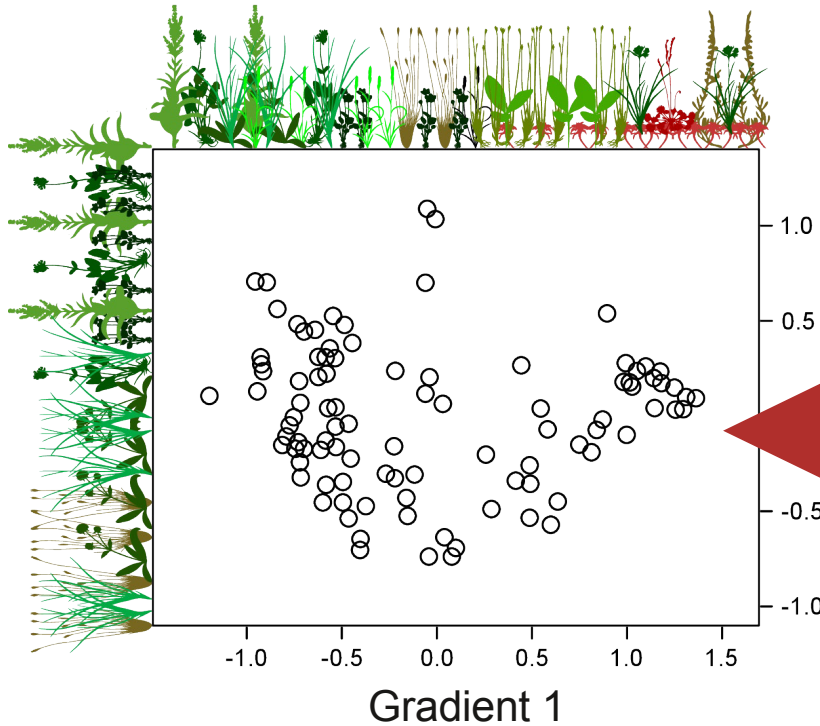
B/C: 0 common species

or, including cover fractions:

Dissimilarity

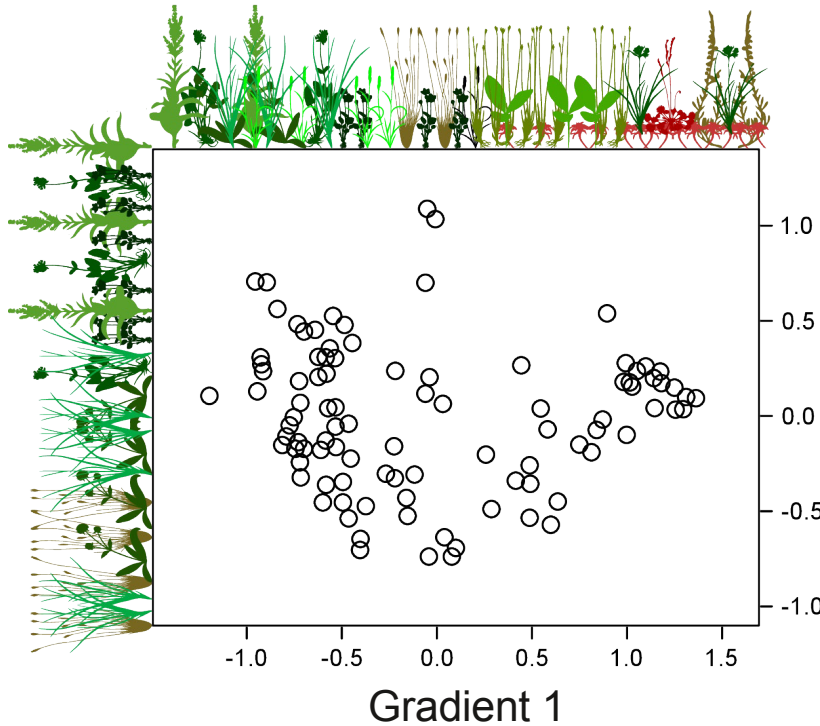
	A	B
B	0.750	
C	0.625	1.000





Vegetationsaufnahmen

	<i>Primula.farinosa</i>	<i>Tofieldia.calyculata</i>	<i>Potentilla.erecta</i>	<i>Schoenus.ferrugineus</i>	<i>Ranunculus.bulbosus</i>	<i>Molinia.caerulea</i>	<i>Succisa.pratensis</i>	<i>Carex.flacca</i>	<i>Polygala.amarella</i>	<i>Eriophorum.latifolium</i>
p001	3	1	3	20	10	8	8	2	2	1
p002	5	1	3	25	0	3	0	3	1	1
p003	5	2	5	15	2	5	7	2	1	1
p004	0	0	4	0	0	5	4	5	2	1
p005	0	0	5	0	0	4	4	5	1	1
p006	2	0	2	0	0	0	15	3	2	1
p007	0	0	0	2	0	0	0	0	0	1
p008	0	0	5	10	0	0	0	2	2	1
p009	1	0	7	8	0	0	0	25	2	1
p010	0	0	6	0	0	0	0	25	2	1
p011	0	0	0	0	0	3	0	5	0	1
p012	3	0	3	0	0	20	0	15	1	1
p013	0	0	3	0	3	5	0	3	2	1
p014	0	0	3	0	0	3	0	0	3	1



*Veratrum
album*



*Betonica
officinalis*



*Succisa
pratensis*

*Anthoxanthum
odoratum*



*Trichophorum
caespitosum*

*Eriophorum
vaginatum*



*Sphagnum
div. spec.*



*Calluna
vulgaris*



*Drosera
rotundifolia*



*Menyanthes
trifoliata*



*Schoenus
ferrugineus*

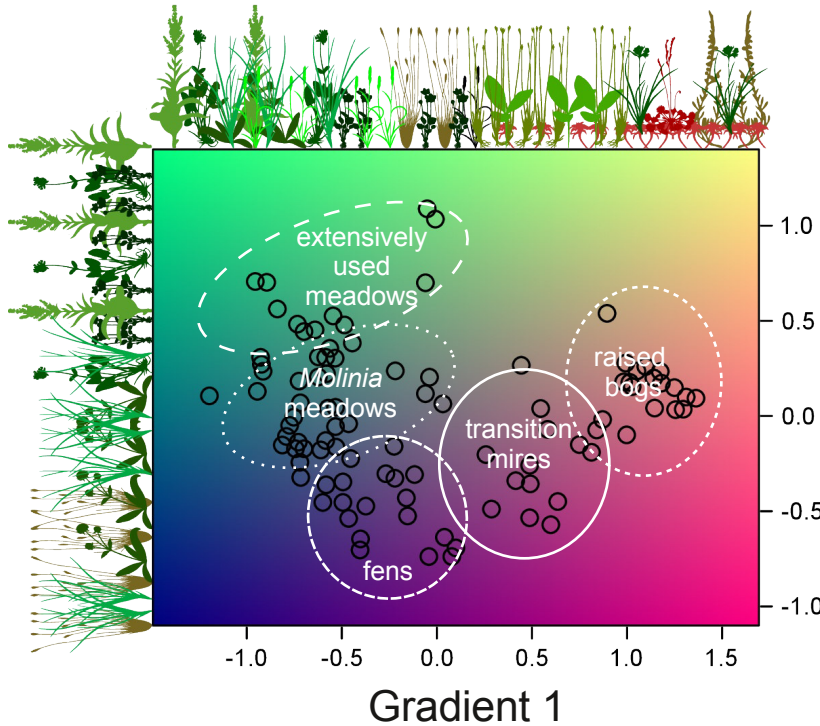


*Parnassia
palustris*



*Carex
div. spec.*

Gradient analysis



Veratrum album



Betonica officinalis



Succisa pratensis

Anthoxanthum odoratum



Trichophorum caespitosum

Eriophorum vaginatum



Sphagnum div. spec.



Calluna vulgaris



Drosera rotundifolia



Menyanthes trifoliata



Schoenus ferrugineus



Parnassia palustris



Carex div. spec.

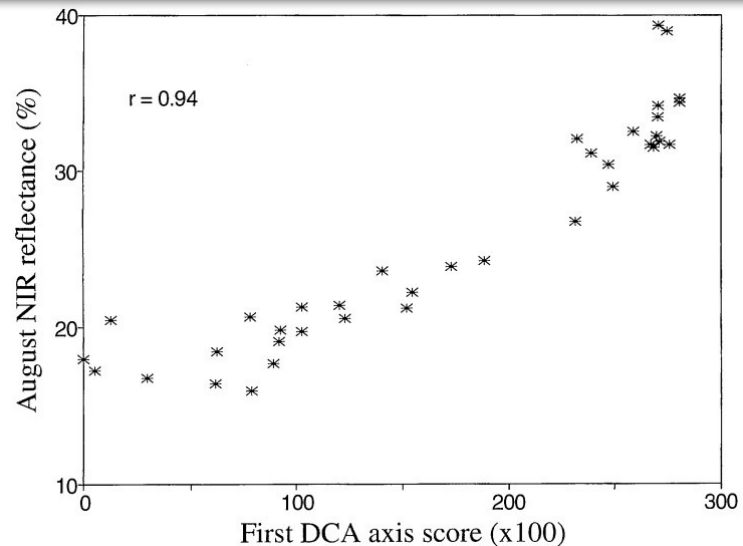
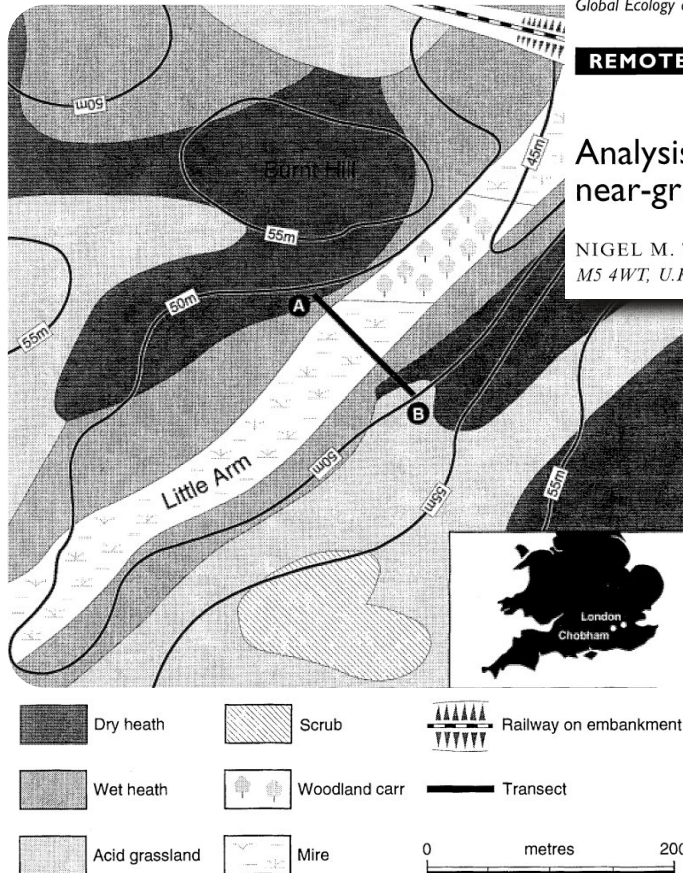


Global Ecology and Biogeography Letters (1996) 5, 206–216

REMOTE SENSING SPECIAL ISSUE

Analysis and representation of heathland vegetation from near-ground level remotely-sensed data

NIGEL M. TRODD* *Telford Institute of Environmental Systems, University of Salford, Manchester M5 4WT, U.K.*





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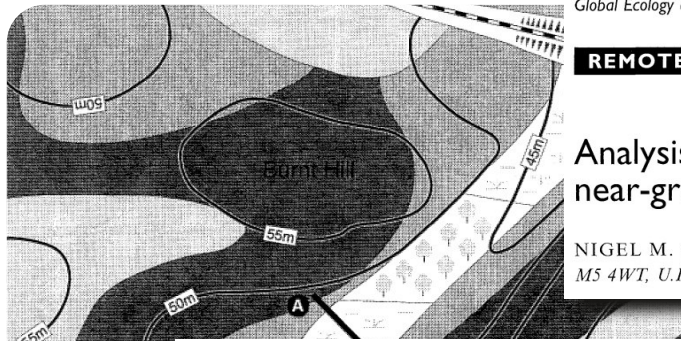
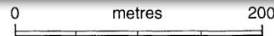
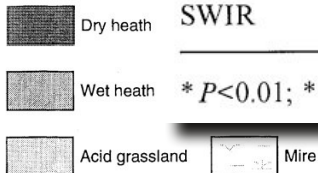
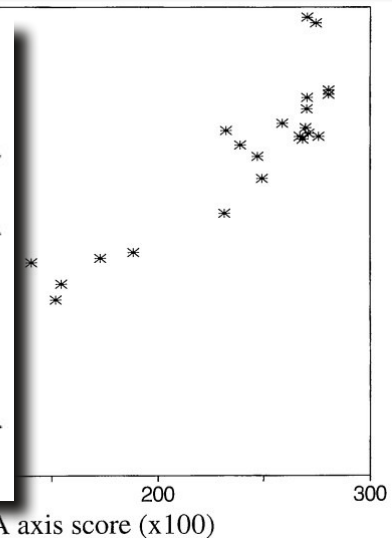


Table 2. Spearman rank correlation coefficients between bidirectional reflectance and scores on the first DCA axis of the vegetation data.

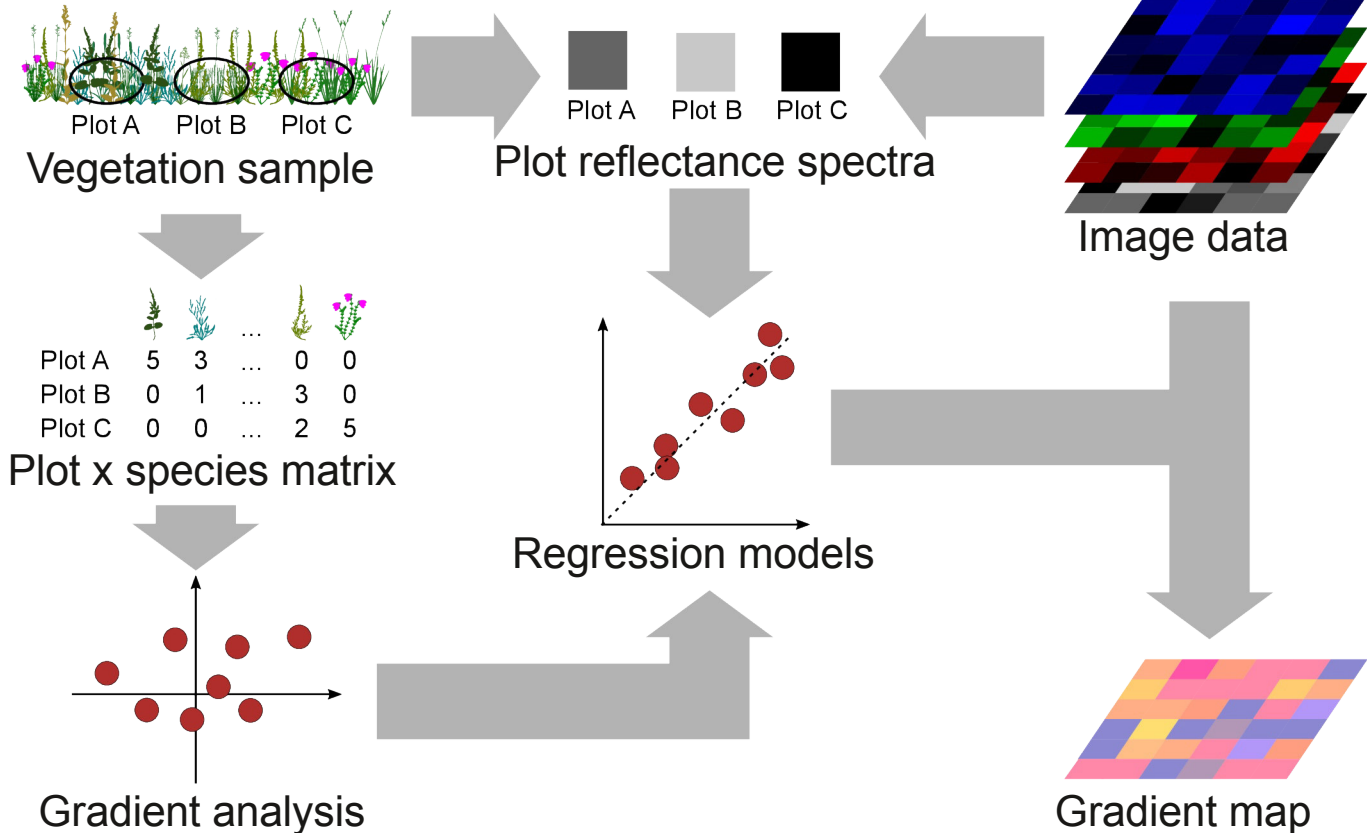
	May	August
Green	0.92**	0.48*
Red	0.91**	-0.09
NIR	0.87**	0.94**
SWIR	0.90**	0.82**

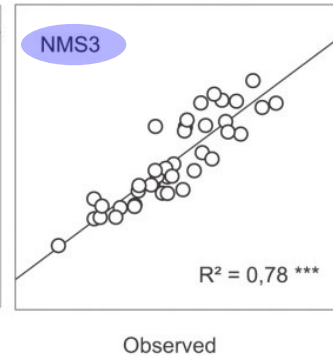
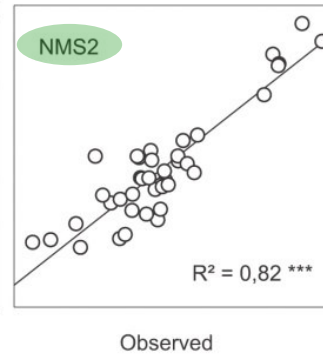
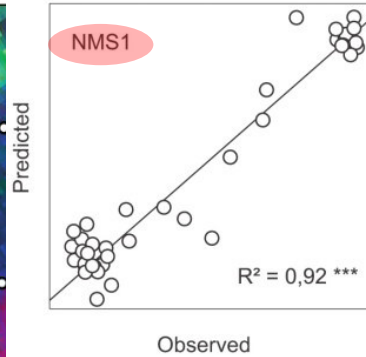
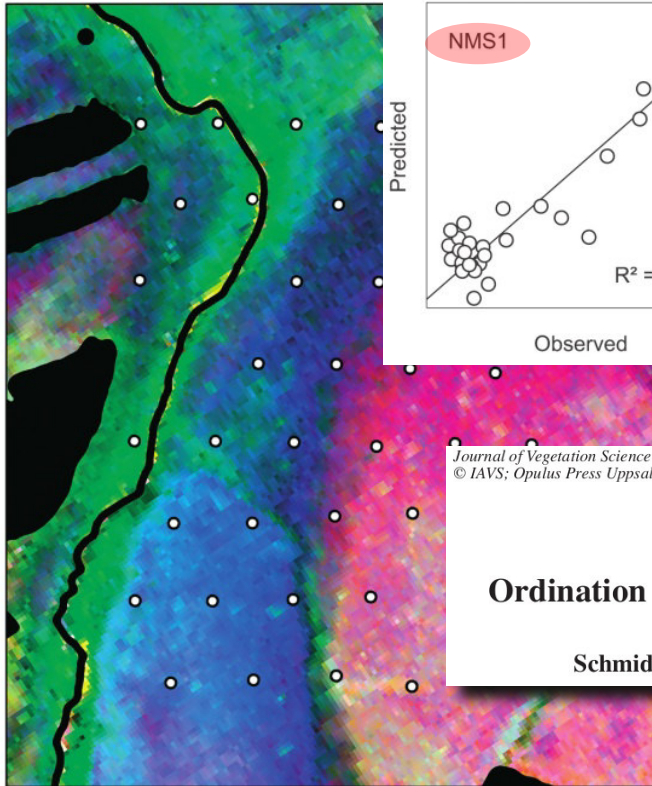
* $P < 0.01$; ** $P < 0.001$.



First DCA axis score (x100)

The modern work flow





Journal of Vegetation Science 18: 131-140, 2007
© IAVS; Opulus Press Uppsala.

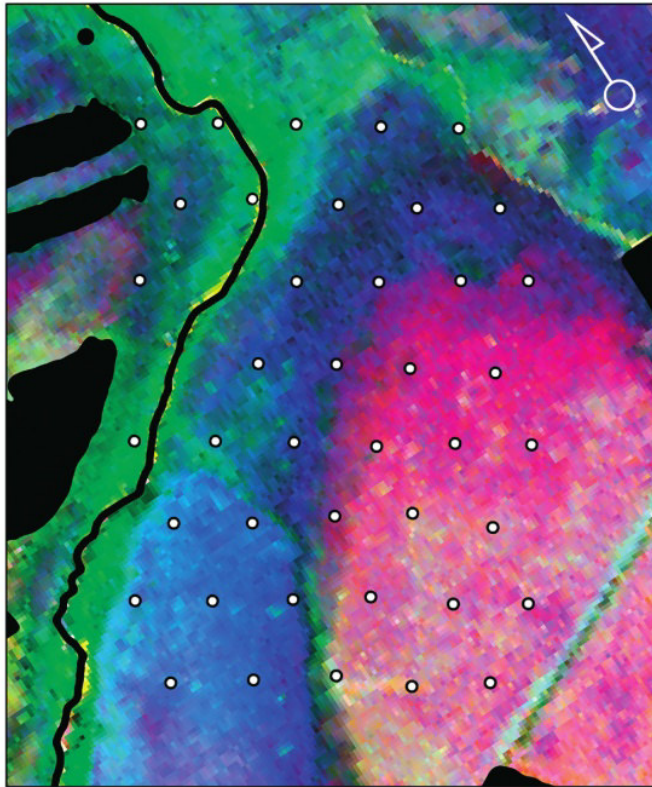
131

Mapping the floristic continuum: Ordination space position estimated from imaging spectroscopy

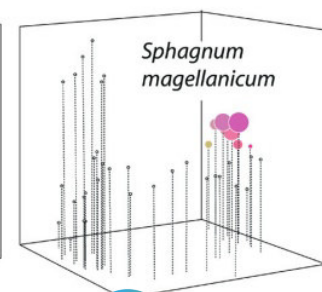
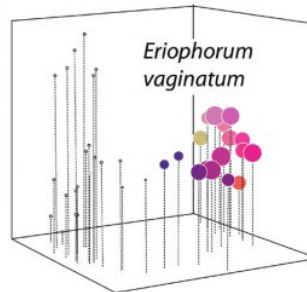
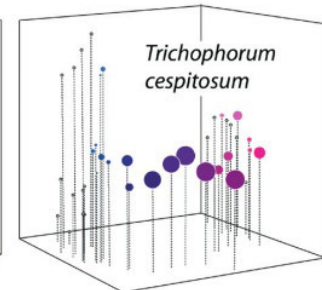
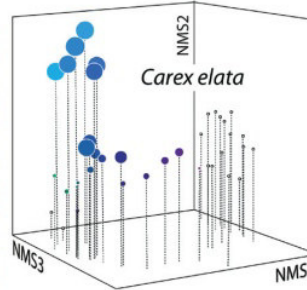
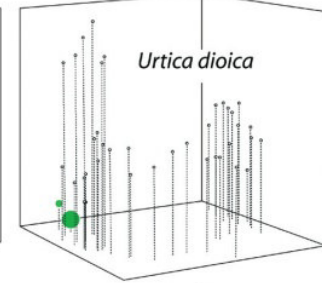
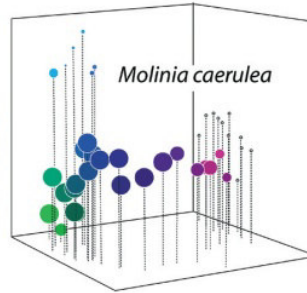
Schmidtlein, S.^{1,2*}; Zimmermann, P.¹; Schüpferling, R.¹ & Weiß, C.³

0 200 400 m

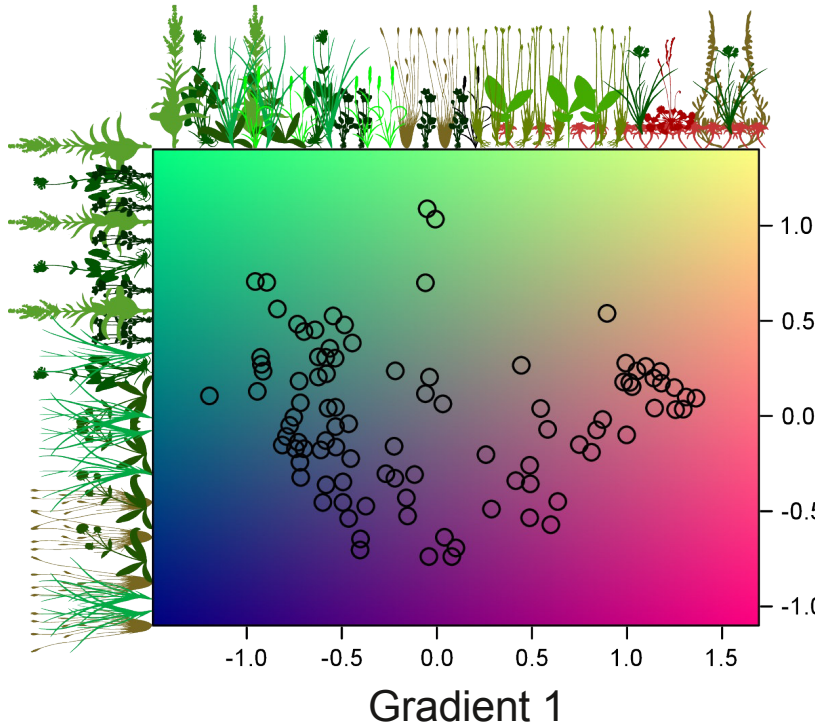
The modern work flow



0 200 400 m



The gradient map



*Veratrum
album*



*Betonica
officinalis*



*Succisa
pratensis*

*Anthoxanthum
odoratum*



*Trichophorum
caespitosum*

*Eriophorum
vaginatum*



*Sphagnum
div. spec.*



*Calluna
vulgaris*



*Drosera
rotundifolia*



*Menyanthes
trifoliata*



*Schoenus
ferrugineus*



*Parnassia
palustris*



*Carex
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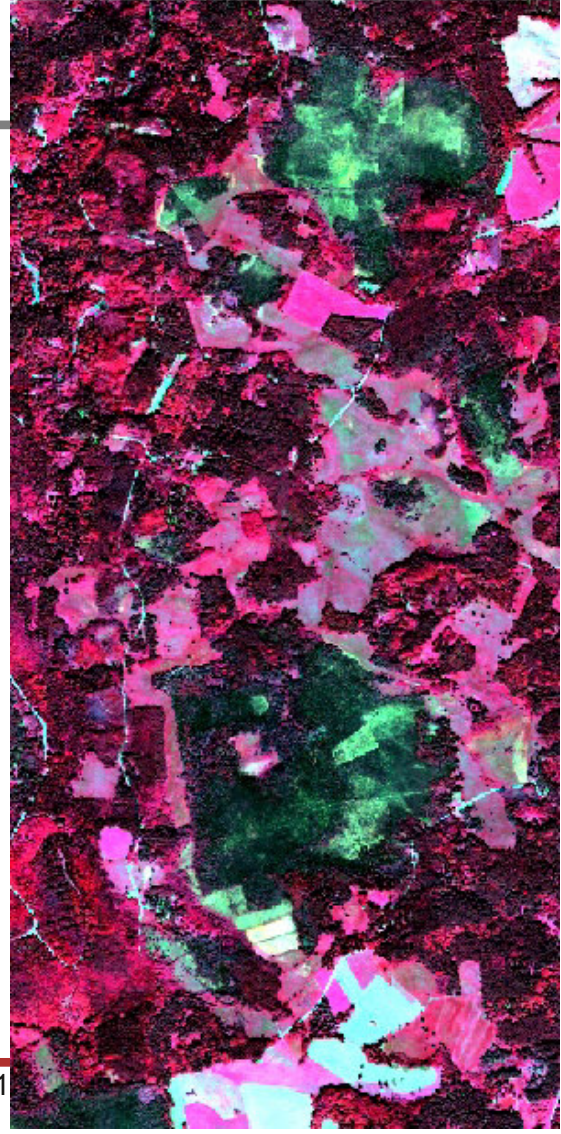
The gradient map

Image data

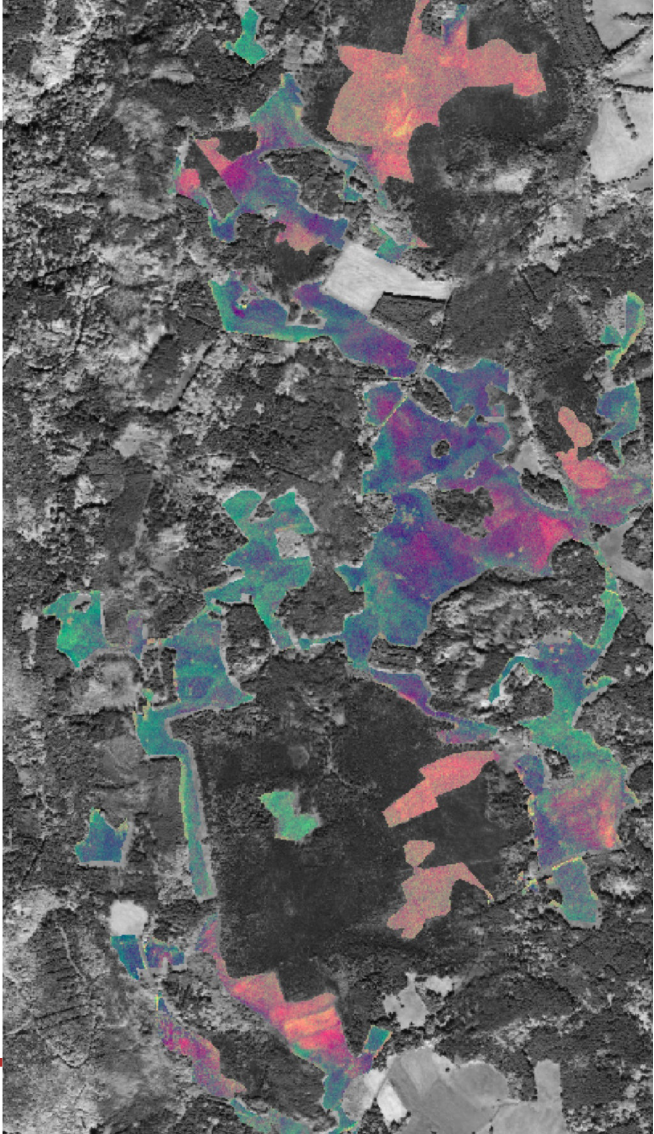
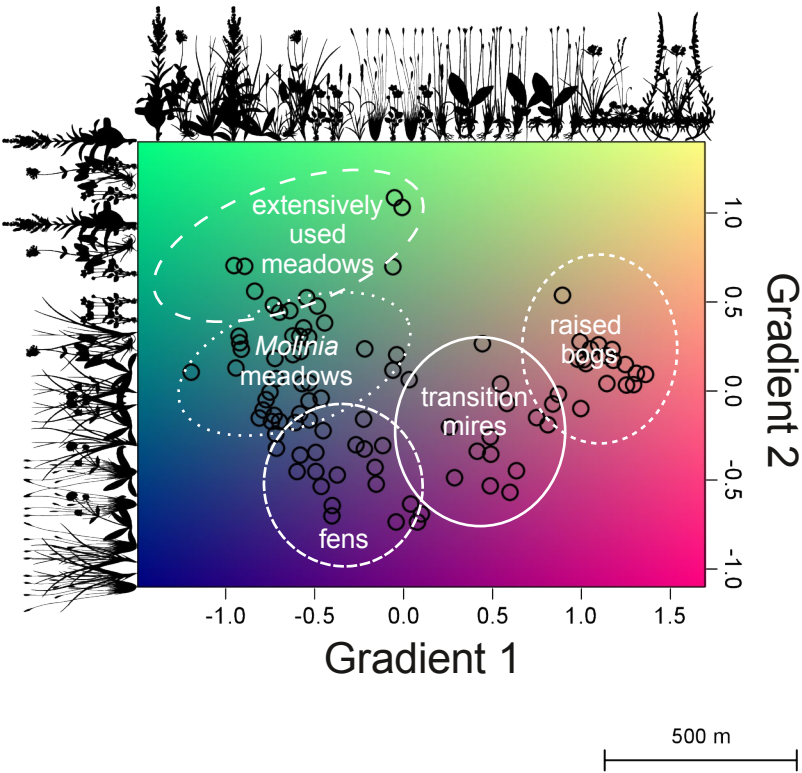
- AISA Dual
- Airborne
- Operator: UFZ

- 267 spectral bands
- 400 - 2500 nm
- 2 m x 2 m spatial resolution

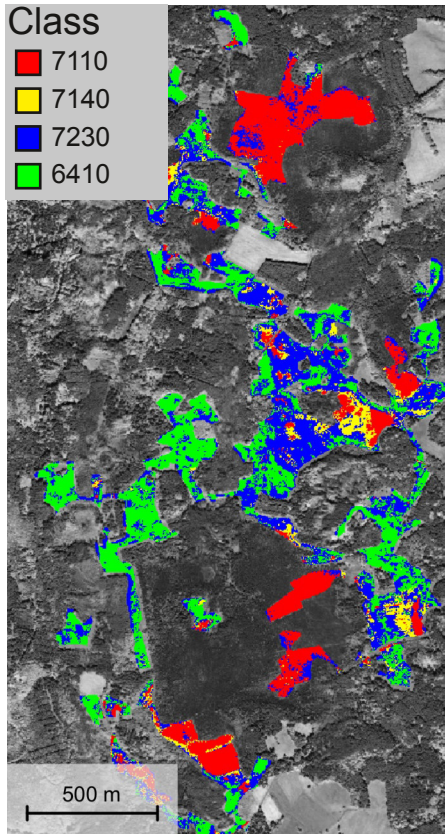
250 m
|-----|



The gradient map

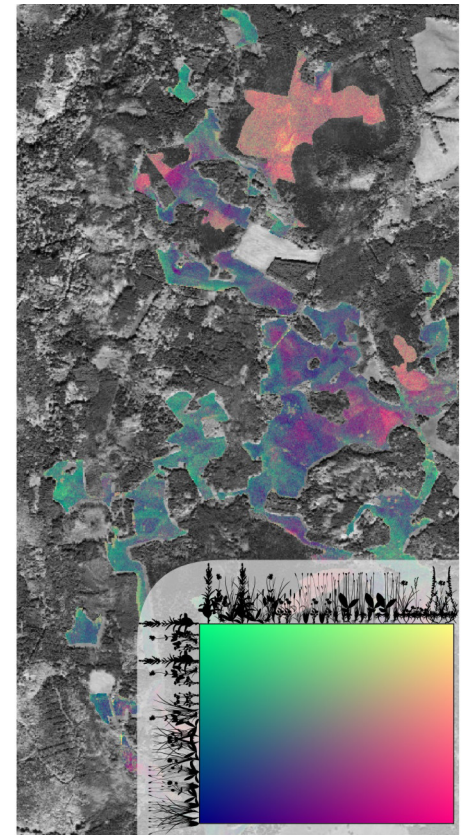


Hard classification



- 😊 Fuzziness of natural vegetation is preserved
- 😊 Even subtle differences become visible
- 😐 Data driven description
- 😞 No (first hand) area statistics

Gradient map



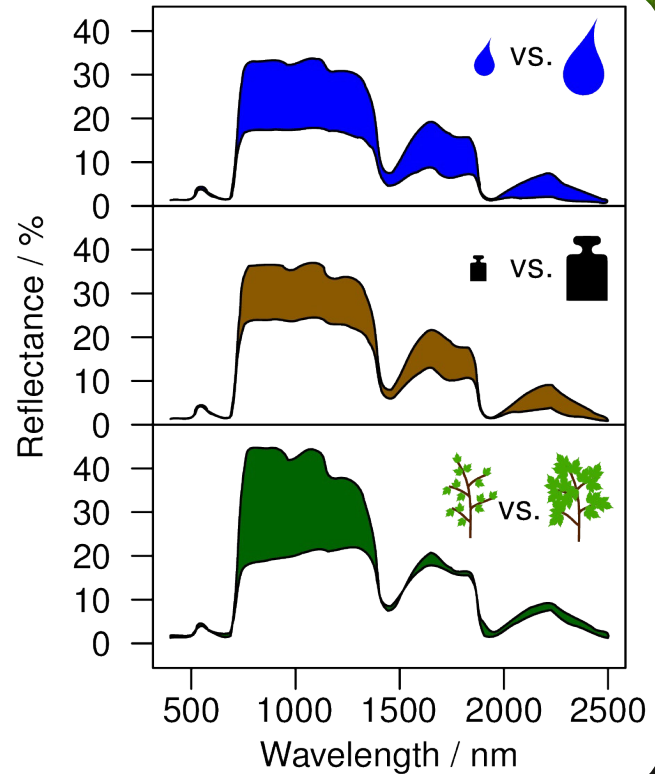
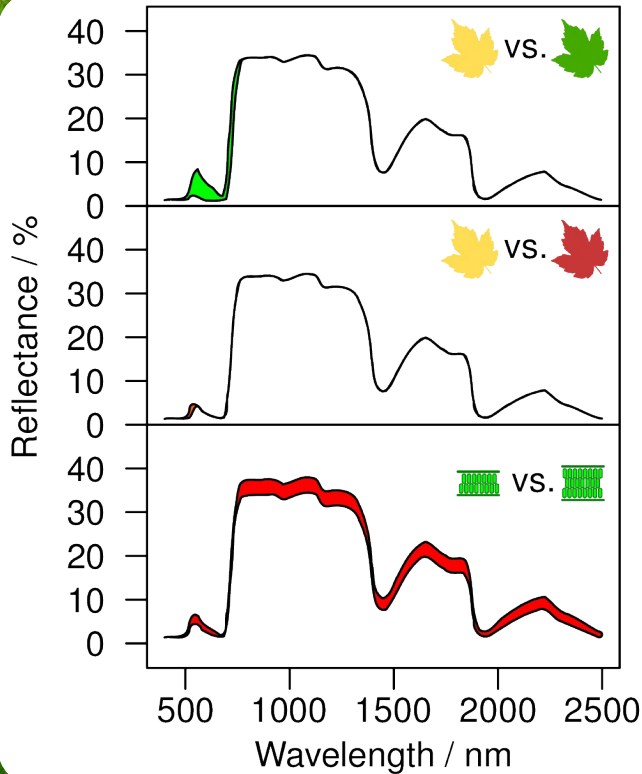
Why can we map the gradients?



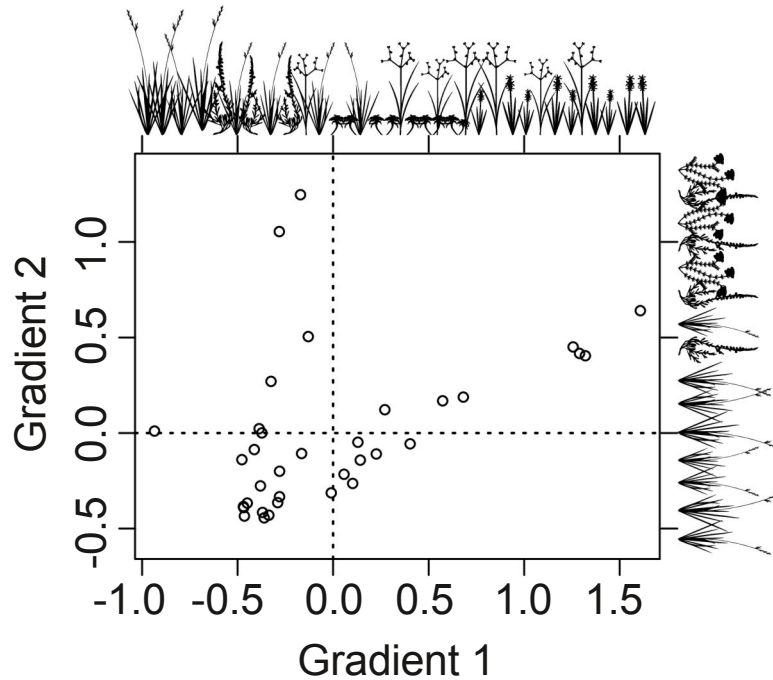
Most plants are green...



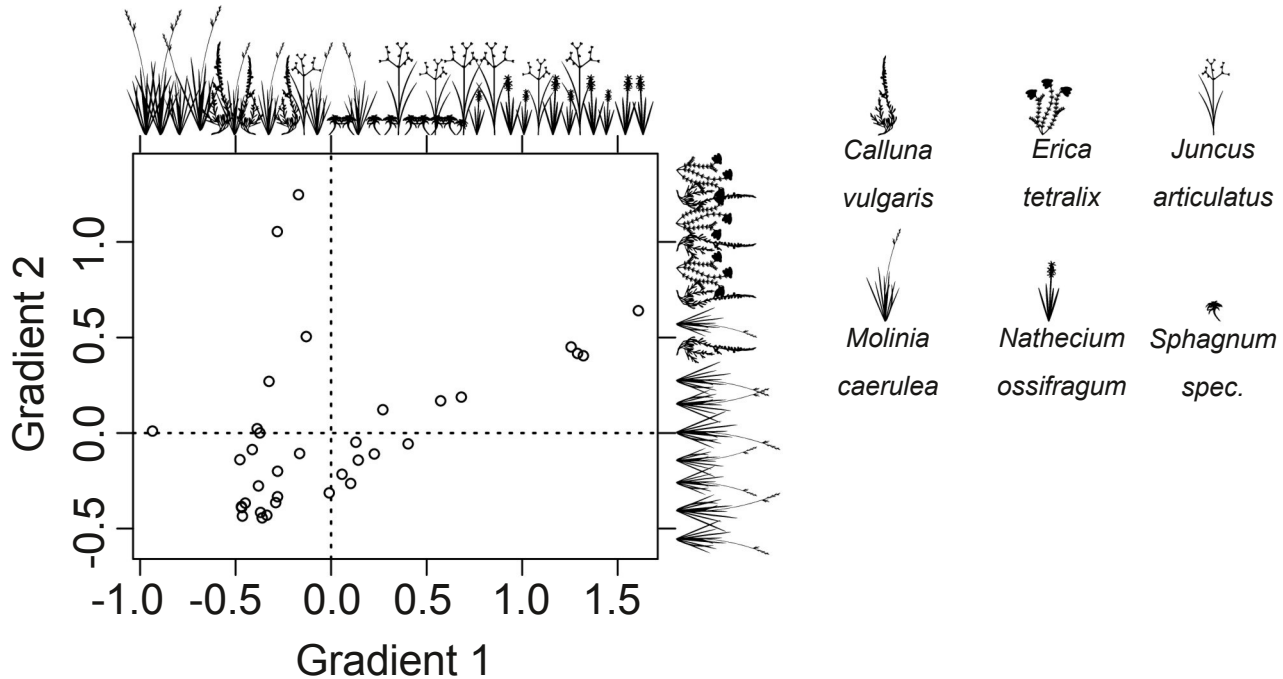
Why can we map the gradients?



Why can we map the gradients?



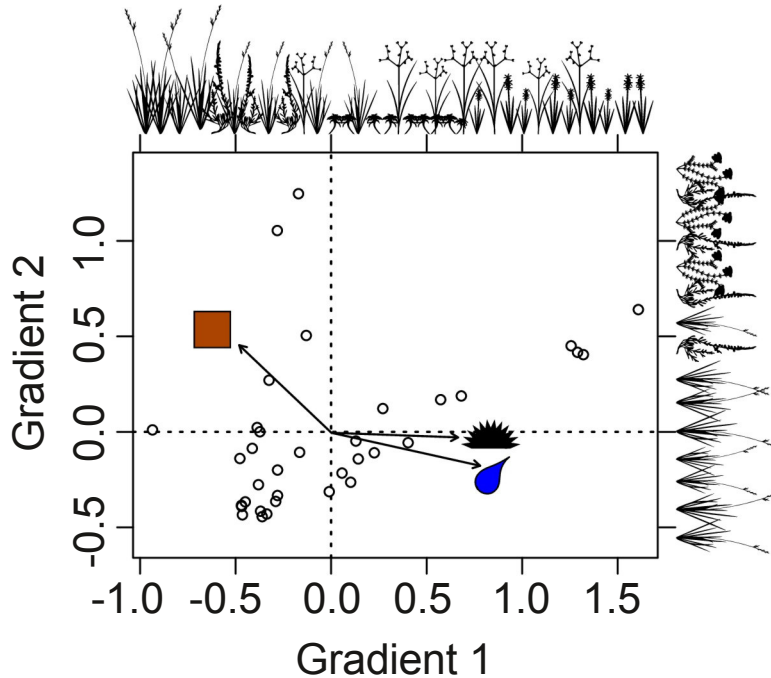
Why can we map the gradients?



Why can we map the gradients?



Jul 2nd



- | | | |
|-------------------------|-----------------------------|---------------------------|
| | | |
| <i>Calluna vulgaris</i> | <i>Erica tetralix</i> | <i>Juncus articulatus</i> |
| | | |
| <i>Molinia caerulea</i> | <i>Nathecium ossifragum</i> | <i>Sphagnum spec.</i> |

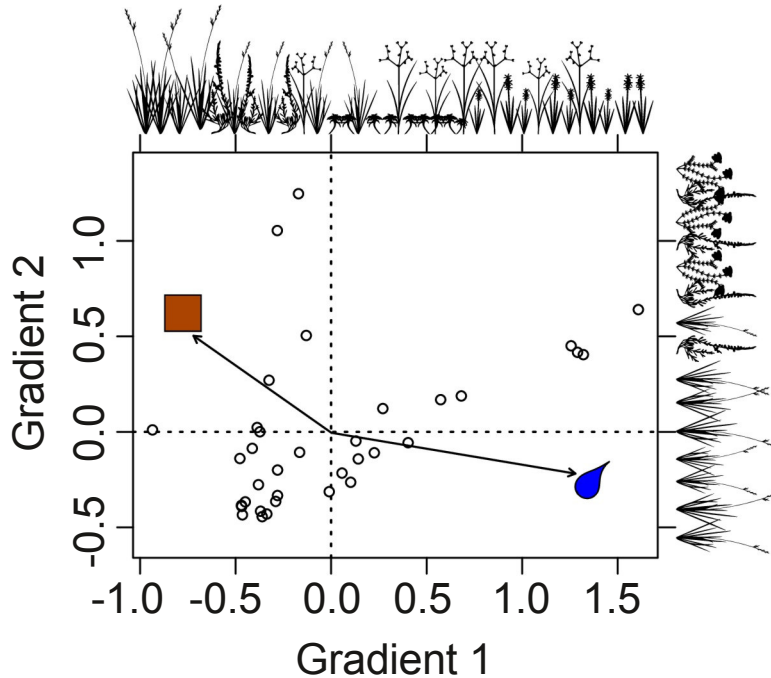
Significant correlations
($p < 0.01$)







- Chl_{ab}
 ▲ Car
 ■ Cbrown
 💧 Water
 ■ LMA
 N N
 LAI
 ALA

Why can we map the gradients?



Jul 30th



 <i>Calluna vulgaris</i>	 <i>Erica tetralix</i>	 <i>Juncus articulatus</i>
 <i>Molinia caerulea</i>	 <i>Nathecium ossifragum</i>	 <i>Sphagnum spec.</i>

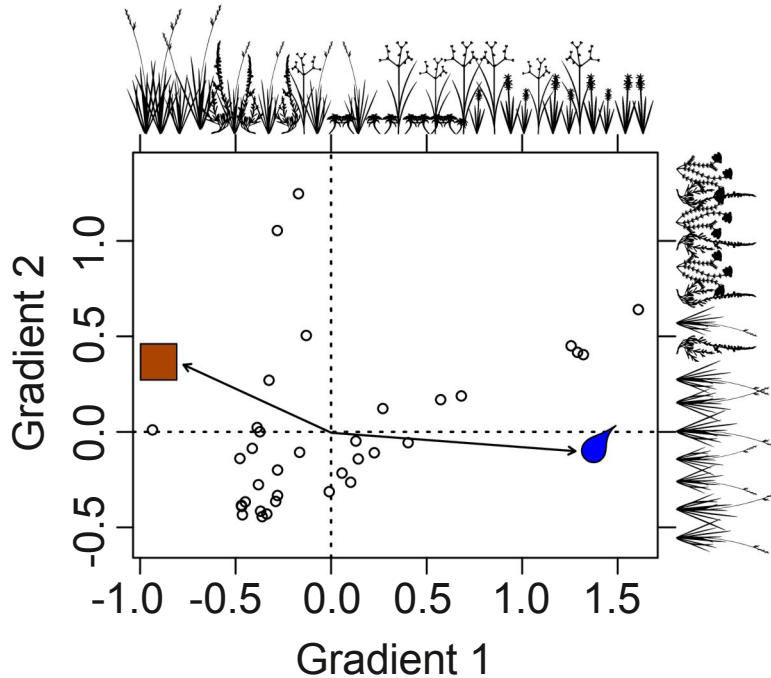
Significant correlations
($p < 0.01$)

● Chl_{ab}
▲ Car
 ■ Cbrown
 💧 Water
 🧴 LMA
 N N
 🍃 LAI
 ☀️ ALA

Why can we map the gradients?



Aug 29th



- | | | |
|-----------------------------|---------------------------------|-------------------------------|
| | | |
| <i>Calluna
vulgaris</i> | <i>Erica
tetralix</i> | <i>Juncus
articulatus</i> |
| | | |
| <i>Molinia
caerulea</i> | <i>Nathecium
ossifragum</i> | <i>Sphagnum
spec.</i> |

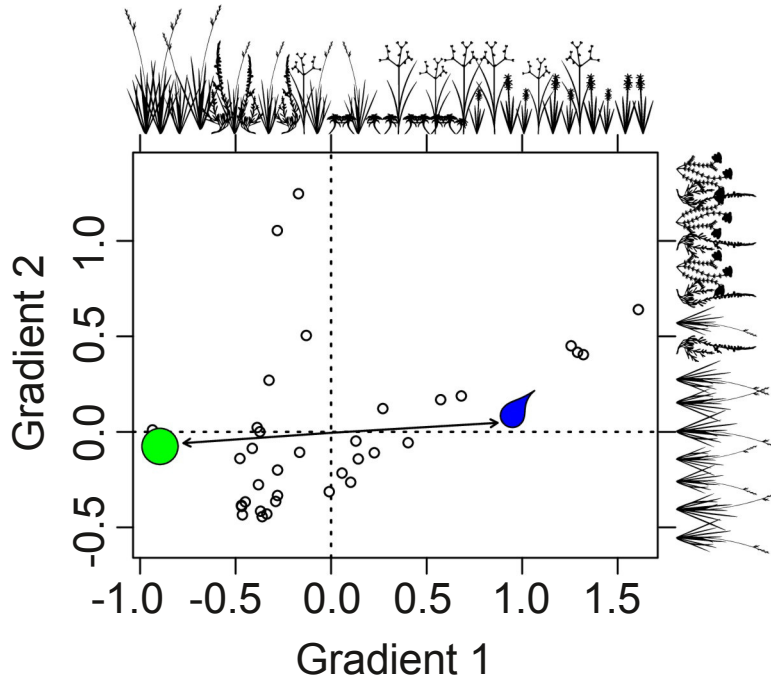
Significant correlations
($p < 0.01$)

- Chl_{ab}
▲ Car
 ■ Cbrown
 ◐ Water
 ■ LMA
 N N
 ■ LAI
 ■ ALA

Why can we map the gradients?



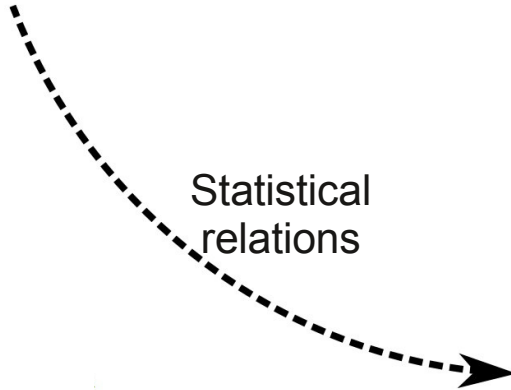
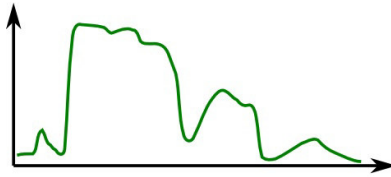
Sep 25th



Significant correlations
($p < 0.01$)

● Chl_{ab} ▲ Car ■ Cbrown ● Water ♪ LMA N N 🍃 LAI 🌞 ALA

Ways towards new data products?

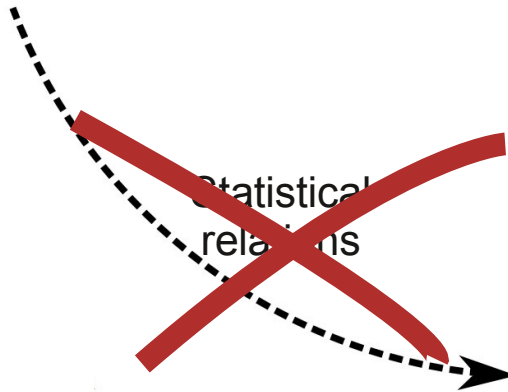
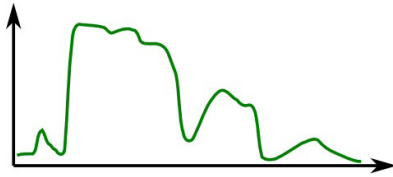


Statistical
relations



Vegetation
patterns

Ways towards new data products?



Statistical
relations

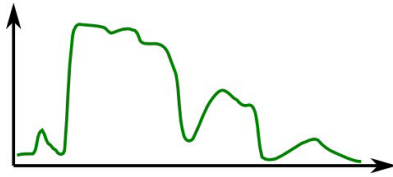


Vegetation
patterns

Ways towards new data products?



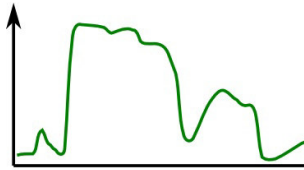
Translate the spectral reflectance space into the optical trait space to generate robust and meaningful biodiversity indicators



Trait data products

Vegetation
patterns

Translate the spectral reflectance space into the optical trait space to generate robust and meaningful biodiversity indicators



PERSPECTIVE

<https://doi.org/10.1038/s41559-021-01451-x>

nature
ecology & evolution

Check for updates

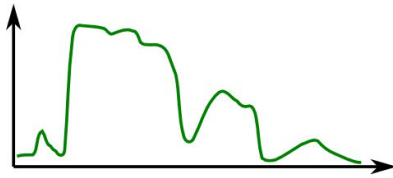
Priority list of biodiversity metrics to observe from space

Andrew K. Skidmore^{1,2,3}, Nicholas C. Coops³, Elnaz Neinavaz¹, Abebe Ali^{1,4}, Michael E. Schaepman⁵, Marc Paganini⁶, W. Daniel Kissling⁷, Petteri Vihervaara⁸, Roshanak Darvishzadeh¹, Hannes Feilhauer^{9,10}, Miguel Fernandez^{11,12}, Néstor Fernández^{13,14}, Noel Gorelick¹⁵, Ilse Geizendorffer¹⁶, Uta Heiden¹⁷, Marco Heurich^{18,19}, Donald Hobern²⁰, Stefanie Holzwarth¹⁷, Frank E. Muller-Karger²¹, Ruben Van De Kerchove²², Angela Lausch^{23,24}, Pedro J. Leitão^{25,26}, Marcelle C. Lock^{1,2}, Caspar A. Mürger²⁷, Brian O'Connor²⁸, Duccio Rocchini^{29,30}, Claudia Roeoesli⁵, Woody Turner³¹, Jan Kees Vis³², Tiejun Wang¹, Martin Wegmann³³ and Vladimir Wingate³⁴



Trait data products

Vegetation patterns



Translate the spectral reflectance space into the optical trait space to generate robust and meaningful biodiversity indicators

- Which parameters/traits are actually meaningful biodiversity indicators?
- How can these parameters be robustly and accurately retrieved across multiple scales?
- Are these indicators sensitive to ecosystem changes?



Trait data products



Vegetation
patterns

Thank you for your attention!

