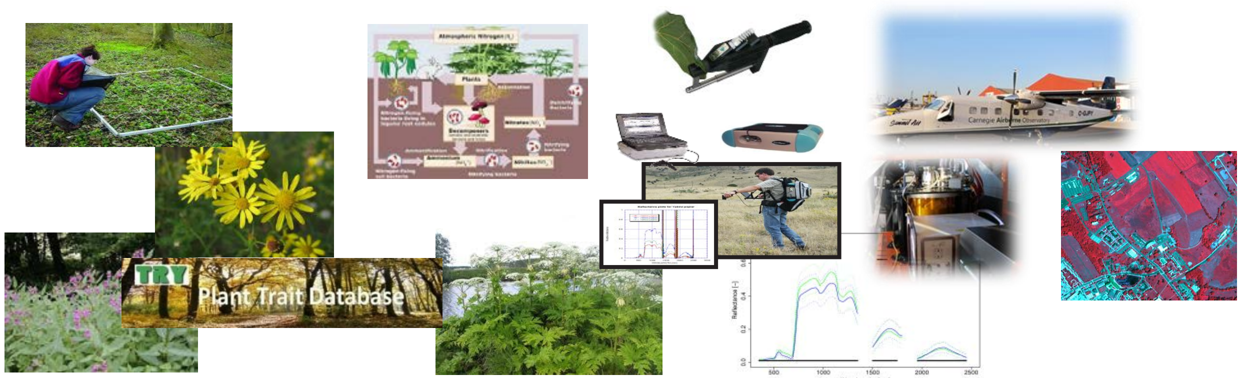
INPLANT

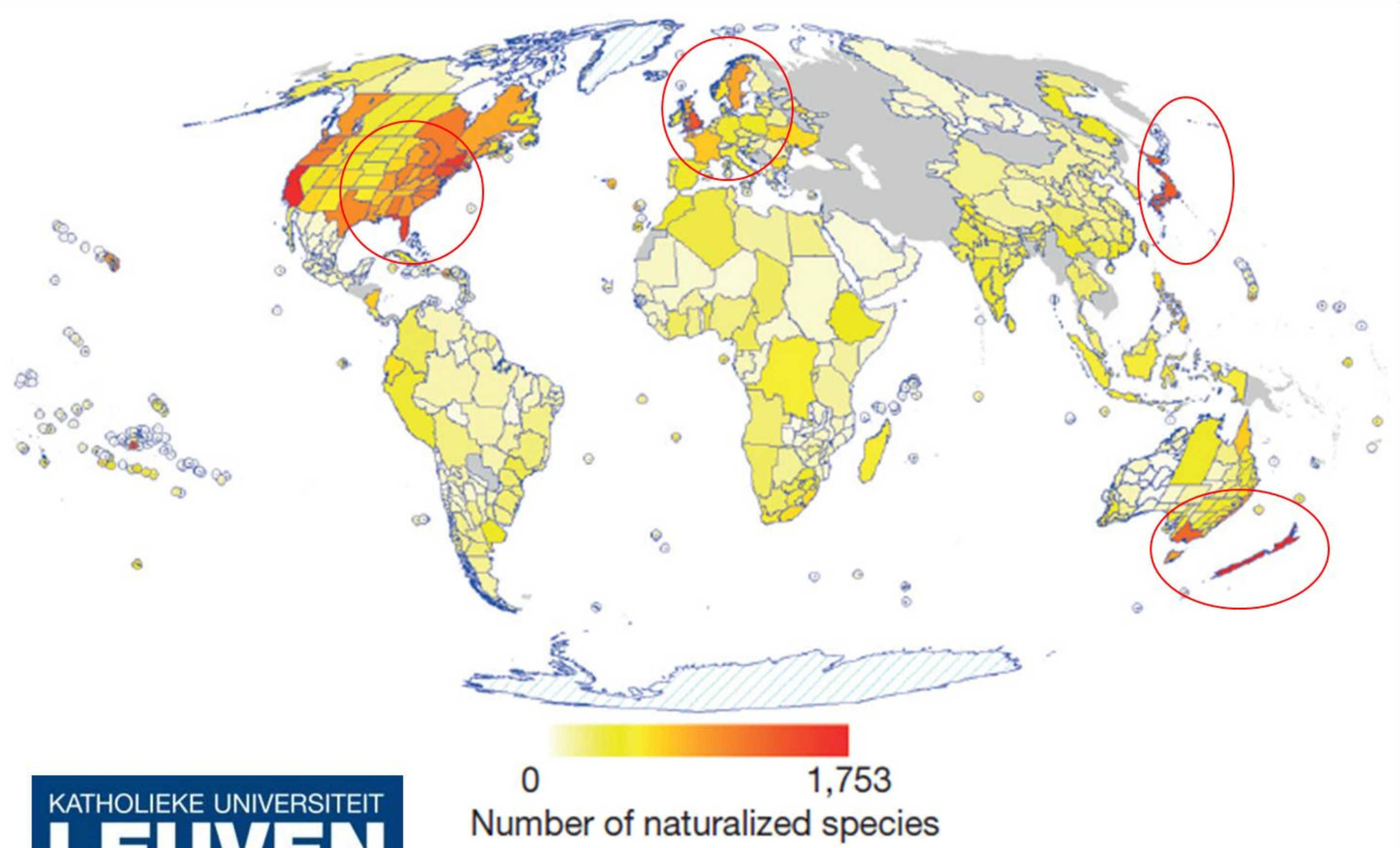
PLANT OPTICAL TYPES TO PREDICT ECOSYSTEM IMPACTS OF PLANT INVASIONS



Elisa Van Cleemput, Hannes Feilhauer, Olivier Honnay, Ben Somers

28 NOVEMBER 2019

Invasives are a major problem : Currently 13,000 plant species (3.9% of the extant flora) have become naturalized somewhere as a result of human activity

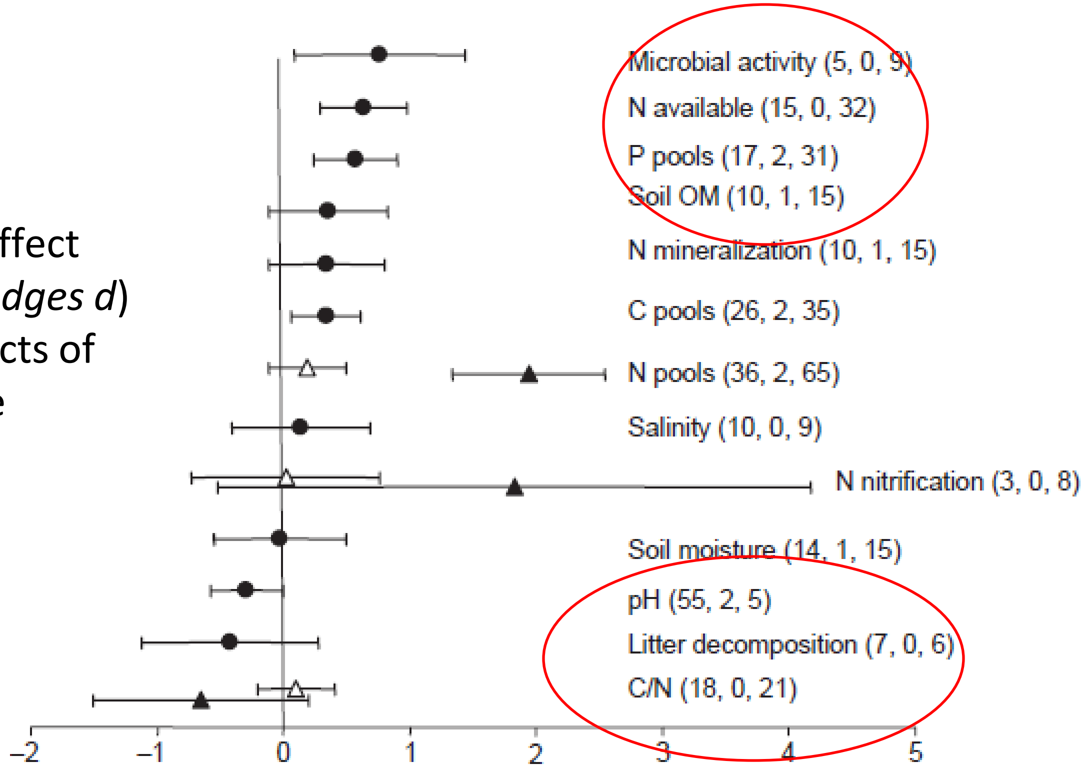


KATHOLIEKE UNIVERSITEIT LEUVEN

Van Kleunen et al. (2015) *Nature*

Invasive plant species also strongly affect the *functioning of ecosystems*

Mean effect size (*Hedges d*) of impacts of invasive species



Vila et al. (2011) *Ecol. Letters*

Predicting the effects of new exotic species on ecosystem functions would allow to set up an _early warning system_

• Predictions have been not successful so far;

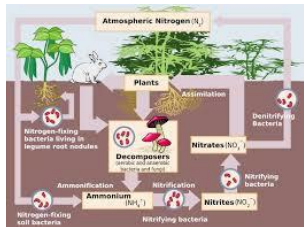
• The typical approach among plant ecologists is based on the framework of the **plant traits** (or plant characteristics).

TRY Plant Trait Database

The LEDA Traitbase

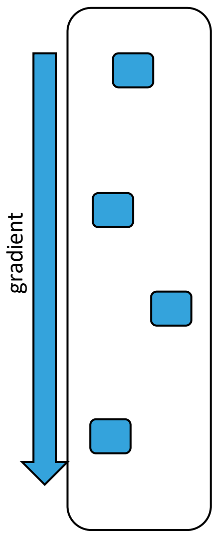
drivers ?

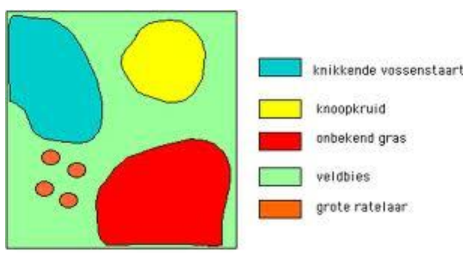
PROCESSES/FUNCTIONS



PLANT FUNCTIONAL TYPES

FUNCTIONAL TRAITS





FUNCTIONAL TRAITS

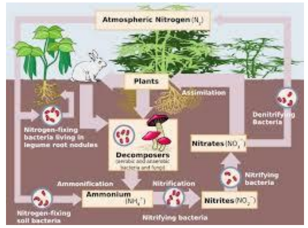
growth form
life form
nutrients
biomass
leaf size/shape
rooting depth
seed mass
vegetation height

TRY Plant Trait Database

The LEDA Traitbase

Processes/Functions

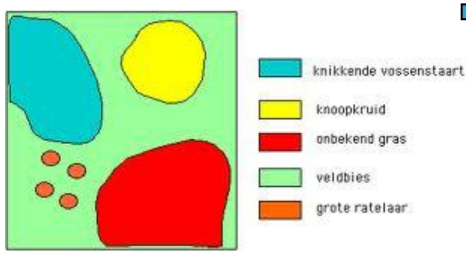
drivers ?



Plant Functional Types

Functional Traits

gradient



Functional Traits

growth form

life form

nutrients

biomass

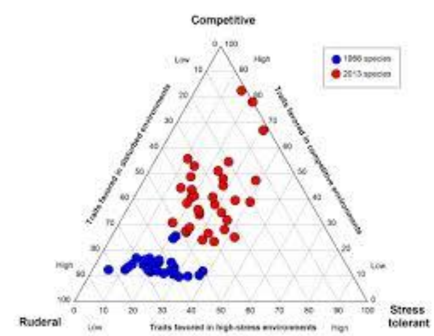
leaf size/shape

rooting depth

seed mass

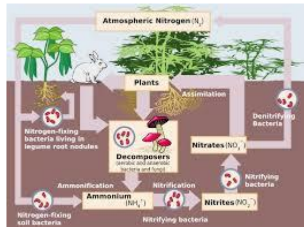
vegetation height

Plant Functional Types



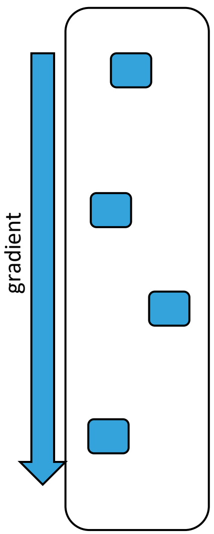
PROCESSES/FUNCTIONS

drivers ?

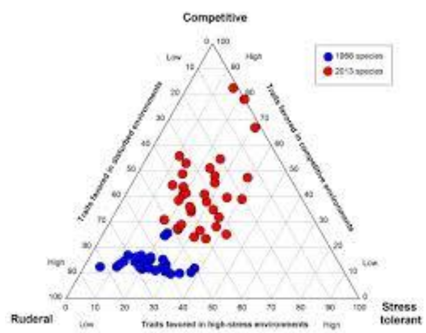


PLANT FUNCTIONAL TYPES

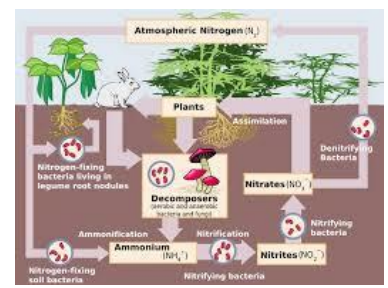
FUNCTIONAL TRAITS



PLANT FUNCTIONAL TYPES

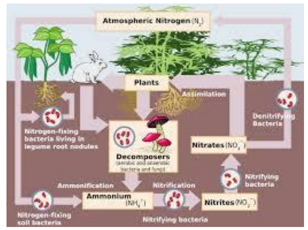


PROCESSES/FUNCTIONS



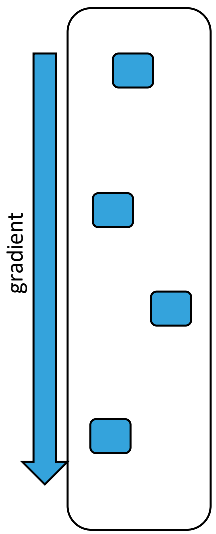
Processes/Functions

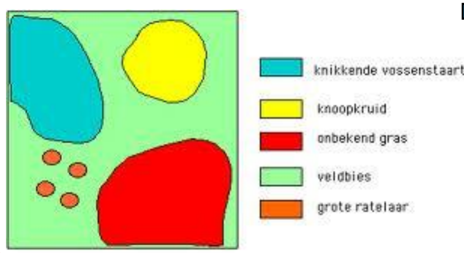
drivers ?



Plant Functional Types

Functional Traits





Functional Traits

growth form

life form

nutrients

biomass

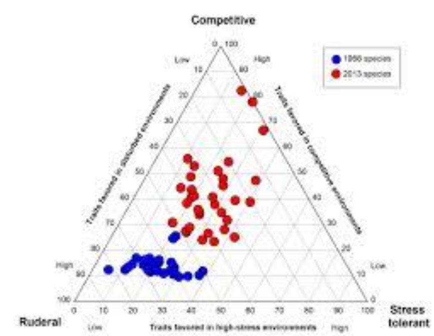
leaf size/shape

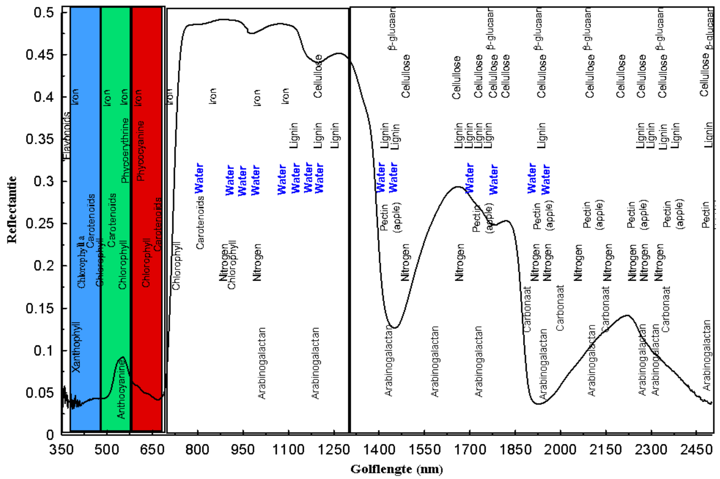
rooting depth

seed mass

vegetation height

Plant Functional Types

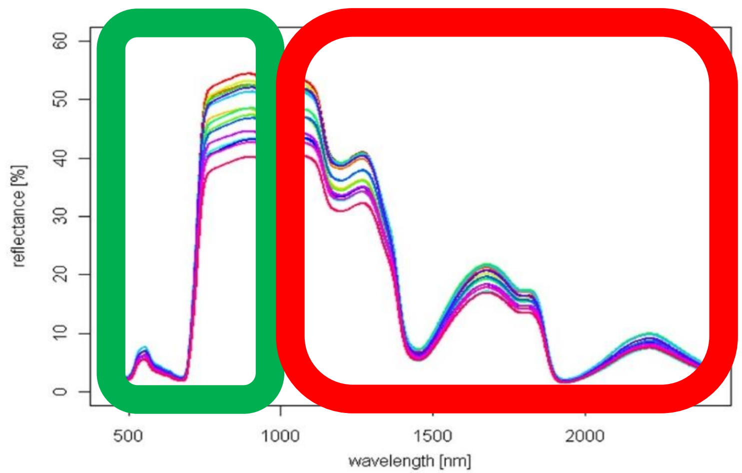




SPECTRAL INFORMATION?

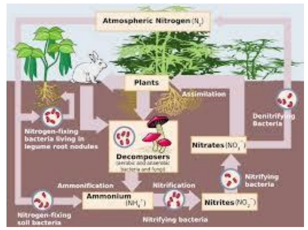
Foliar defense & longetivity
(cellulose, lignin, phenols, tanins)

Ligth Capture & growth
(pigments, nutrients, leaf mass)



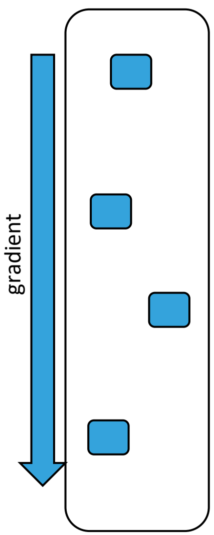
Processes/Functions

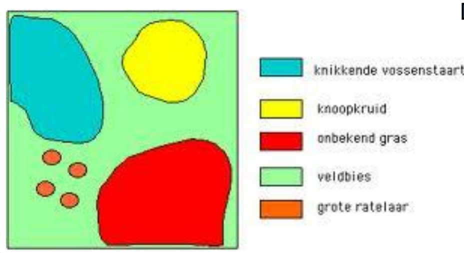
drivers → ?



Plant Functional Types

Functional Traits





Functional Traits

growth form

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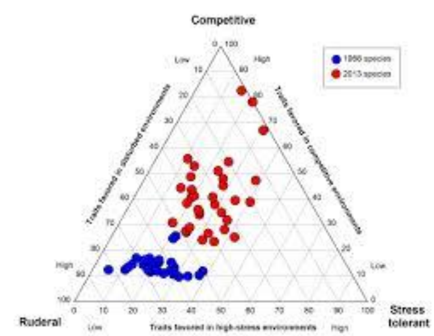
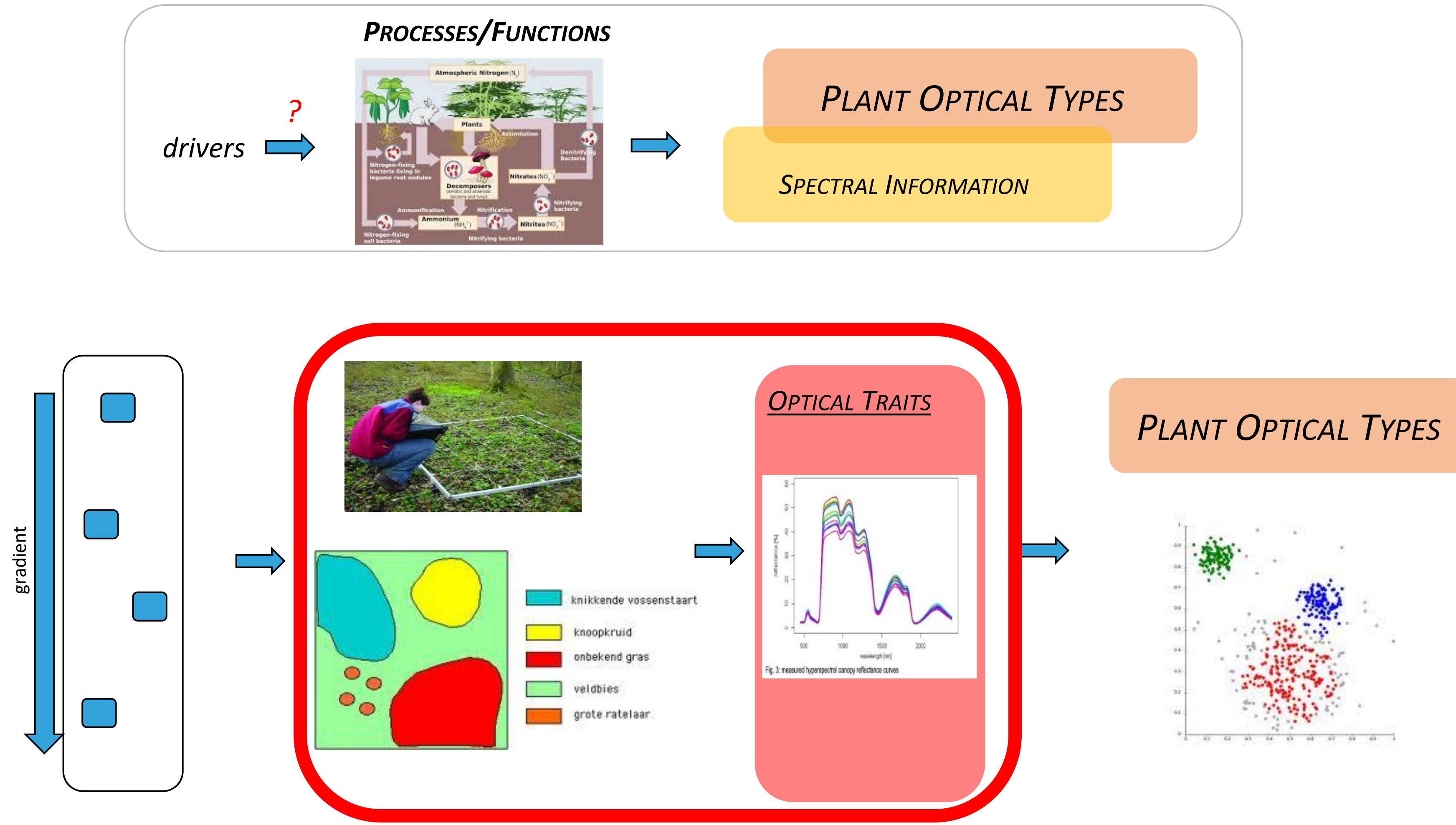
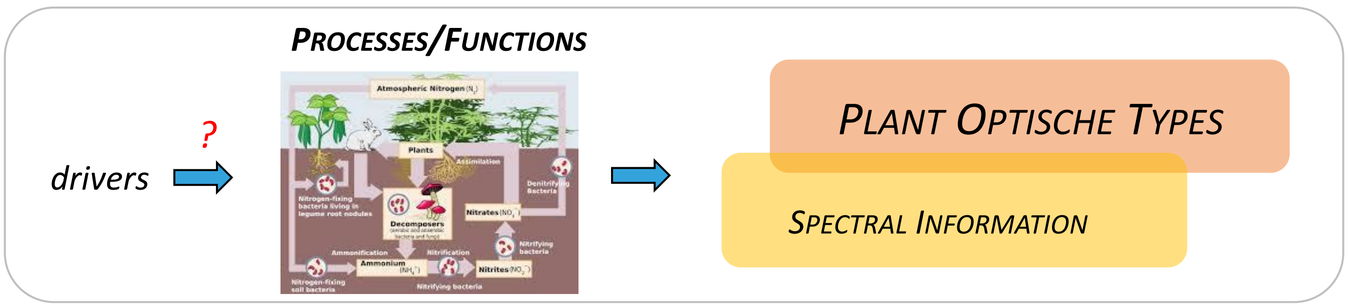
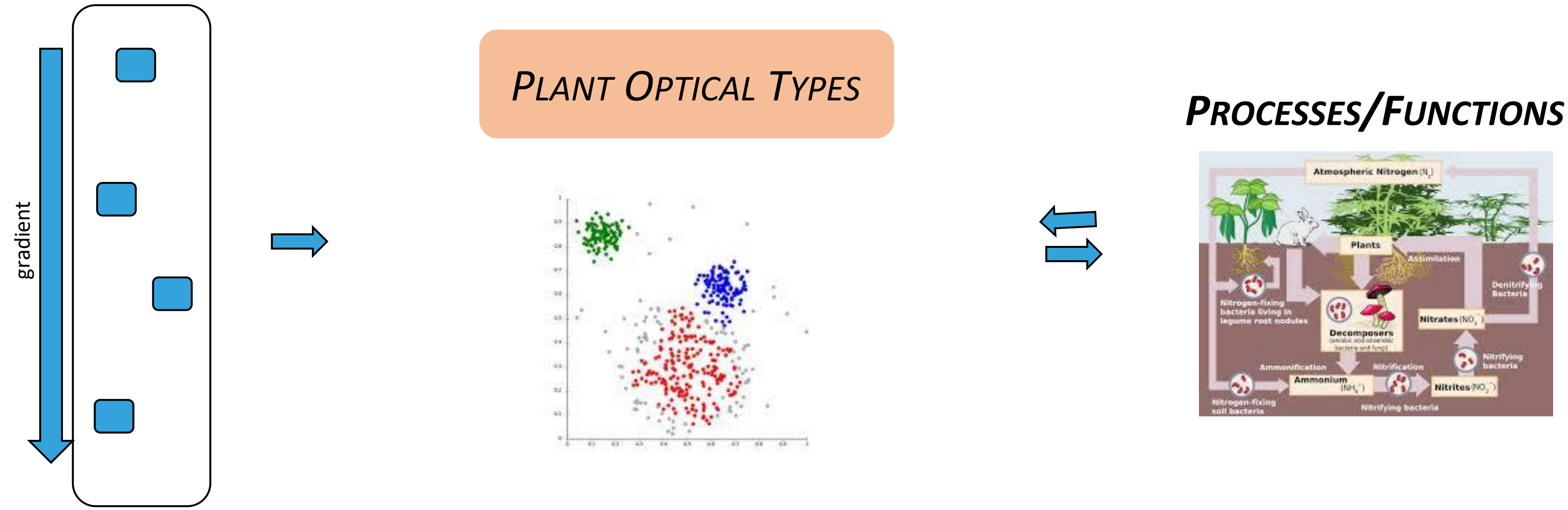
Plant Functional Types



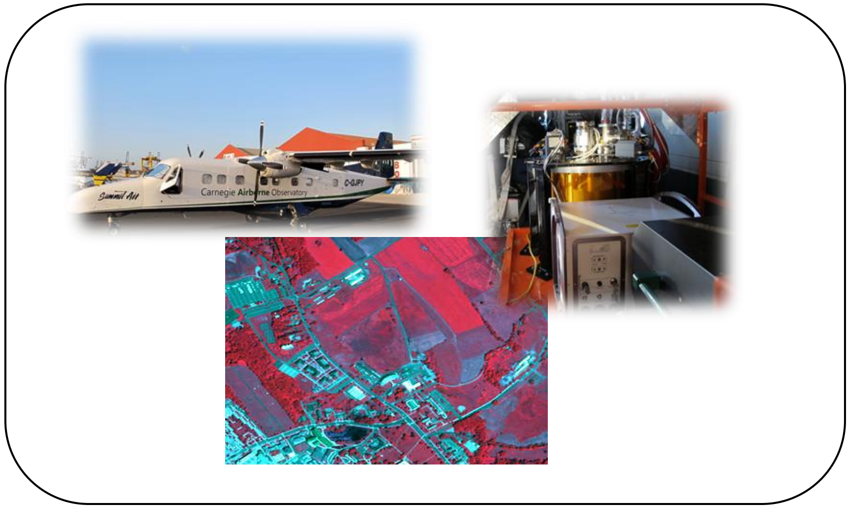


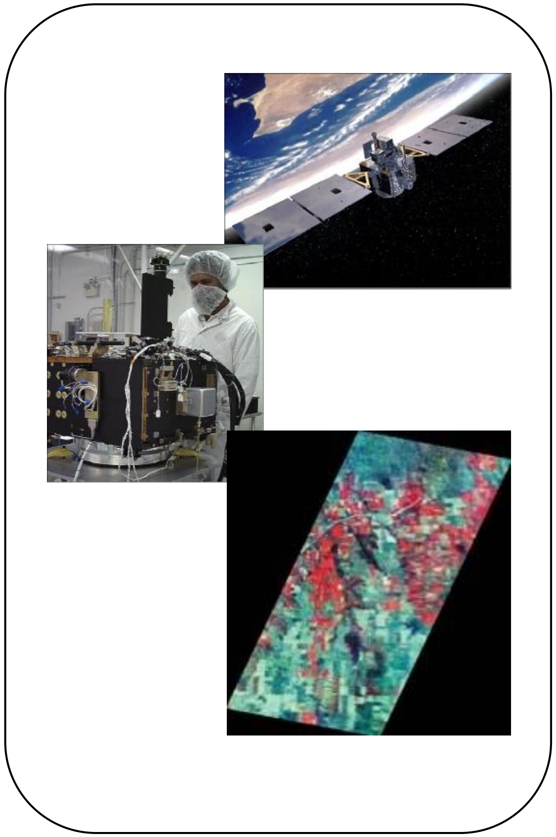
Processes/Functions
drivers
?
Plant Optical Types
Spectral Information
gradient
knikkende vossenstaart
knoopkruid
onbekend gras
veldbies
grote ratelaar
Optical Traits
Plant Optical Types


Processes/Functions
drivers
?
Atmospheric Nitrogen
Plants
Decomposers
Nitrates
Nitrites
Ammonium
Plant Optische Types
Spectral Information


gradient
Plant Optical Types
Processes/Functions
Atmospheric Nitrogen
Plants
Assimilation
Nitrogen-fixing bacteria living in legume root nodules
Decomposers
Denitrifying Bacteria
Nitrates
Nitrifying bacteria
Ammonification
Nitrification
Ammonium
Nitrites
Nitrogen-fixing soil bacteria
Nitrifying bacteria

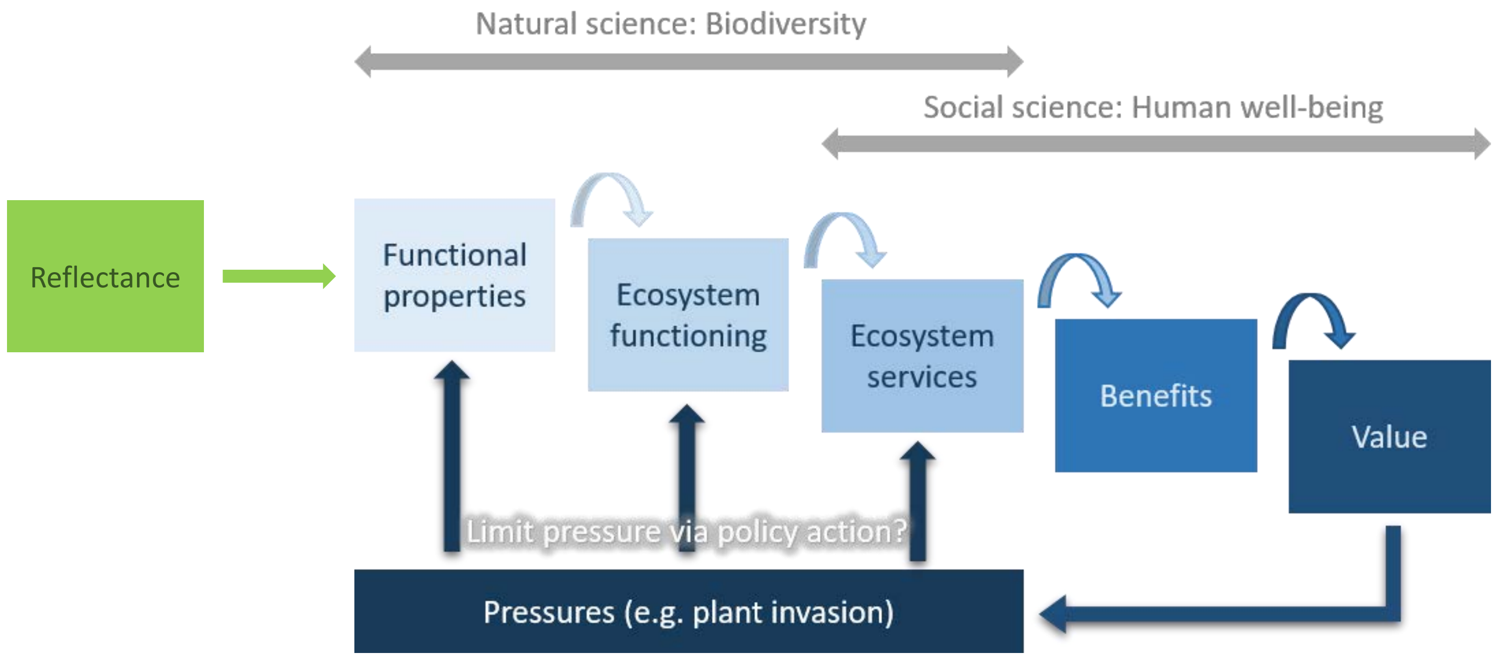
Spectral Information?





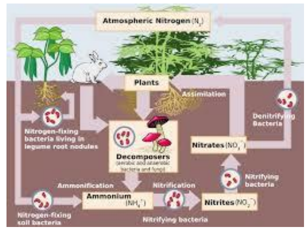
Overall objective and vision

Develop and examine a **functional-trait-based framework, founded on optical data**, that enables us to better monitor and **understand invasion impacts** on the functioning of grassland ecosystems



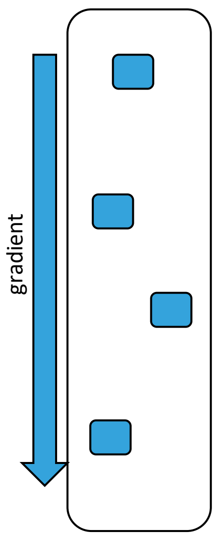
Processes/Functions

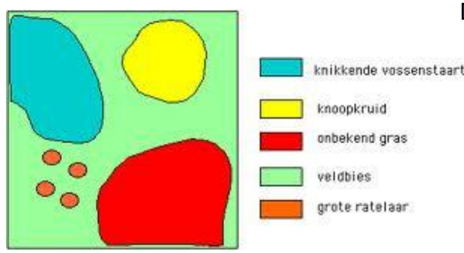
drivers → ? →



→ *Plant Functional Types*

Functional Traits

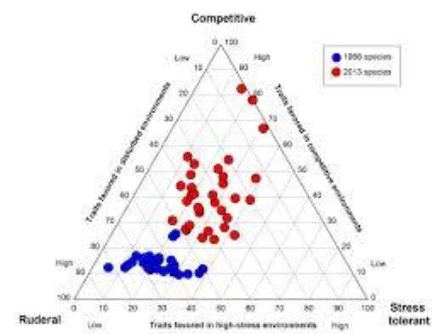


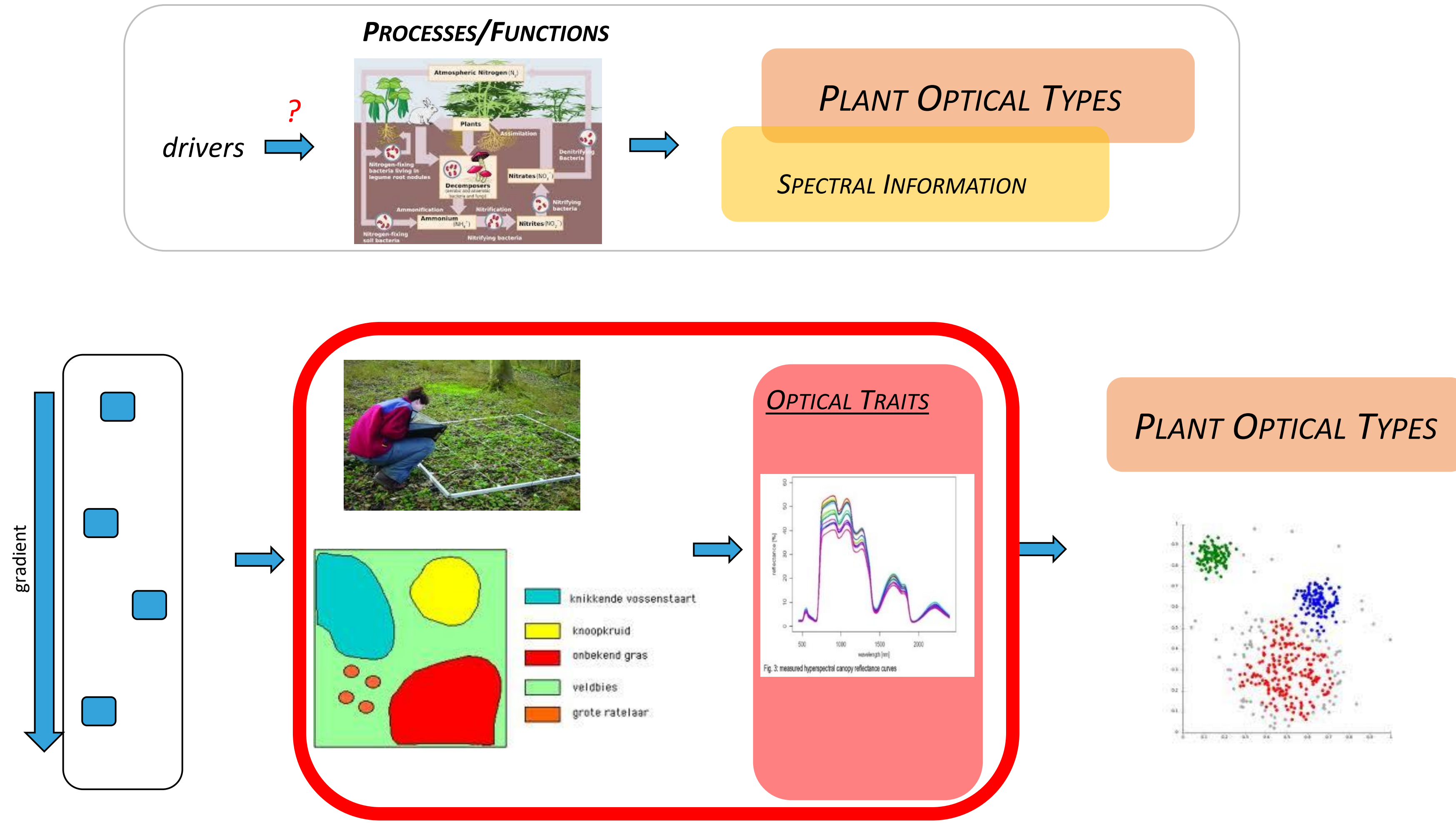


Functional Traits

- *growth form*
- *life form*
- *nutrients*
- *biomass*
- *leaf size/shape*
- *rooting depth*
- *seed mass*
- *vegetation height*

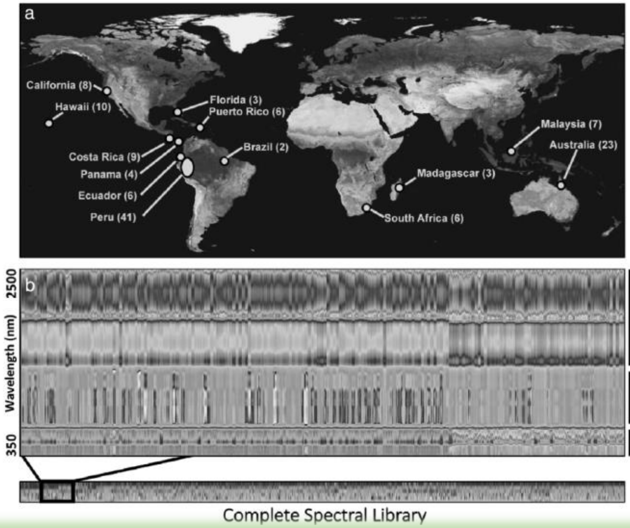
Plant Functional Types

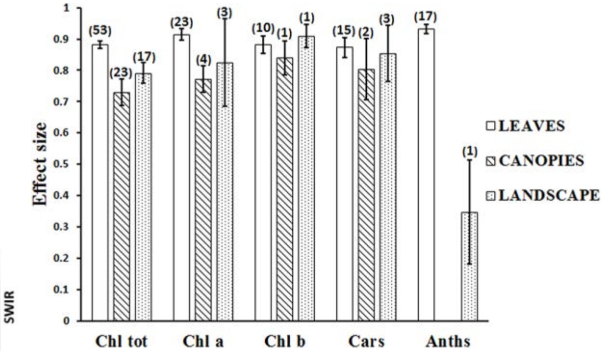



PROCESSES/FUNCTIONS
drivers
?
Atmospheric Nitrogen (N2)
Plants
Assimilation
Decomposers
Nitrates (NO3-)
Ammonium (NH4+)
Nitrites (NO2-)
Ammonification
Nitrification
Nitrifying bacteria
PLANT OPTICAL TYPES
SPECTRAL INFORMATION
gradient
knikkende vossenstaart
knoopkruid
onbekend gras
veldbies
grote ratelaar
OPTICAL TRAITS
Fig. 3: measured hyperspectral canopy reflectance curves
PLANT OPTICAL TYPES

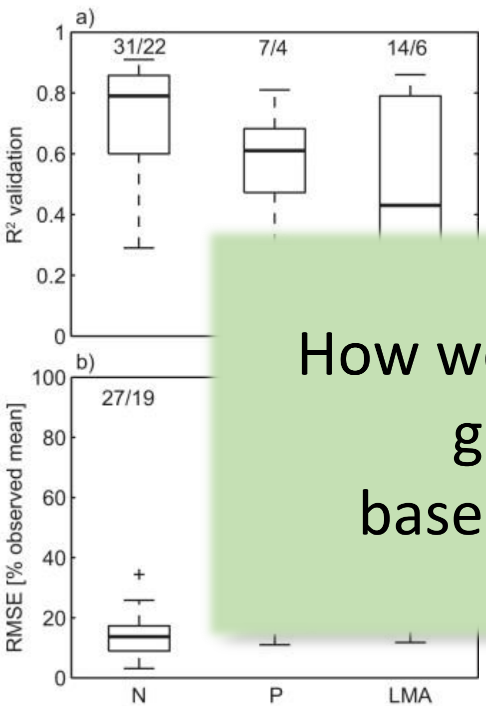
PREFACE

WHAT DO WE KNOW?





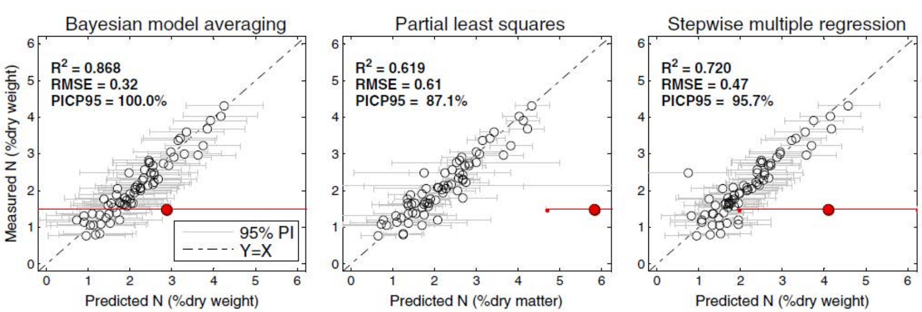
Mean pigment accuracy retrieval (R^2) for a wide range of vegetation types (Huang et al., 2015)



How well can we estimate functional traits in grass- and shrubland ecosystems, based on hyperspectral remote sensing?

Empirical prediction accuracy for a wide range of vegetation types (Homolová et al., 2013)

		R_G, R_{NIR}/R_R, R_{NIR}/R_{RE}, R_B/R_G,
		$R_{445})/(R_{705}-R_{445})$
		R_{675}
		R_{650}
Ratio Analysis of Reflectance Spectra	RARS	$RARS_a = R_{675}/R_{700}$
		$RARS_b = R_{675}/(R_{650} \times R_{700})$
Normalized Difference Vegetation Index	NDVI	$NDVI = (R_{NIR} - R_R)/(R_{NIR} + R_R)$
Red-edge NDVI	mNDVI	$mNDVI = (R_{750} - R_{705})/(R_{750} + R_{705})$
Modified Red-edge Normalized Difference Vegetation Index	mNDI	$mNDVI = (R_{750} - R_{705})/(R_{750} + R_{705} - 2R_{445})$
Green NDVI	gNDVI	$gNDVI = (R_{750} - R_G)/(R_{750} + R_G)$
Pigment Specific Normalized Difference	PSND	$PSND_a = (R_{800} - R_{675})/(R_{800} + R_{675})$
		$PSND_b = (R_{800} - R_{650})/(R_{800} + R_{650})$
Eucalyptus Pigment Indexes	EPI	$Chl_{a,b} = \alpha_{a,b} \times (R_{672}/(R_{550} \times R_{708}))^{\beta_{a,b}}$
Summed Reflectance Index	SRI	$S_1 = \int_{700}^{750} (R_\lambda / R_{555} - 1) d\lambda$
		$S_2 = \int_{700}^{750} (R_\lambda / R_{705} - 1) d\lambda$
Red edge position		
Red Edge Inflexion Point Position	IPP	$R''(\lambda_i) = 0$



Empirical non-parametric regression techniques (Zhao et al., 2013)

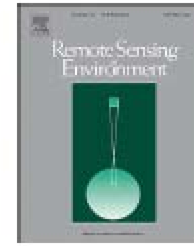
Spectral indices for chlorophyll (Ustin et al., 2009)

Remote Sensing of Environment 209 (2018) 747–763

Contents lists available at ScienceDirect

Remote Sensing of Environment

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



Review

The functional characterization of grass- and shrubland ecosystems using hyperspectral remote sensing: trends, accuracy and moderating variables

Elisa Van Cleemput[a,*], Laura Vanierschot[a], Belén Fernández-Castilla[b], Olivier Honnay[c], Ben Somers[a]

[a] Division of Forest, Nature and Landscape, KU Leuven, Celestijnenlaan 200E, 3001 Leuven, Belgium
[b] Faculty of Psychology and Educational Sciences and Imec-Itec, KU Leuven, Etienne Sabbelaan 51, 8500 Kortrijk, Belgium
[c] Division of Ecology, Evolution and Biodiversity Conservation, KU Leuven, Kasteelpark Arenberg 31, 3001 Leuven, Belgium

Meta-analysis

Meta-analysis: A synthesis of studies

Contents lists available at SciVerse ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

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

Hyperspectral determination of feed quality constituents in temperate pastures: Effect of processing methods on predictive relationships from partial least squares regression

→ R^2 and nRMSE of trait estimation model

International Journal of Remote Sensing
Vol. 32, No. 1, 10 January 2011, 103–124

Taylor & Francis

Potential for spectral indices to remotely sense phosphorus and potassium content of legume-based pasture as a means of assessing soil phosphorus and potassium fertility status

K. KAWAMURA*†‡, A. D. MACKAY‡, M. P. TUOHY¶, K. BETTERIDGE‡, I. D. SANCHES¶ and Y. INOUE§

→ R^2 and nRMSE of trait estimation model

Contents lists available at ScienceDirect

Ecological Indicators

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

Successive projections algorithm-based three-band vegetation index for foliar phosphorus estimation

Junjie Wang[a,b], Tiezhu Shi[a,b], Huizeng Liu[a], Guofeng Wu[a,b,*]

[a] Key Laboratory for Geo-Environmental Monitoring of Coastal Zone of the National Administration of Surveying, Mapping and Geo-information & Shenzhen Key Laboratory of Spatial-temporal Smart Sensing and Services, Shenzhen University, 518060 Shenzhen, China
[b] College of Life and Marine Sciences, Shenzhen University, 518060 Shenzhen, China

→ R^2 and nRMSE of trait estimation model

…

…

Article

Estimating Plant Traits of Grasslands from UAV-Acquired Hyperspectral Images: A Comparison of Statistical Approaches

Alessandra Capolupo [1,*], Lammert Kooistra [2], Clara Berendonk [3], Lorenzo Boccia [1] and Juha Suomalainen [2]

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

Estimation of foliar chlorophyll and nitrogen content in an ombrotrophic bog from hyperspectral data: Scaling from leaf to image

M. Kalacska *, M. Lalonde, T.R. Moore

Department of Geography and Global Environmental & Climate Change Centre, McGill University, 805 Sherbrooke Street West, Montréal, QC H3A 0B9, Canada

→ Weighted mean R^2
Weighted mean nRMSE

Three-level meta-analysis

3 sources of variation

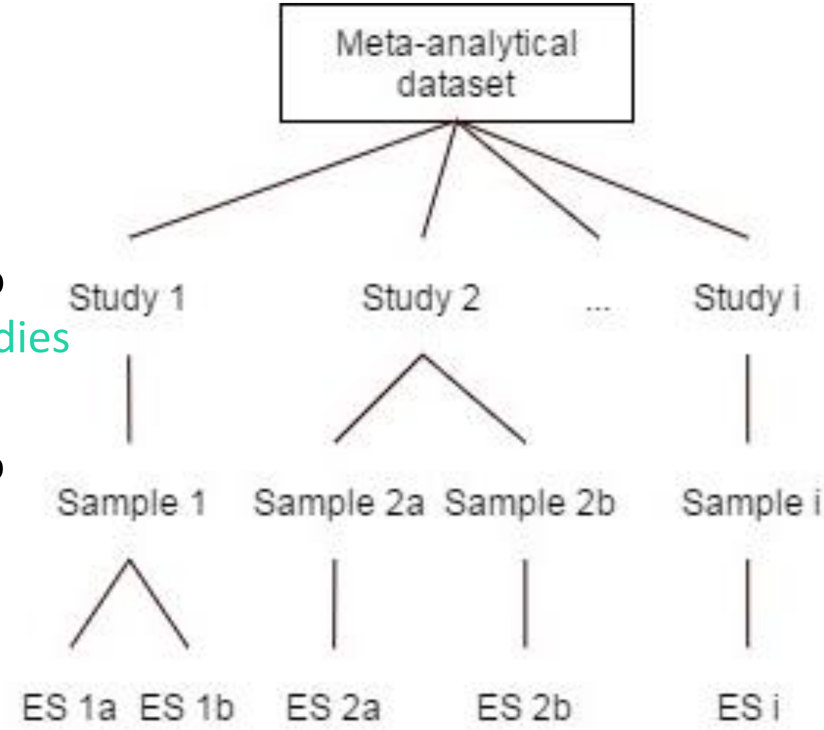
$R^2{}_{study\ i} = \overline{R^2}$ Overall mean ES

between-study variation

$+v_i$ random deviation due to differences between studies

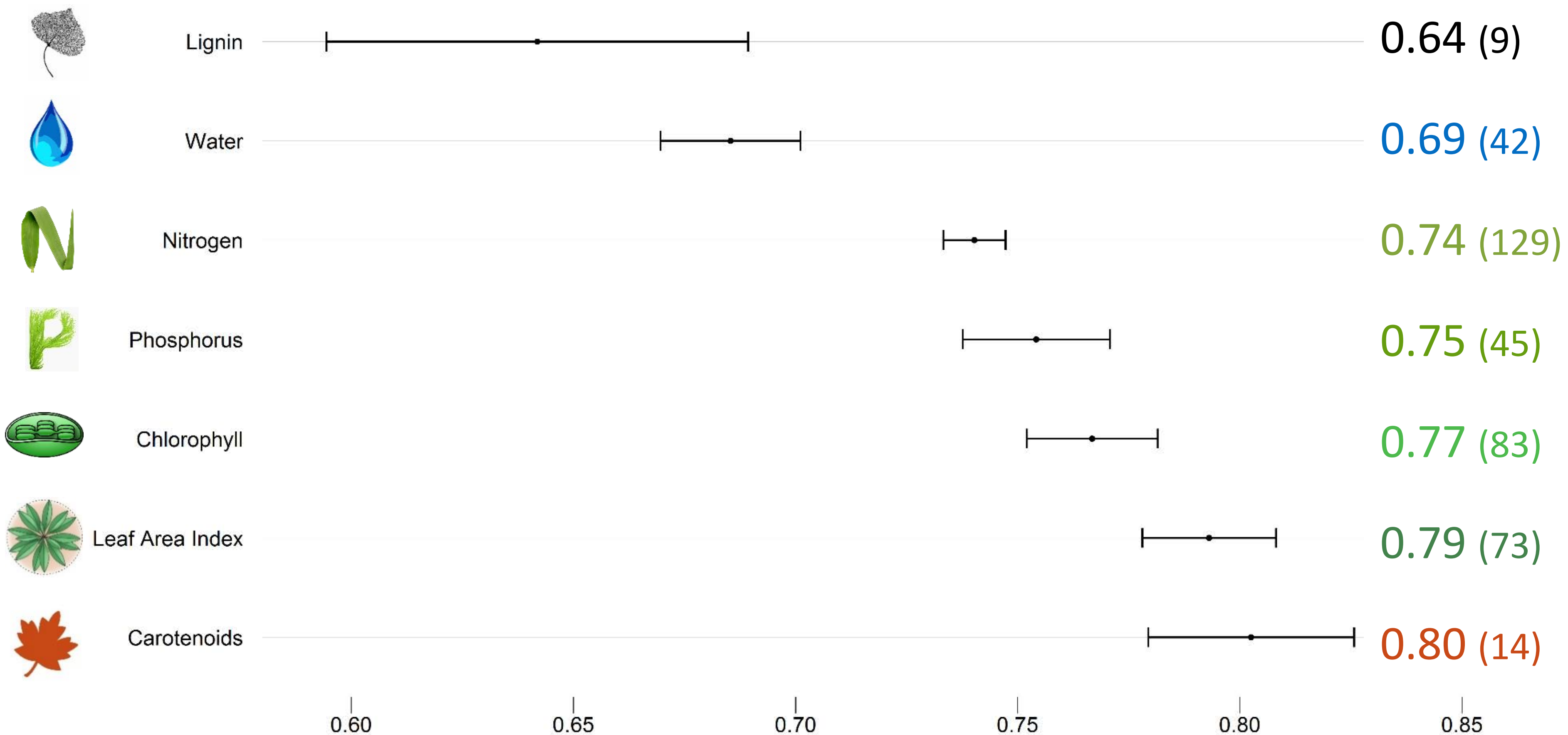
$+u_{ik}$ random deviation due to differences between samples within studies

$+e_{ik}$ Residual due to random sampling variation



Mean R^2

95% confidence interval (# effect sizes)



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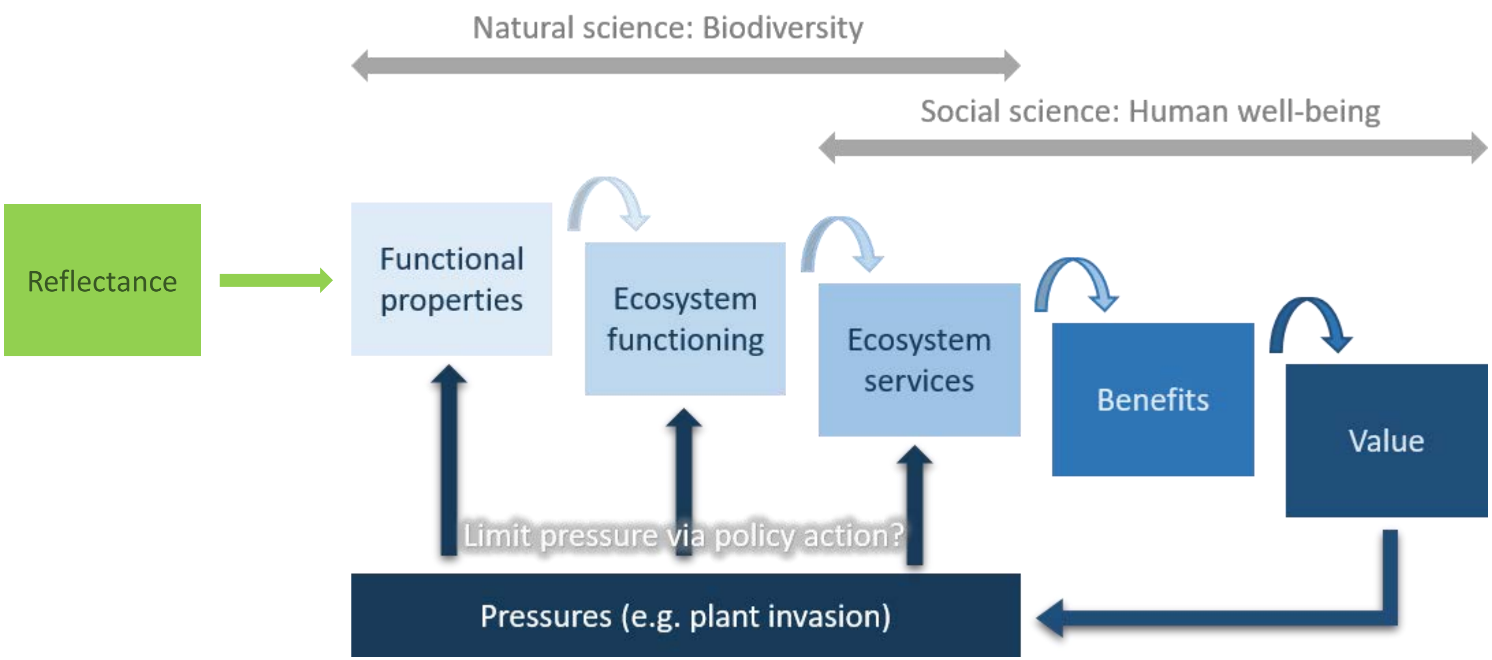


STUDY SITES AND SAMPLING DESIGN

Impatiens glandulifera
Himalayan balsam
Reuzenbalsemien

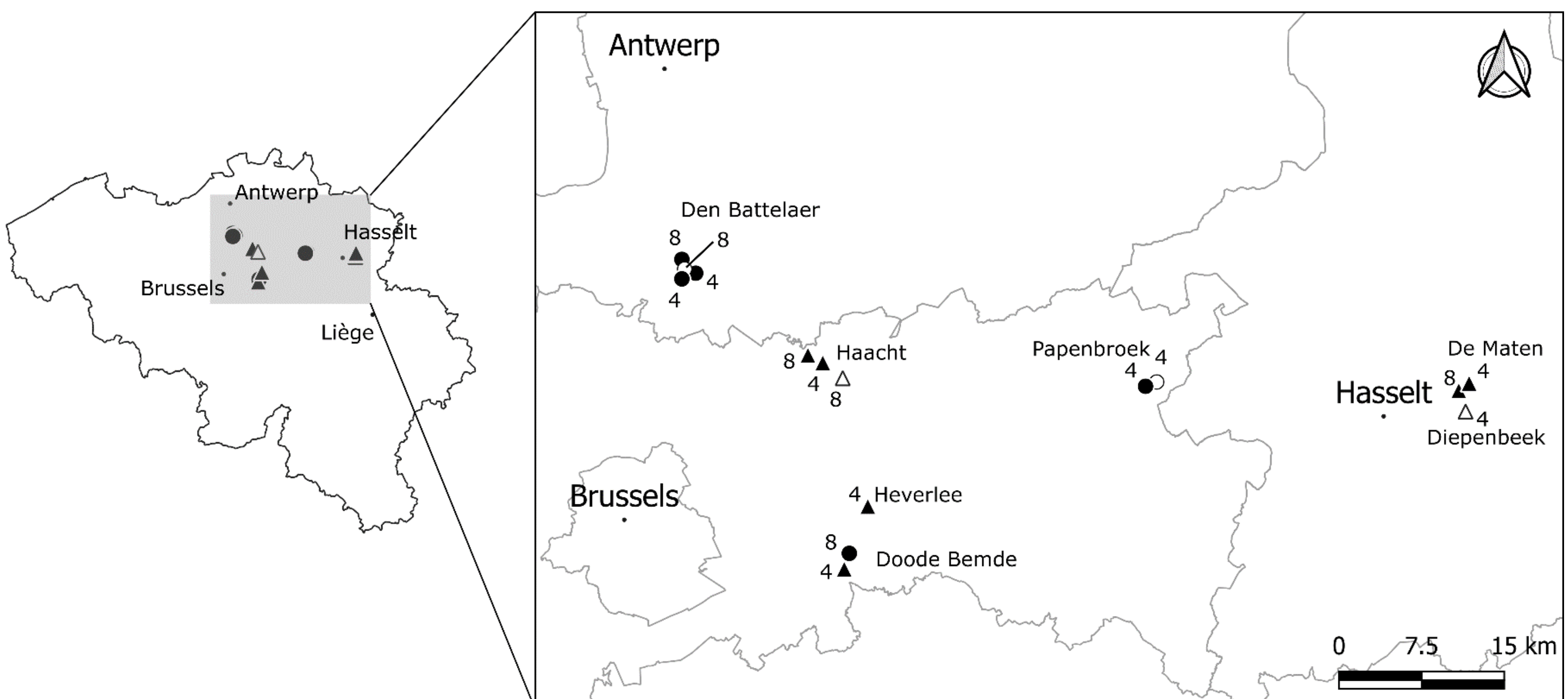
Himalayas
19th century
Annual forb

7 sites

8 sites

Solidago gigantea
Giant goldenrod
Late guldenroede

North America
Mid-1700s
Perennial forb, rhizomes



STUDY SITES AND SAMPLING DESIGN

Impatiens glandulifera
Himalayan balsam
Reuzenbalsemien

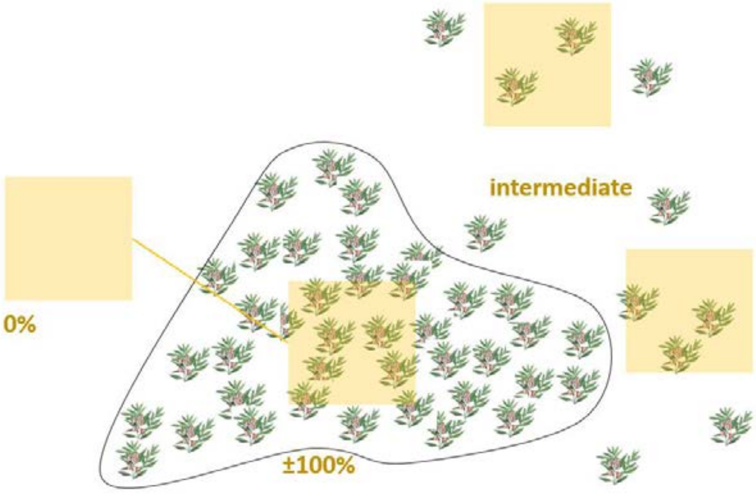
40 plots

Solidago gigantea
Giant goldenrod
Late guldenroede

44 plots

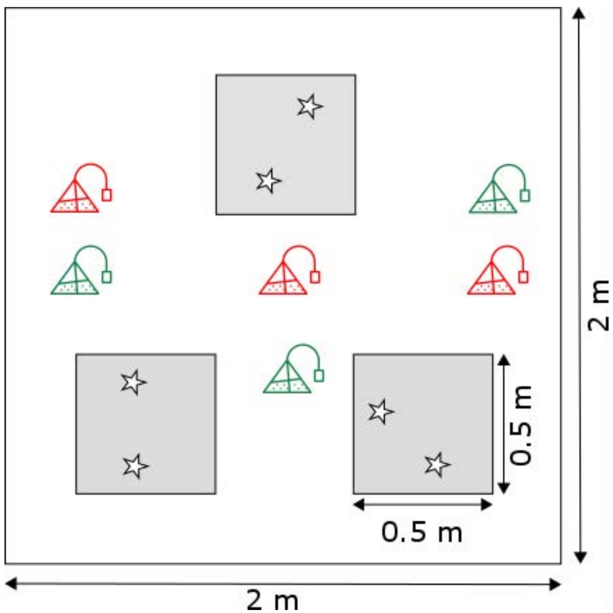
Plots:

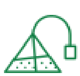
- Space-for-time substitution
- 2m x 2m
- Vegetation survey (Londo)
- **Quantification of ecosystem functioning**
- **Functional and spectral characterization of dominant species**



ECOSYSTEM FUNCTIONING

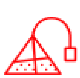
1. Peak live aboveground biomass
2. Soil elements: available P, N, C
3. Decomposition rate of standard material:
   Tea bag Index





Mass loss of green tea

~ Stabilisation of labile fraction into recalcitrant fraction



Mass loss of Rooibos tea

~ decomposition rate

Functional and spectral characterization of dominant species

39 dominant herbaceous species → 73 observations

Functional traits

Leaf Economic Spectrum: SLA, LDMC, LNC, LPC, Chlorophyll
Size traits: plant height, leaf area
Decomposition related traits: LCaC, LMgC, carotenoids

FUNCTIONAL AND SPECTRAL CHARACTERIZATION OF DOMINANT SPECIES

39 dominant herbaceous species → 73 observations

Functional traits

Leaf Economic Spectrum: SLA, LDMC, LNC, LPC, Chlorophyll
Size traits: plant height, leaf area
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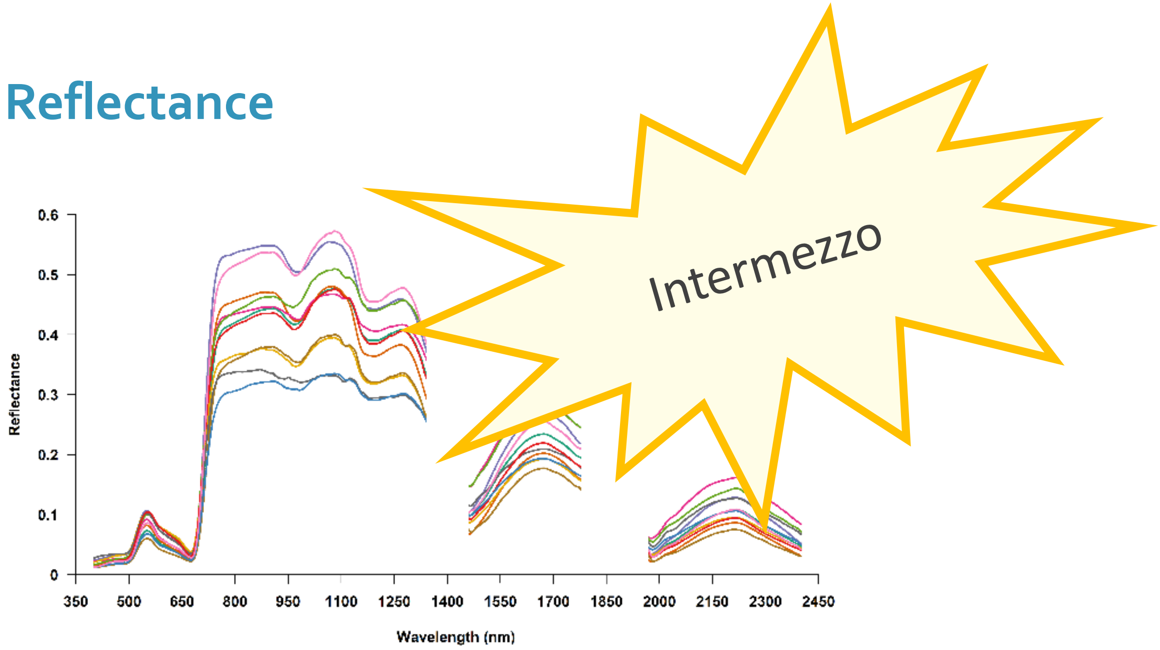
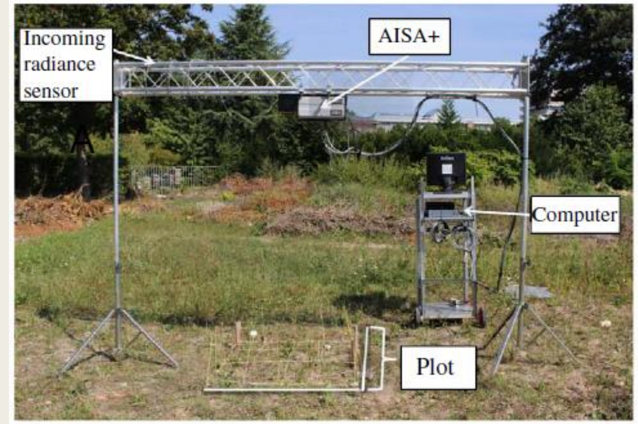
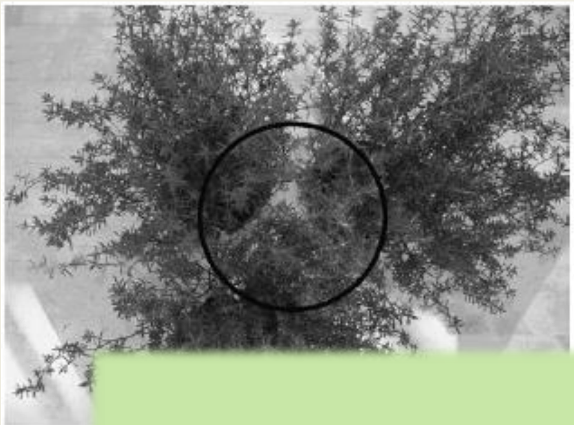
Reflectance



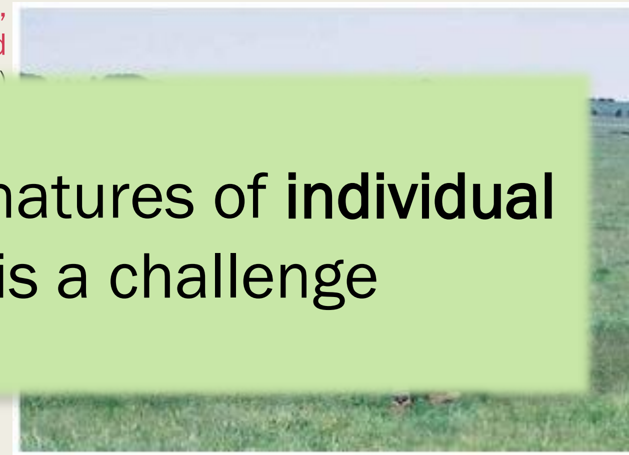
COMMON METHODS

3 mm pixels with
AISA + Eagle spectrometer
(Lopatin et al. 2017)





Point measurements,
hand-held
(Thulin et al. 2012)



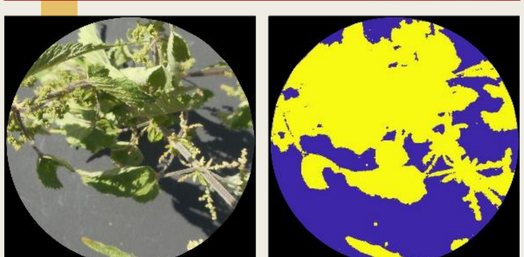
Measuring the spectral signatures of **individual herbaceous species** is a challenge

Lab m
(Darvi

Lab measurements of *Poa pratensis* (Bayat et al., 2016)

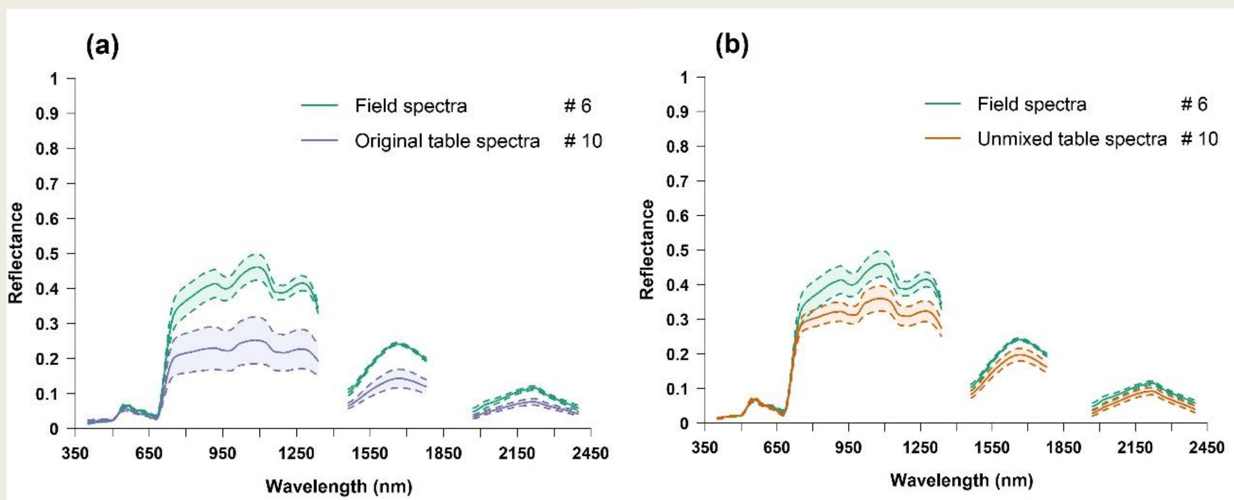
Leaf measurements with leaf clip or integrating sphere (ASD)

	λ_1	λ_2	λ_3	...
b 1				
b 2				
b ...				
b 208				



Linear signal unmixing:

$$spectrum_{vegetation} = \frac{spectrum_{measured} - f_{black\ table\ in\ FOV} \cdot spectrum_{black\ table}}{f_{vegetationin\ FOV}}$$



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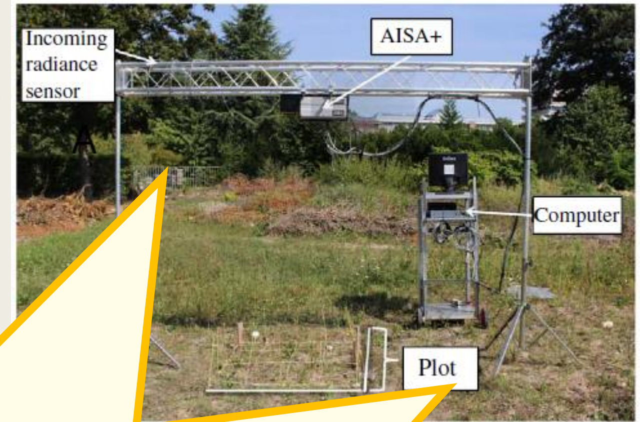


Lab measure

(Darvishzadeh

Received: 20 February 2019 | Accepted: 21 May 2019

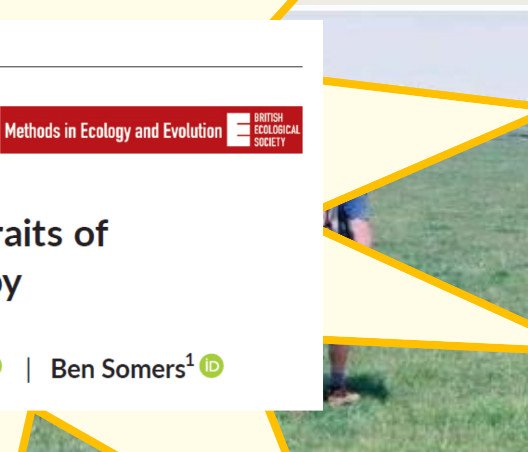
DOI: 10.1111/2041-210X.13237

Methods in Ecology and Evolution BRITISH ECOLOGICAL SOCIETY

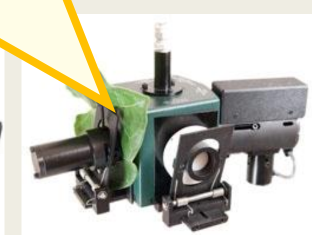
PRACTICAL TOOL

A novel procedure for measuring functional traits of herbaceous species through field spectroscopy

Elisa Van Cleemput[1] | Dar A. Roberts[2] | Olivier Honnay[3] | Ben Somers[1]



Lab measurements of *Poa pratensis* (Bayat et al., 2016)



Leaf measurements with leaf clip or integrating sphere (ASD)

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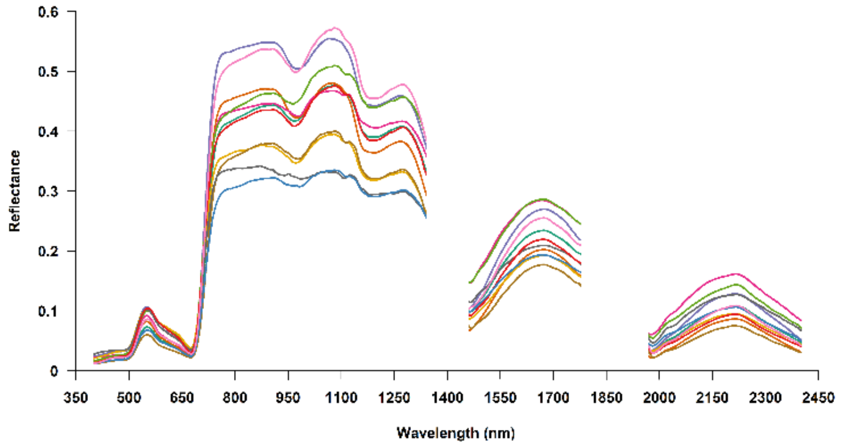


Two specific approaches and RQs

Develop and examine a **functional-trait-based framework, founded on optical data**, that enables us to better monitor and **understand invasion impacts** on the functioning of grassland ecosystems

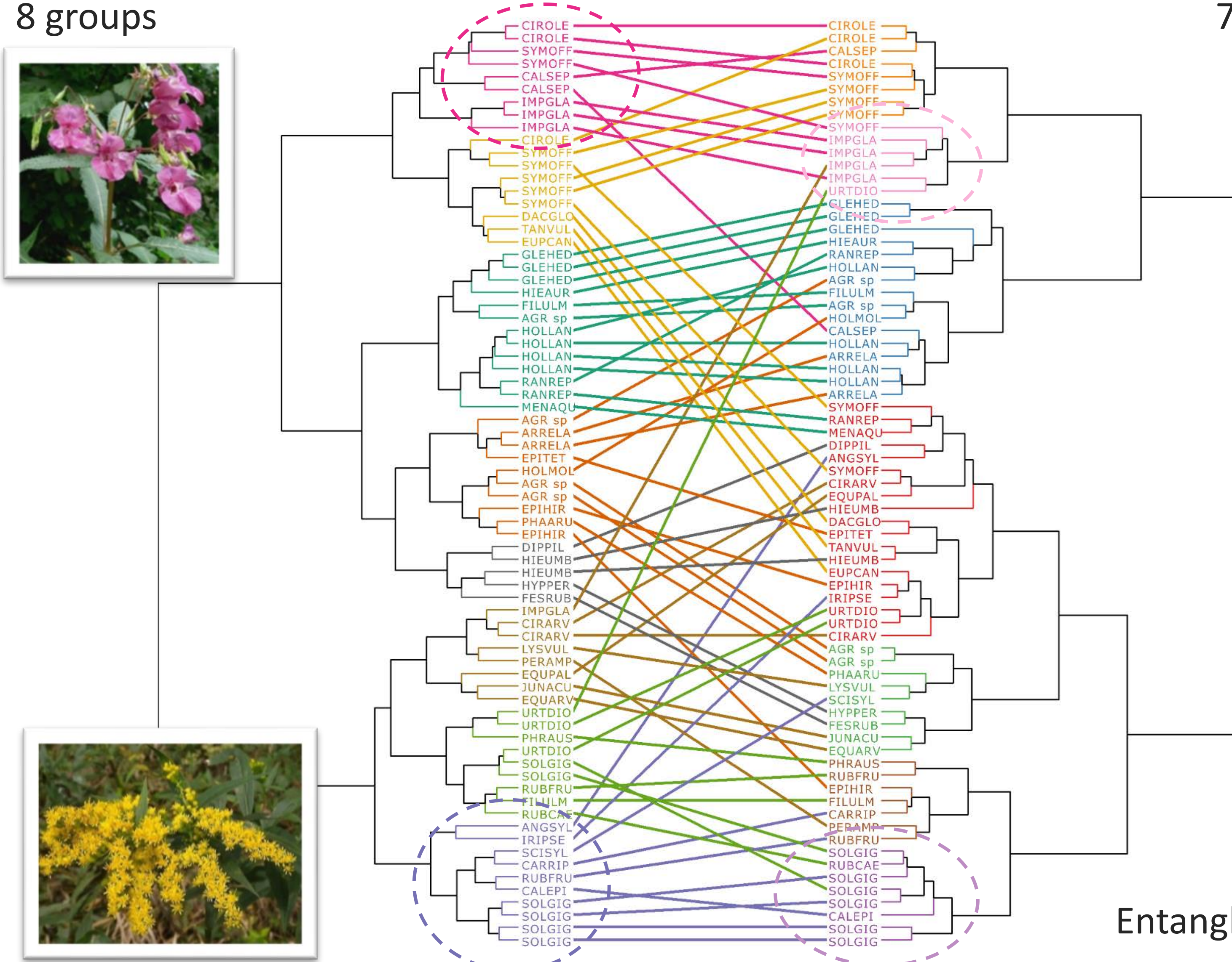
1. **Can we delineate meaningul PFT's in a herbaceous context, and to what extent are they spectrally deductible?**

2. What are the mechanisms through which invasive alien species alter ecosystem functioning?

Emergent PFTs vs. Emergent POTs

8 groups

7 groups



Entanglement = 0.13

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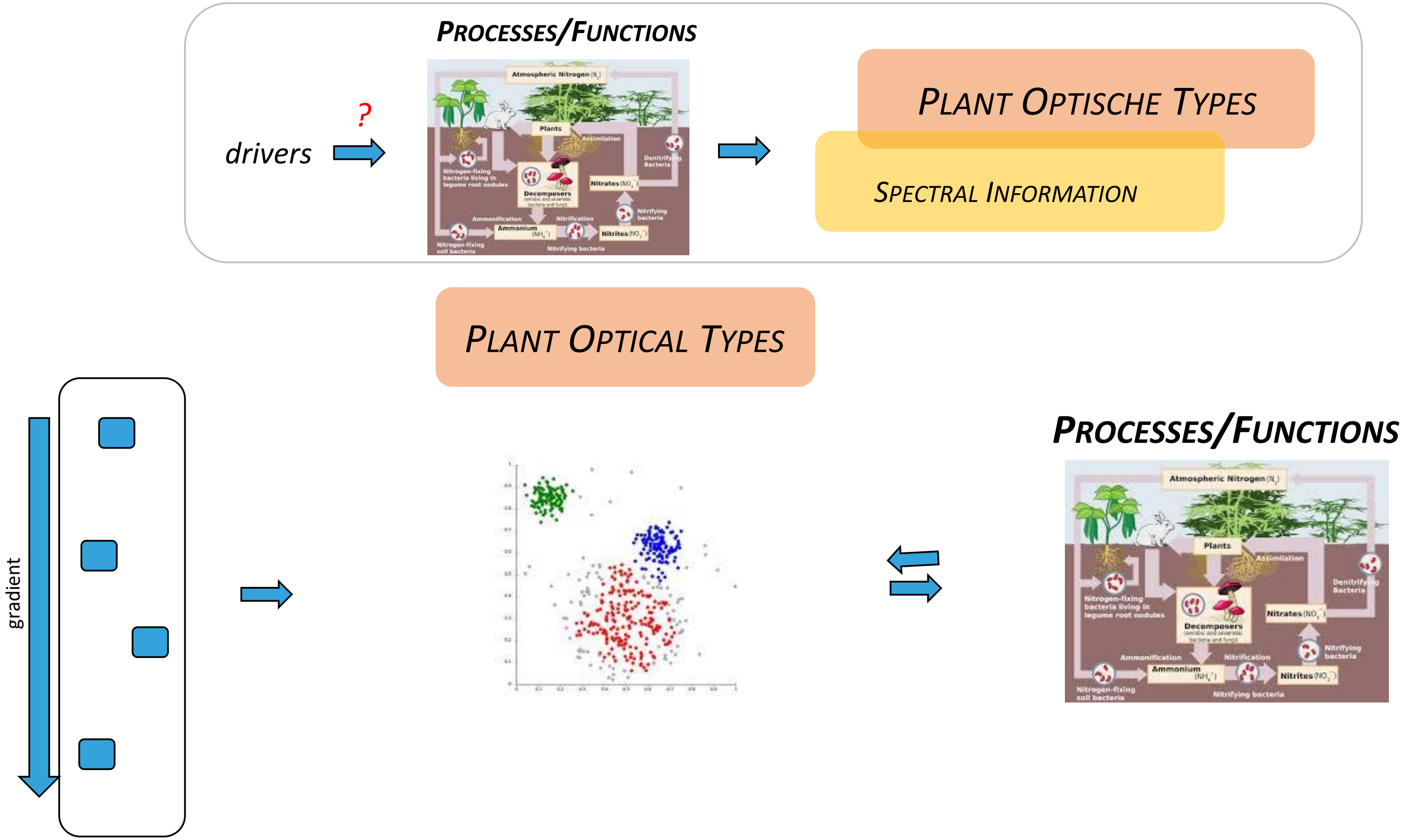
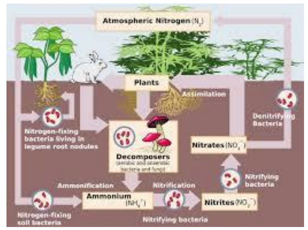

PROCESSES/FUNCTIONS
drivers
?
PLANT OPTISCHE TYPES
SPECTRAL INFORMATION
PLANT OPTICAL TYPES
gradient
PROCESSES/FUNCTIONS
Atmospheric Nitrogen (N2)
Plants
Assimilation
Denitrifying Bacteria
Nitrogen-fixing bacteria living in legume root nodules
Decomposers
Nitrates
Nitrifying bacteria
Ammonification
Nitrification
Ammonium
Nitrites
Nitrogen-fixing soil bacteria
Nitrifying bacteria

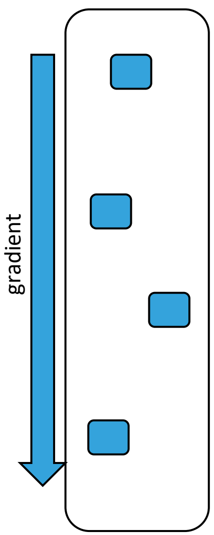
Processes/Functions

drivers ?

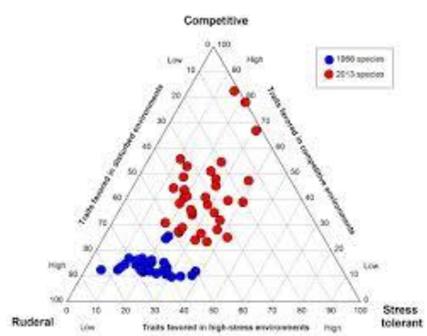


Plant Functional Types

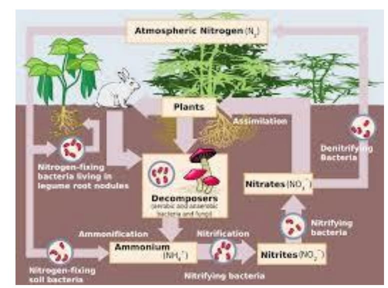
Functional Traits



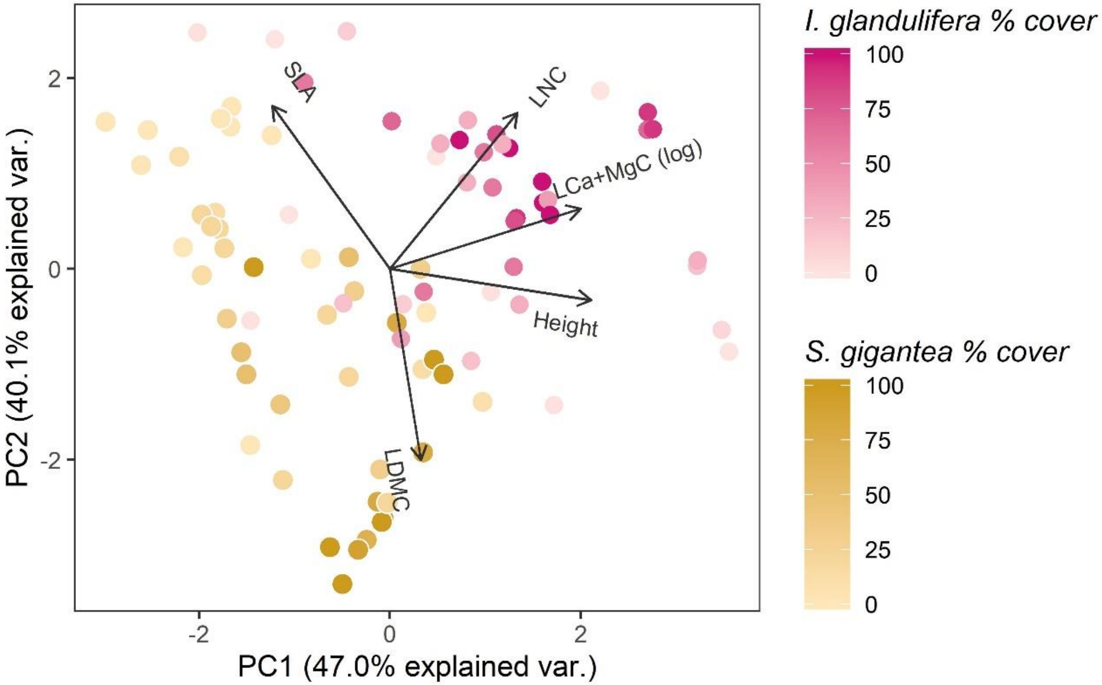
Plant Functional Types



Processes/Functions



Traits space defined by PCA on CWM functional traits



I. glandulifera leads to more nutrient-rich plant communities.

S. gigantea shifts the community towards more conservative traits.

Similar pattern were observed both for the optical and functional traits space (Procrustes $r = 0.46$, $p \leq 0.001$)

Two specific approaches and RQs

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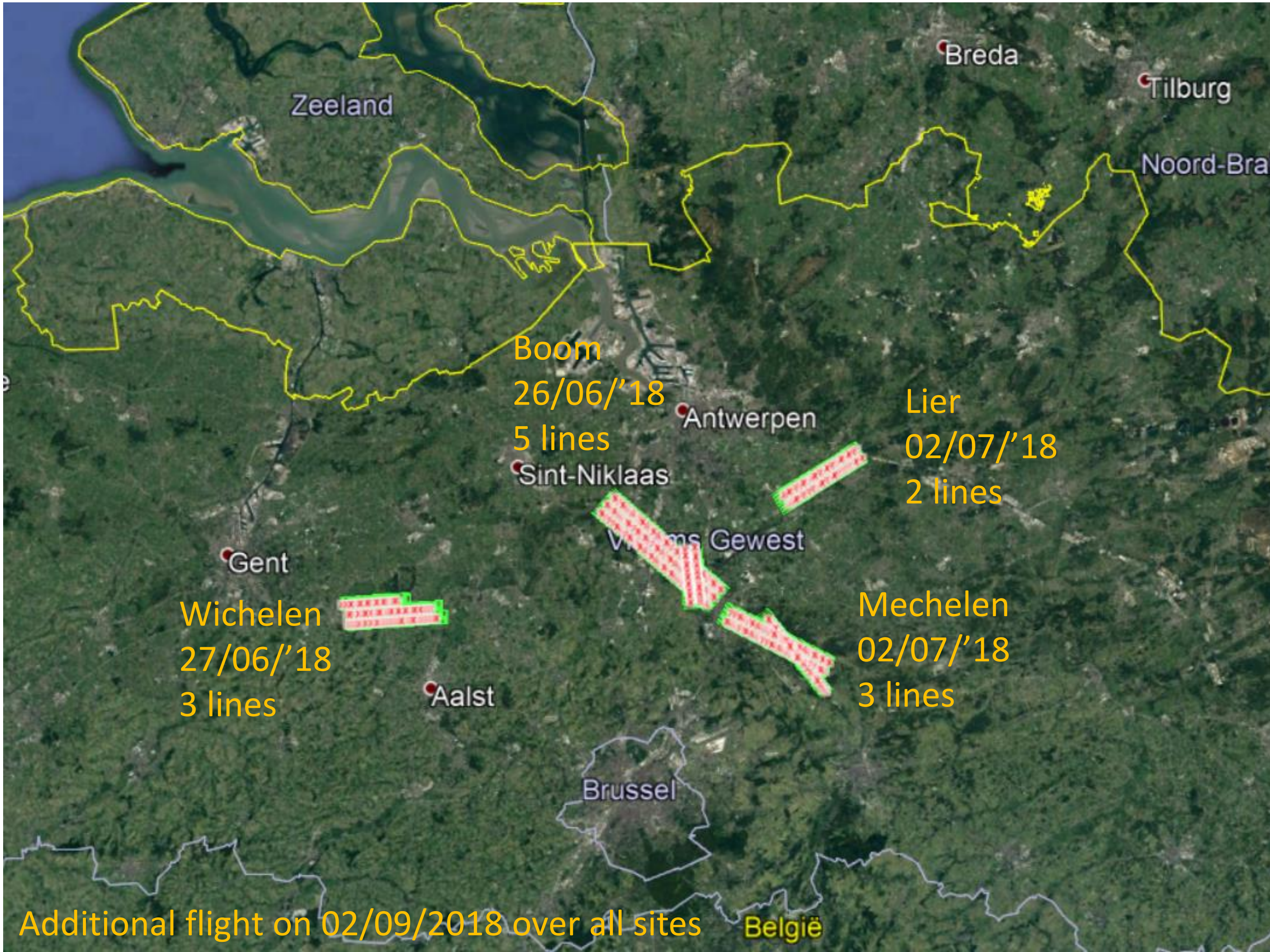
SCHEDULED FLIGHT AND FIELD CAMPAIGN SUMMER ~~2017~~ 2018



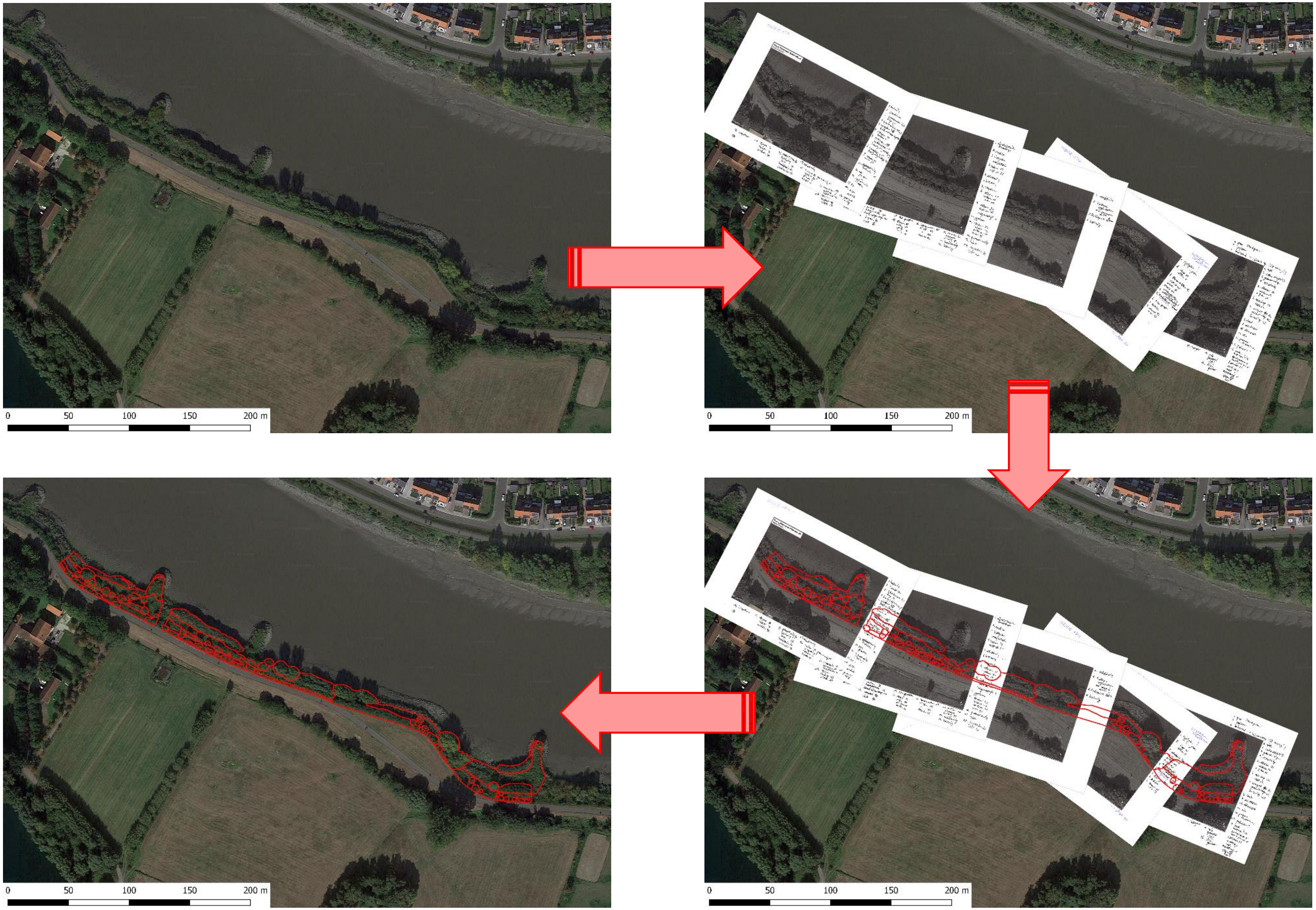
FIELD SURVEY

19/07/18 Elisa

Vegetation survey

Sunphotometer: aerosols

DIGITIZING



Acknowledgements

Belgian Science Policy Office
belspo

KU LEUVEN

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

vito vision on technology

Inplant

https://inplant-project.weebly.com/

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