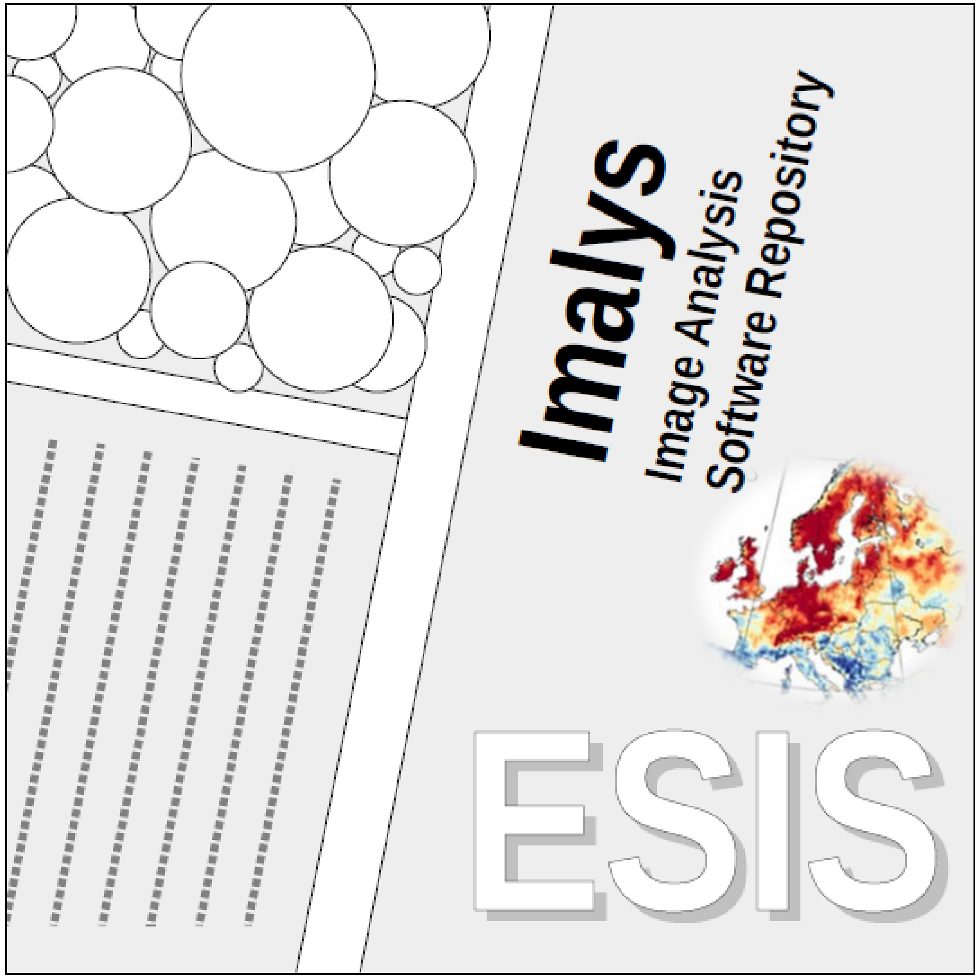
UFZ HELMHOLTZ Zentrum für Umweltforschung

EcoSystem Integrity – RS / Modelling –Tool (ESIS) for monitoring vegetation diversity & geodiversity with RS and traits



GitLab: https://doi.org/10.5281/zenodo.8116370

Prof. Dr. habil. Angela Lausch
Dr. Jan Bumberger
Prof. Dr. Marion Pause
Prof. Dr. Erik Borg
Dr. Peter Selsam (Developer of ESIS)

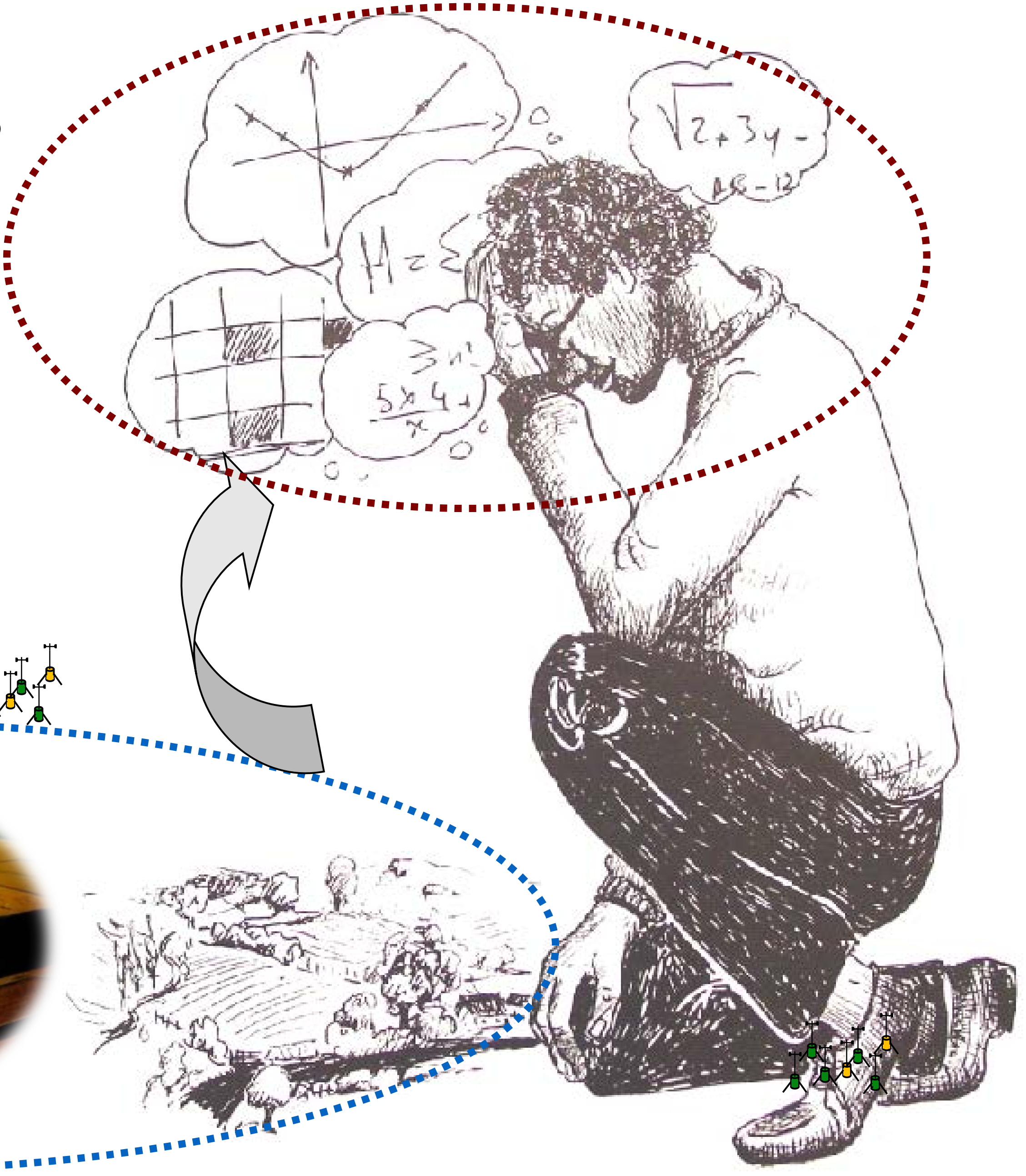
Helmholtz Centre for Environmental Research GmbH
– UFZ Permoserstraße 15, 04318 Leipzig, Germany
angela.lausch@ufz.de, peter.selsam@ufz.de

Selsam, P., Bumberger, J., Wellmann, T., Pause, M., Gey, R., Borg, E., Lausch, A., 2024. Ecosystem Integrity Remote Sensing—Modelling and Service Tool—ESIS/Imalys. Remote Sens. 16, 1139. https://doi.org/10.3390/rs16071139

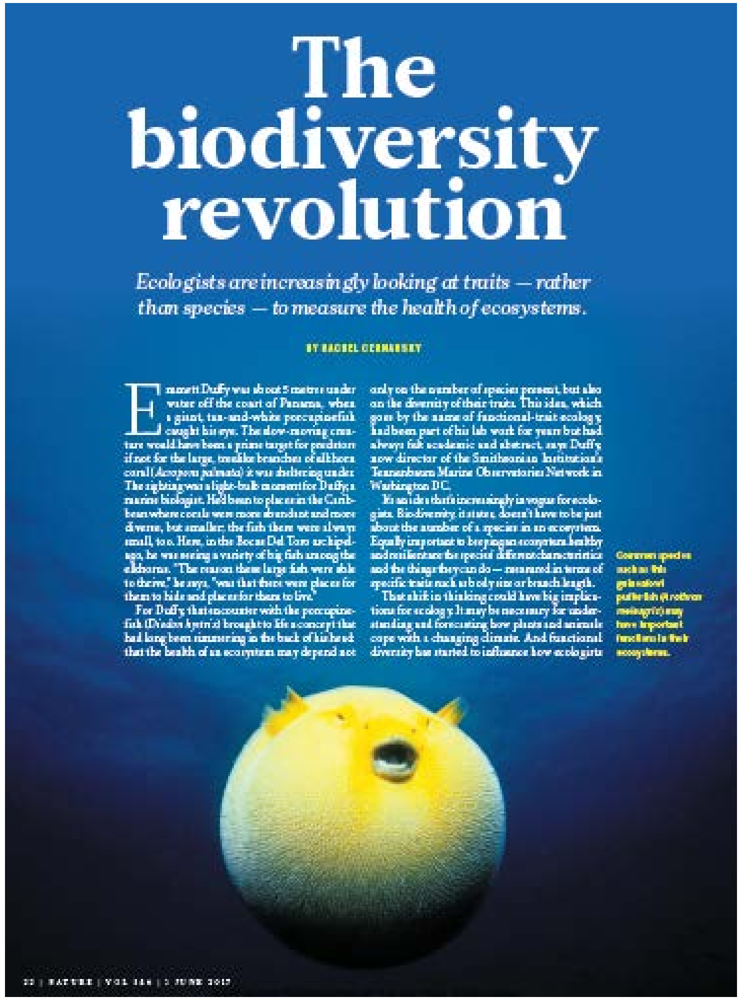
- How can we **monitor vegetation- & geodiversity & hazards** with **RS**?

- How can we **link in-situ (field) data with RS** approaches?

- How can we quantify
  - Genese patterns/diversity
  - Trait pattern/diversity
  - Structural patterns/diversity
  - Taxonomic patterns/diversity
  - **Functional patterns/diversity**



"Ecologists are increasingly looking **at traits** - **rather than species** - to measure the health of ecosystems"


The biodiversity revolution

Ecologists are increasingly looking at traits — rather than species — to measure the health of ecosystems.

BY RACHEL CERNANSKY

Traits

↓

Indicators & Filters of Bio-Geodiversity & Interactions

Status
Changes
Stress
Disturbances
Ressource limitation

↓

Trait-Variations

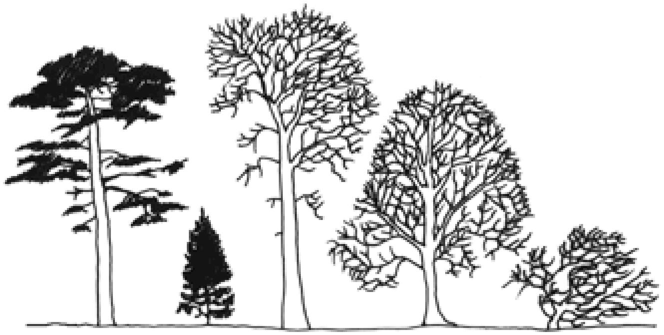
Cernansky, R. Biodiversity moves beyond counting species. *Nature* 2017, *546*, 22–24

Approach: Trait concept – Plant species

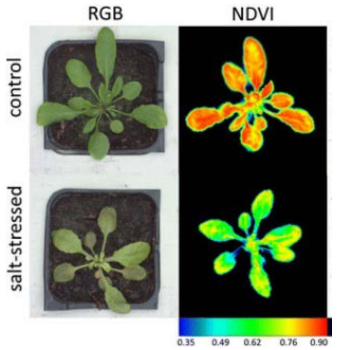
➢**Plant traits → „Anatomical, morphological, biochemical, physiological, structural or phenological characteristics of individuals, plants, populations, communities …..“**

(modified after Kattge et al., 2011)

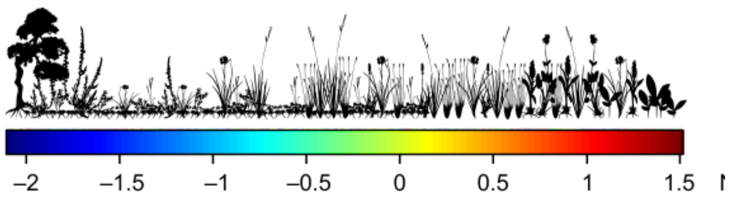
Growth-characteristics



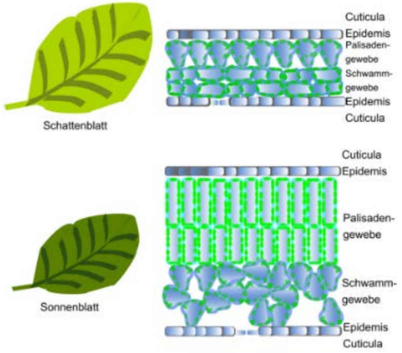
Leaf-biochemic traits



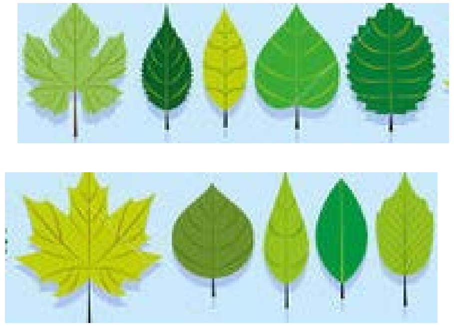
Flower-gradients



Leaf-morphology

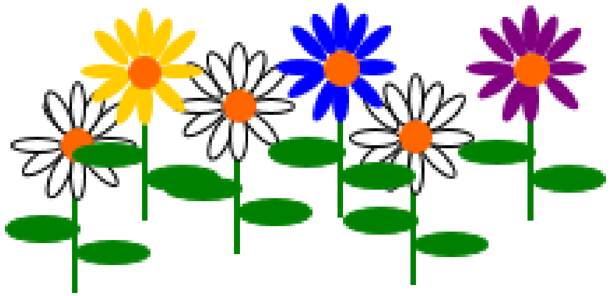


Leaf-shape



Flower-shape

Flower-colour



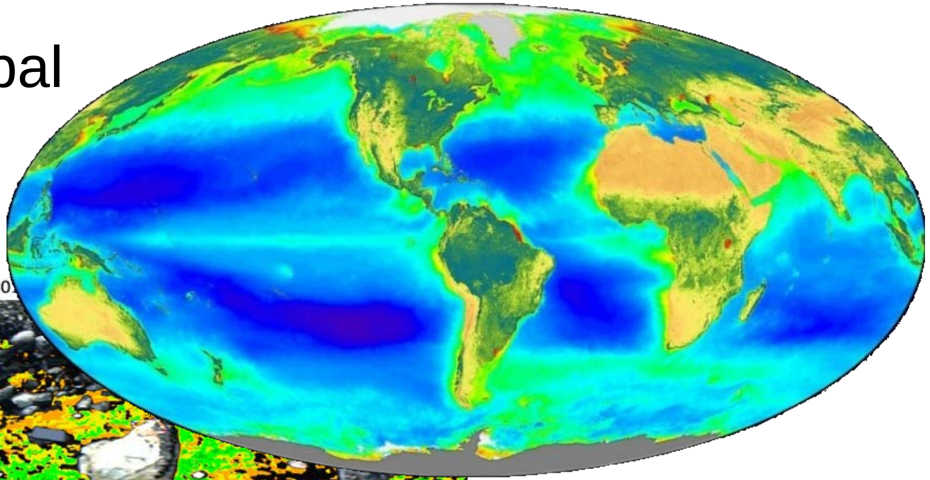
Kattge, J., et al.2011. TRY - a global database of plant traits. Glob. Chang. Biol. 17, 2905–2935. doi:10.1111/j.1365-2486.2011.02451.x

Approach: Trait concept – Plant species - Scaling

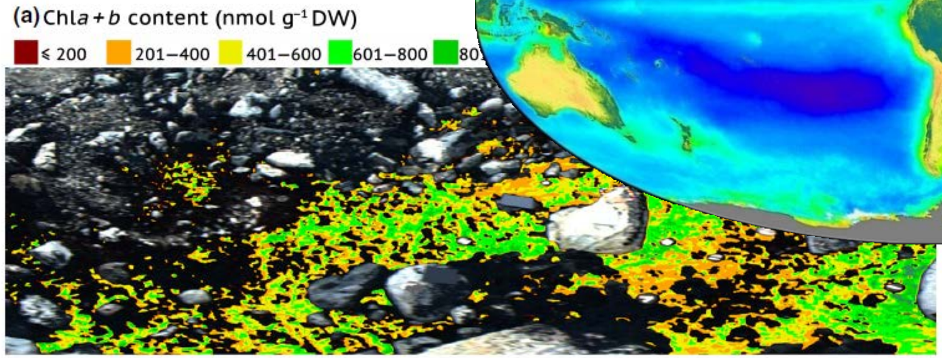
- Traits → exist on all spatial, temporal & directional scales
- Traits → important linking between scales

e.g. NDVI, Greeness

Global

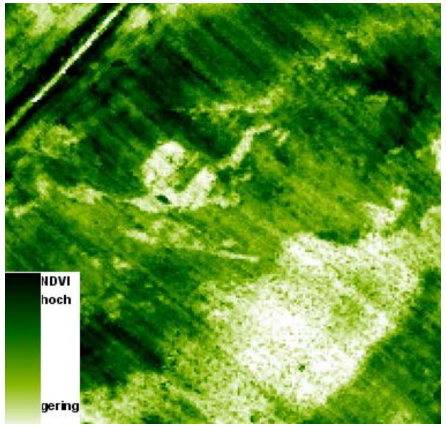


Local

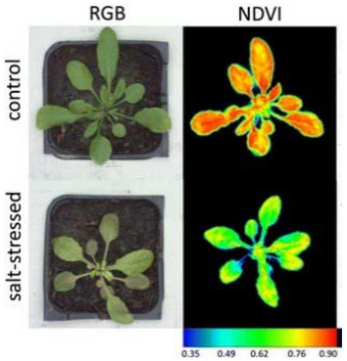


Malenovsky et al., 2015; https://upload.wikimedia.org

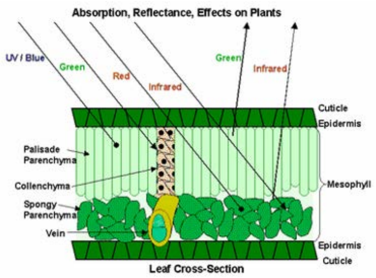
Plot



Individual



Cellular



Lausch, A., et. al., 2016. Understanding Forest Health with Remote Sensing -Part I-A Review of Spectral Traits, Processes and Remote-Sensing Characteristics. Remote Sens. 2016, Vol. 8, Page 1029 8, 1029. doi:10.3390/RS8121029

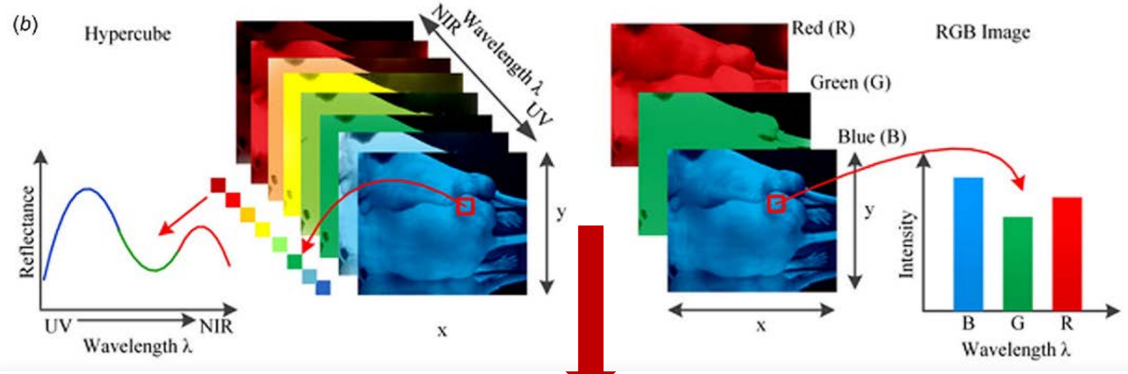
Approach: Remote Sensing to Monitor Vegetation diversity & Changes

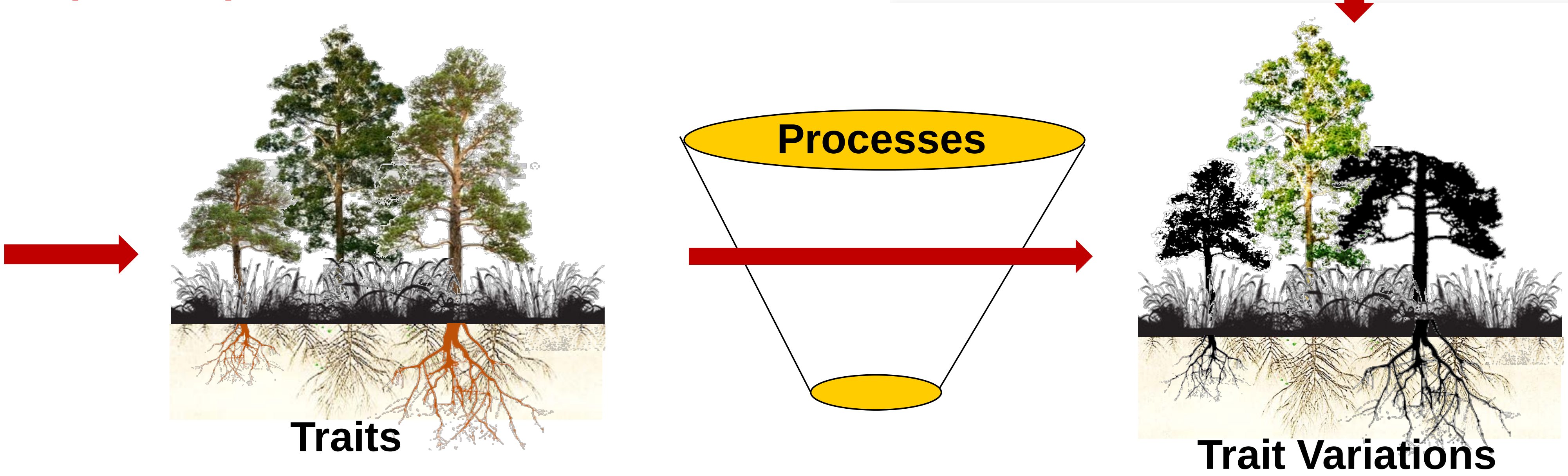
- Remote Sensing (RS) → Physical based system, but:
- RS records „Traits and Trait variations“ of
- surface, vegetation, soil, water …

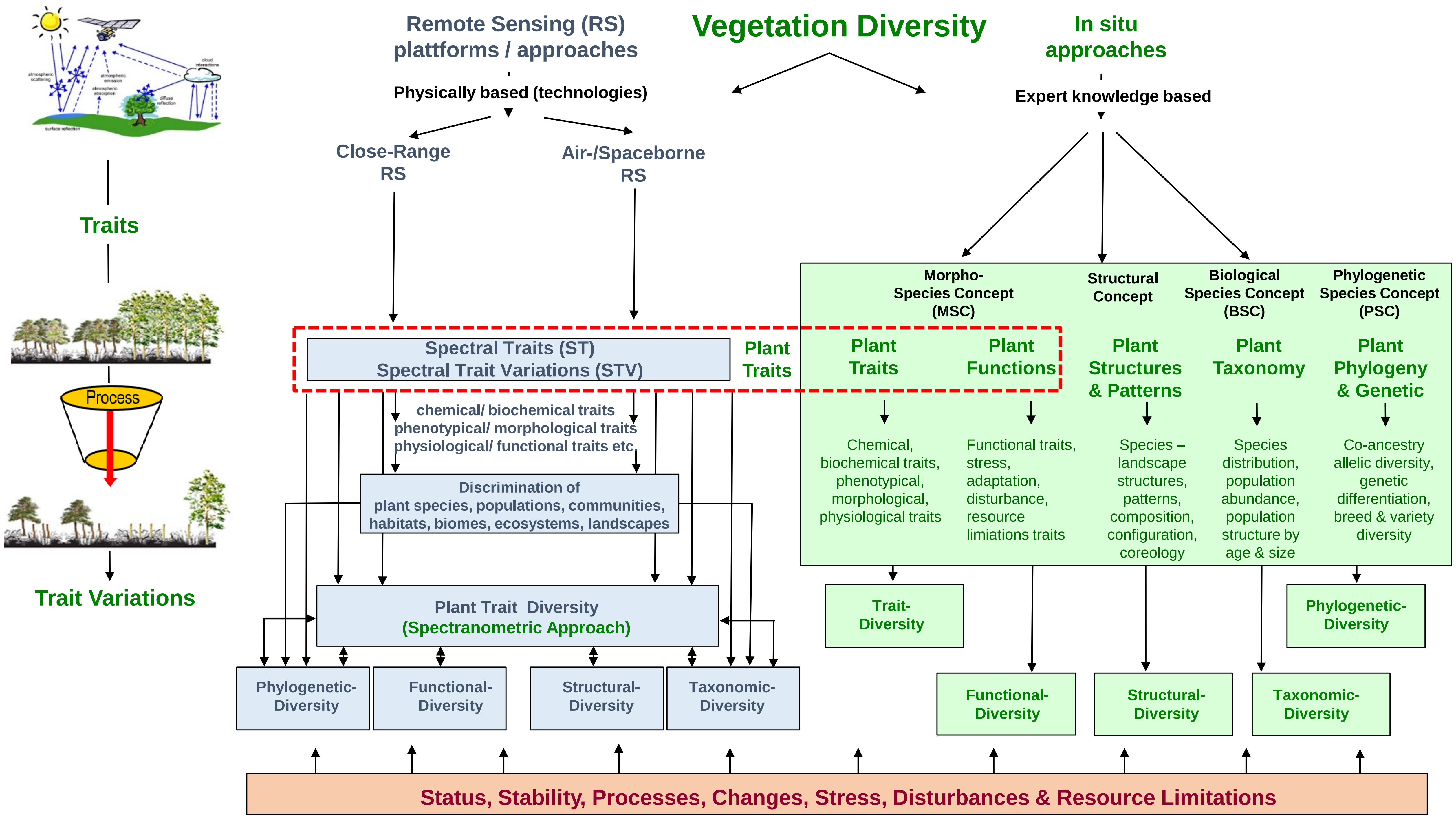
- Bio-and Geodiversity and their interactions!

- Spectral response, is a reaction to
  - status, changes, structures, processess
  - disturbances,
  - ressource limitations
  - pattern process interaction

EnMAP

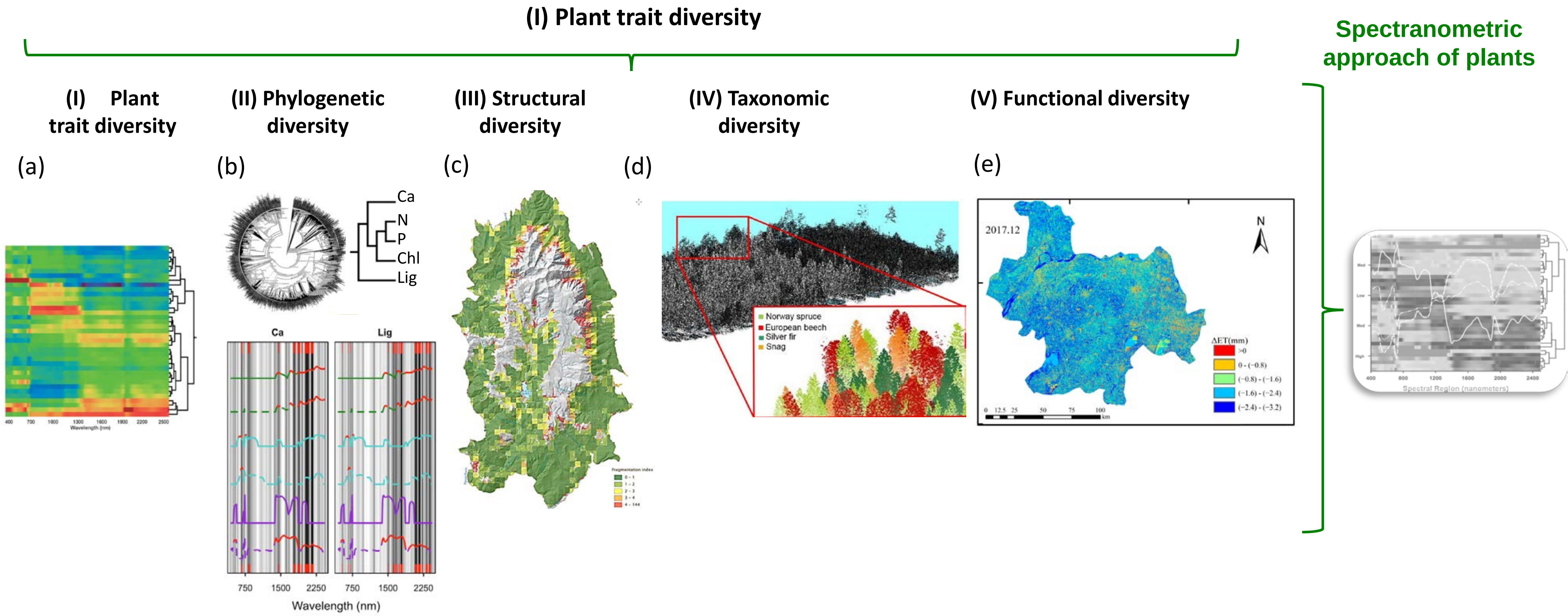




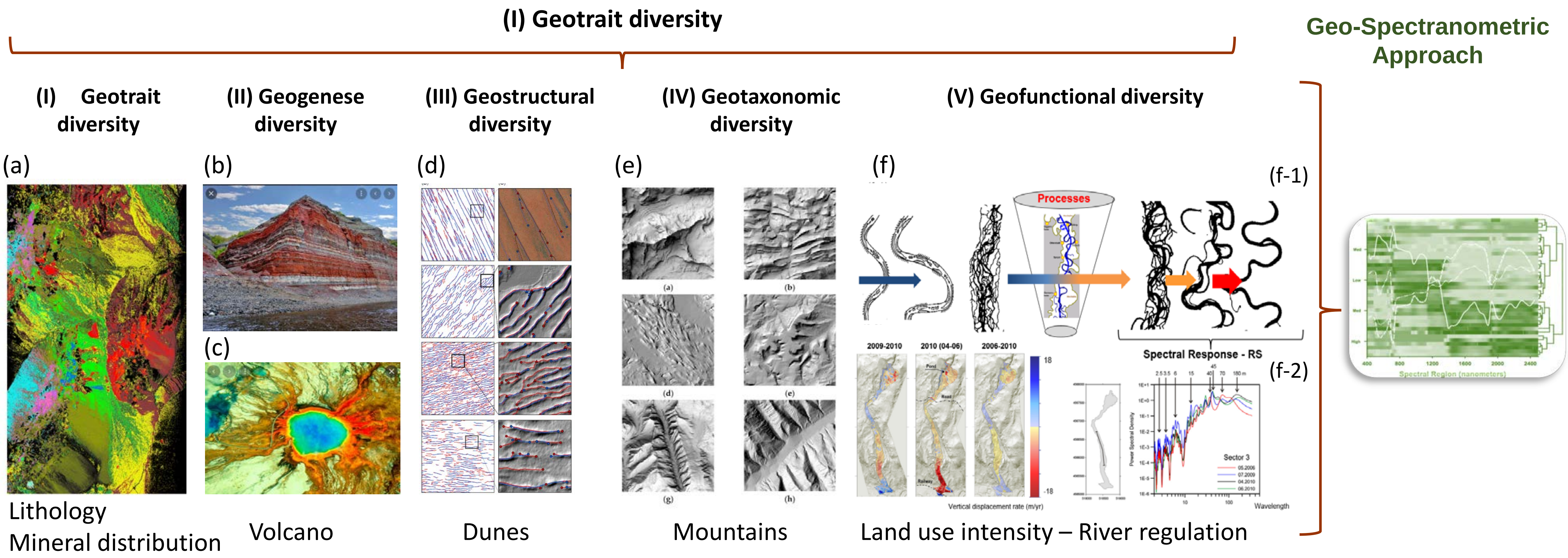


Remote Sensing (RS)
plattforms / approaches
Vegetation Diversity
In situ
approaches
Physically based (technologies)
Expert knowledge based
Close-Range
RS
Air-/Spaceborne
RS
Traits
Process
Trait Variations
Morpho-
Species Concept
(MSC)
Structural
Concept
Biological
Species Concept
(BSC)
Phylogenetic
Species Concept
(PSC)
Spectral Traits (ST)
Spectral Trait Variations (STV)
Plant
Traits
Plant
Traits
Plant
Functions
Plant
Structures
& Patterns
Plant
Taxonomy
Plant
Phylogeny
& Genetic
chemical/ biochemical traits
phenotypical/ morphological traits
physiological/ functional traits etc.
Chemical,
biochemical traits,
phenotypical,
morphological,
physiological traits
Functional traits,
stress,
adaptation,
disturbance,
resource
limiations traits
Species –
landscape
structures,
patterns,
composition,
configuration,
coreology
Species
distribution,
population
abundance,
population
structure by
age & size
Co-ancestry
allelic diversity,
genetic
differentiation,
breed & variety
diversity
Discrimination of
plant species, populations, communities,
habitats, biomes, ecosystems, landscapes
Plant Trait Diversity
(Spectranometric Approach)
Trait-
Diversity
Phylogenetic-
Diversity
Phylogenetic-
Diversity
Functional-
Diversity
Structural-
Diversity
Taxonomic-
Diversity
Functional-
Diversity
Structural-
Diversity
Taxonomic-
Diversity
Status, Stability, Processes, Changes, Stress, Disturbances & Resource Limitations

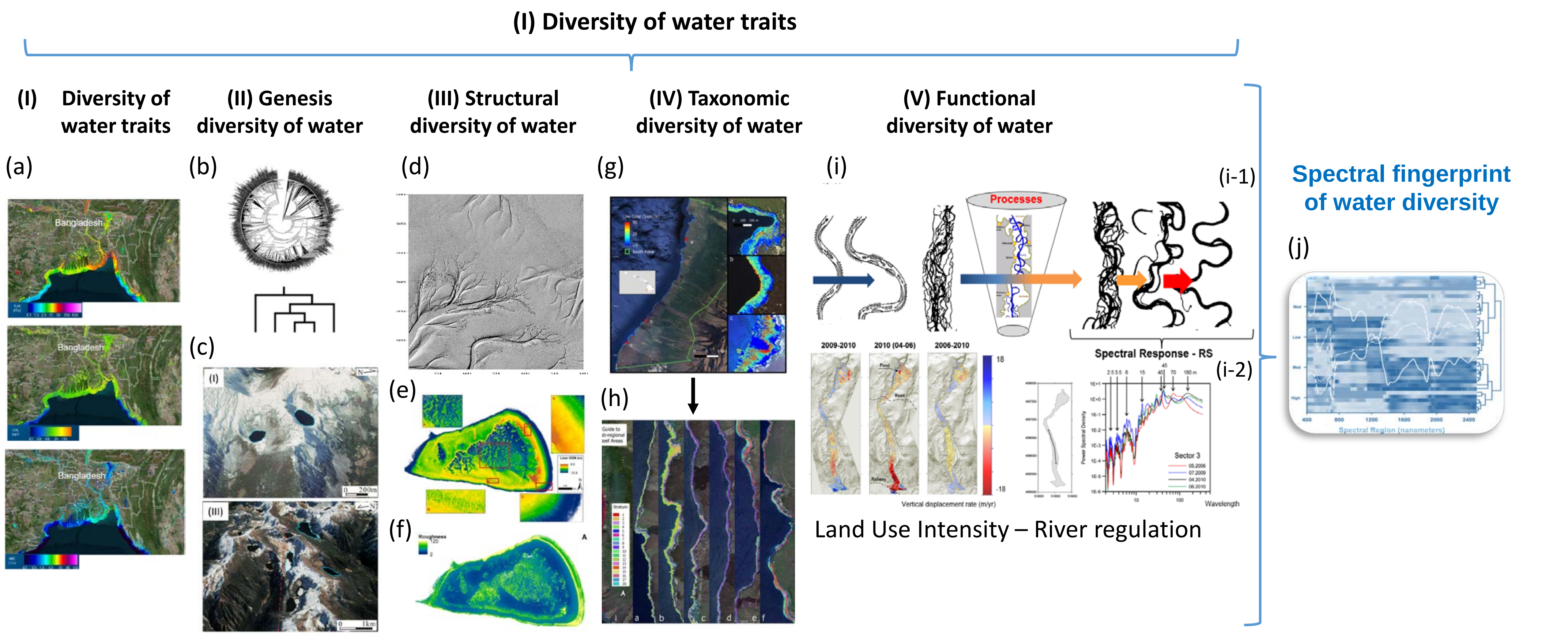
Remote Sensing - Spectral Fingerprint of Vegetation Diversity



Remote Sensing - Spectral Fingerprint of Geodiversity

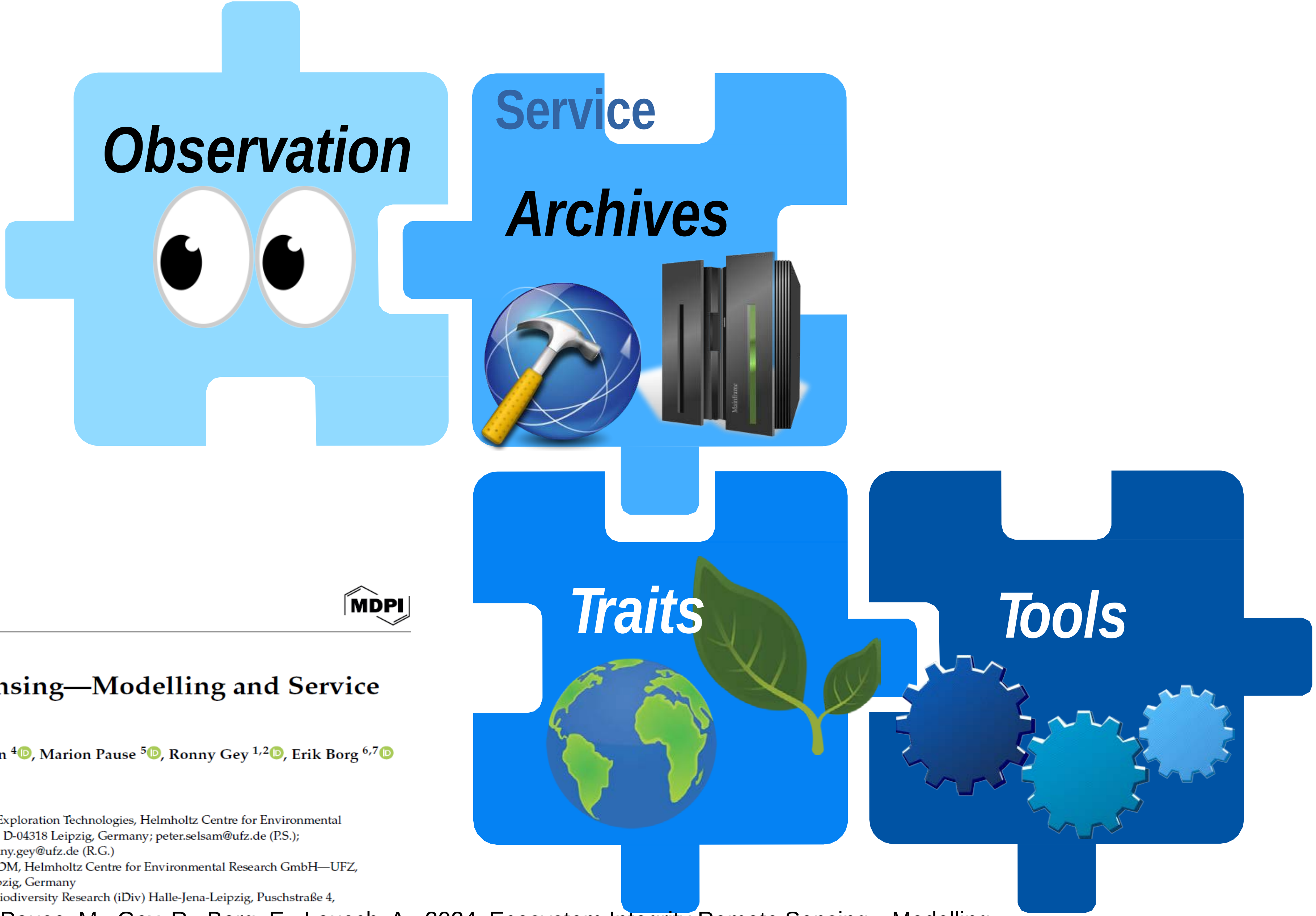


Monitoring the five characteristics of water diversity using remote sensing



EcoSystem Integrity RS/Modeling – Service – Tool (ESIS)

- https://zenodo.org/record/7189794#.Y0bEz0pBwkI



remote sensing

MDPI

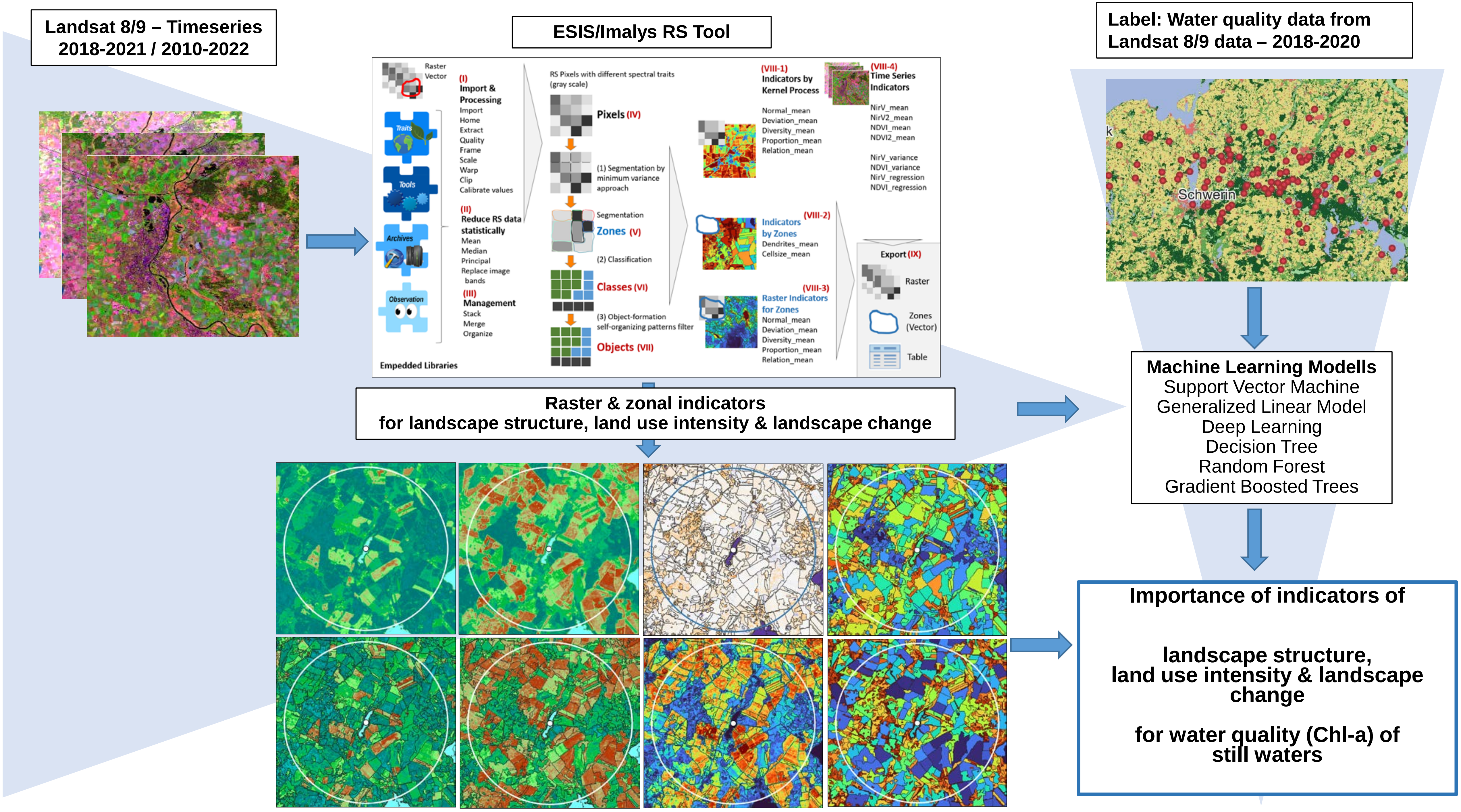
Technical Note

Ecosystem Integrity Remote Sensing—Modelling and Service Tool—ESIS/Imalys

Peter Selsam [1,2], Jan Bumberger [1,2,3], Thilo Wellmann [4], Marion Pause [5], Ronny Gey [1,2], Erik Borg [6,7] and Angela Lausch [5,8,9,*]

1 Department of Monitoring and Exploration Technologies, Helmholtz Centre for Environmental Research—UFZ, Permoserstr 15, D-04318 Leipzig, Germany; peter.selsam@ufz.de (P.S.); jan.bumberger@ufz.de (J.B.); ronny.gey@ufz.de (R.G.)
2 Research Data Management—RDM, Helmholtz Centre for Environmental Research GmbH—UFZ, Permoserstraße 15, D-04318 Leipzig, Germany
3 German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Puschstraße 4,

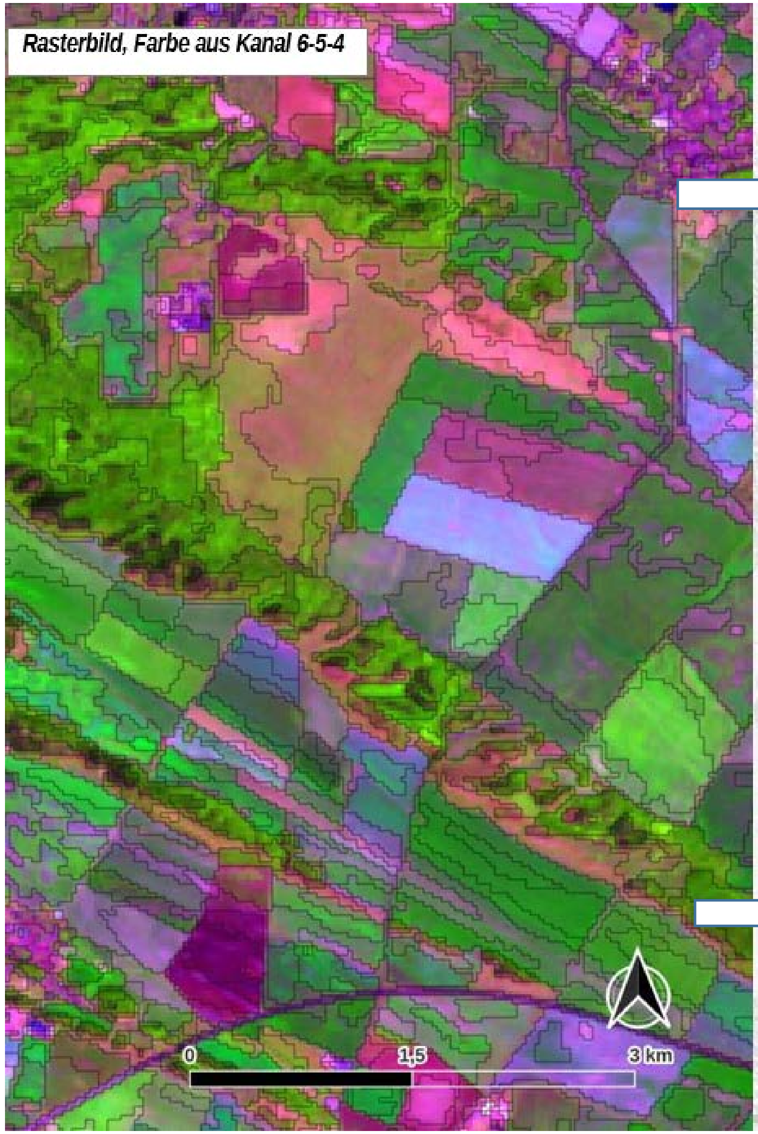
Selsam, P., Bumberger, J., Wellmann, T., Pause, M., Gey, R., Borg, E., Lausch, A., 2024. Ecosystem Integrity Remote Sensing—Modelling and Service Tool—ESIS/Imalys. Remote Sens. 16, 1139. https://doi.org/10.3390/rs16071139



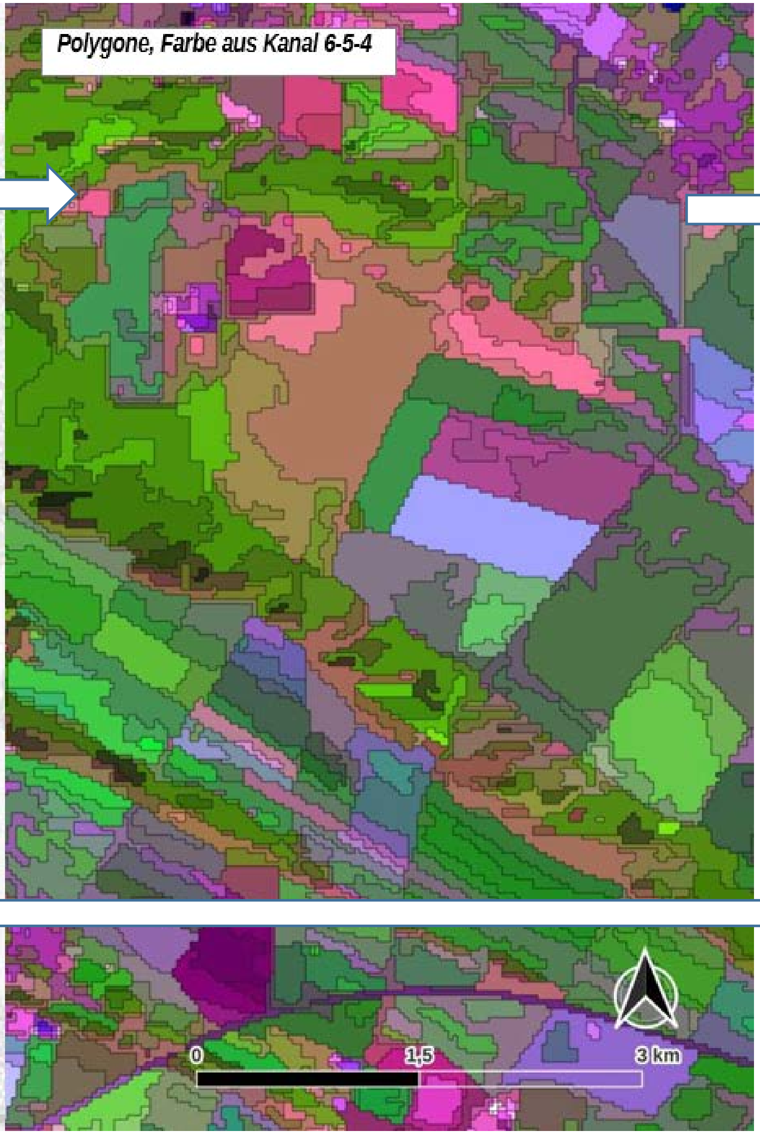
Landsat 8/9 – Timeseries
2018-2021 / 2010-2022
ESIS/Imalys RS Tool
Raster
Vector
(I)
Import & Processing
Import
Home
Extract
Quality
Frame
Scale
Warp
Clip
Calibrate values
Traits
Tools
Archives
Observation
(II)
Reduce RS data statistically
Mean
Median
Principal
Replace image bands
(III)
Management
Stack
Merge
Organize
Empedded Libraries
RS Pixels with different spectral traits (gray scale)
Pixels (IV)
(1) Segmentation by minimum variance approach
Segmentation
Zones (V)
(2) Classification
Classes (VI)
(3) Object-formation self-organizing patterns filter
Objects (VII)
(VIII-1)
Indicators by Kernel Process
Normal_mean
Deviation_mean
Diversity_mean
Proportion_mean
Relation_mean
(VIII-4)
Time Series Indicators
NirV_mean
NirV2_mean
NDVI_mean
NDVI2_mean
NirV_variance
NDVI_variance
NirV_regression
NDVI_regression
Indicators by Zones (VIII-2)
Dendrites_mean
Cellsize_mean
(VIII-3)
Raster Indicators for Zones
Normal_mean
Deviation_mean
Diversity_mean
Proportion_mean
Relation_mean
Export (IX)
Raster
Zones (Vector)
Table
Raster & zonal indicators
for landscape structure, land use intensity & landscape change
Label: Water quality data from
Landsat 8/9 data – 2018-2020
Schwerin
Machine Learning Modells
Support Vector Machine
Generalized Linear Model
Deep Learning
Decision Tree
Random Forest
Gradient Boosted Trees
Importance of indicators of
landscape structure,
land use intensity & landscape change
for water quality (Chl-a) of
still waters

ESIS Approach: - 2. Zone Level (Segmentation)

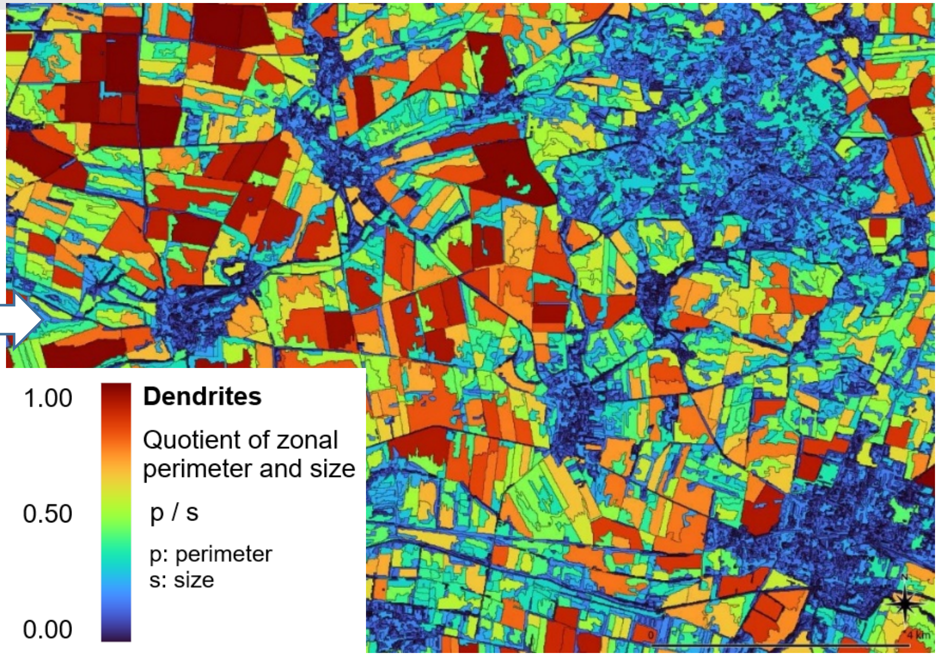
1. Spectral RS patterns



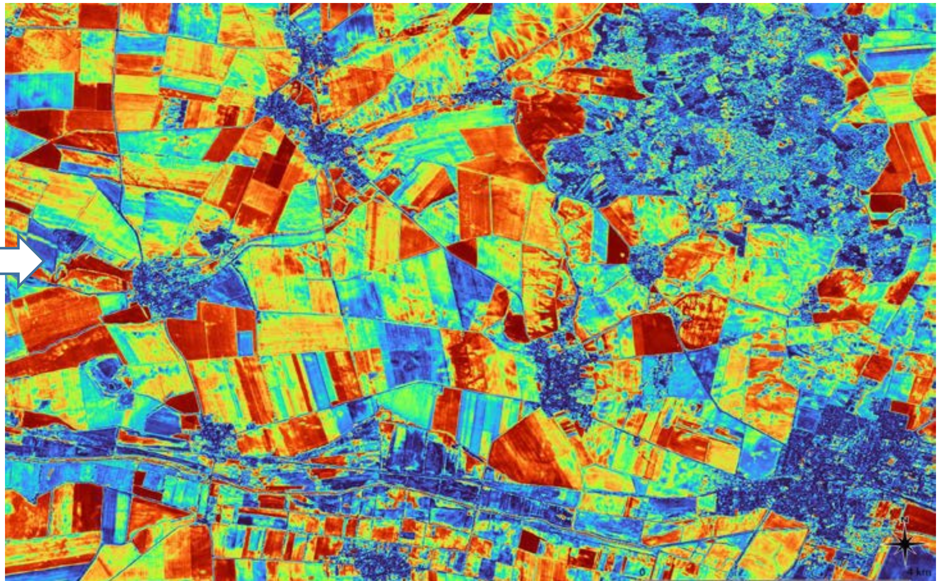
2. Zonal patterns



Zonal patterns (e.g. Dendrites)



Spectral RS patterns



Functional patterns

Raster-Indicator "Variance" –
→ Plant as proxy of soil characteristics (soil moisture)

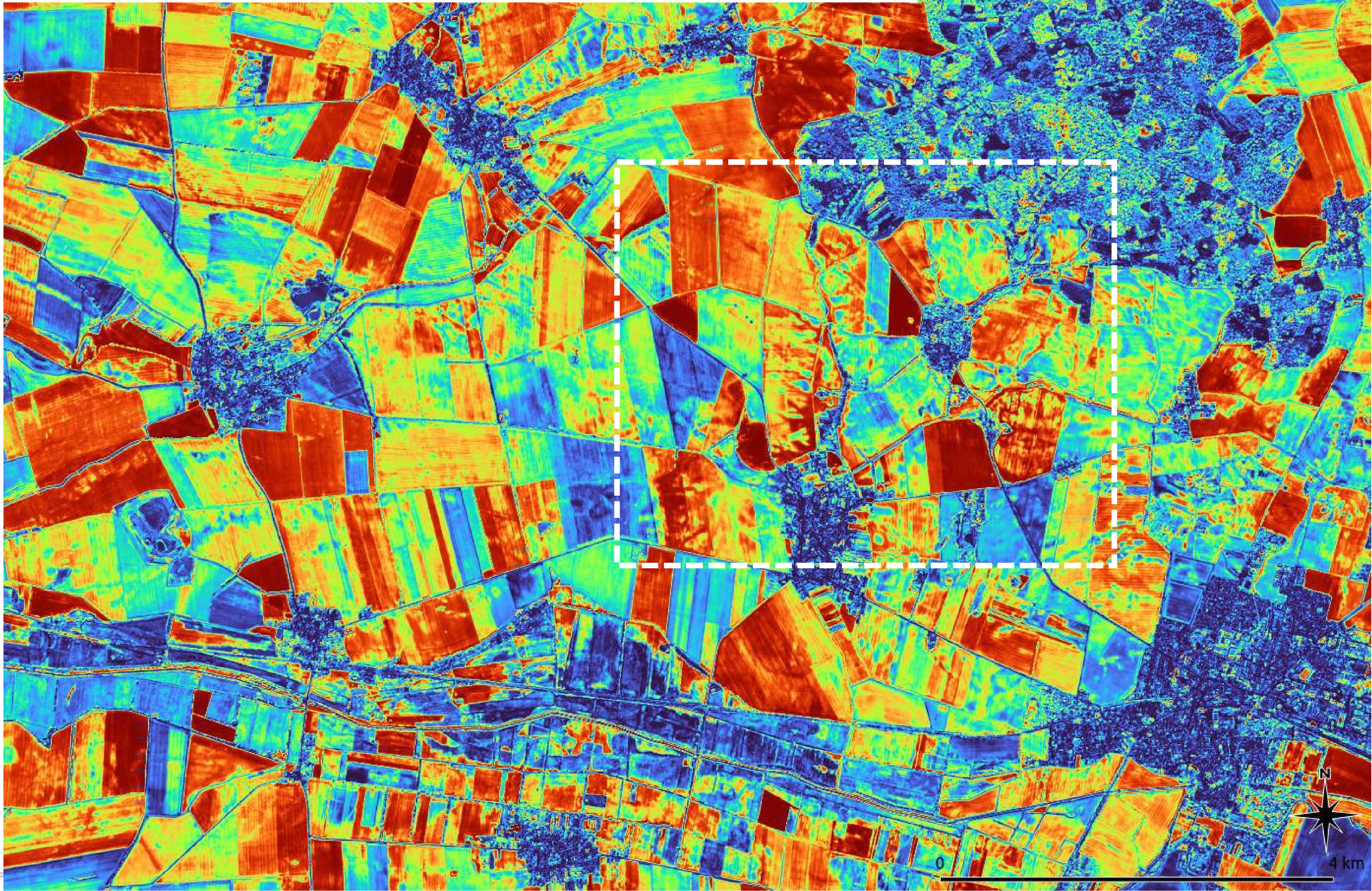
Raster-Indicator "Variance"

Yearly Change as Variance

Variance of the yearly brightness for 5 years

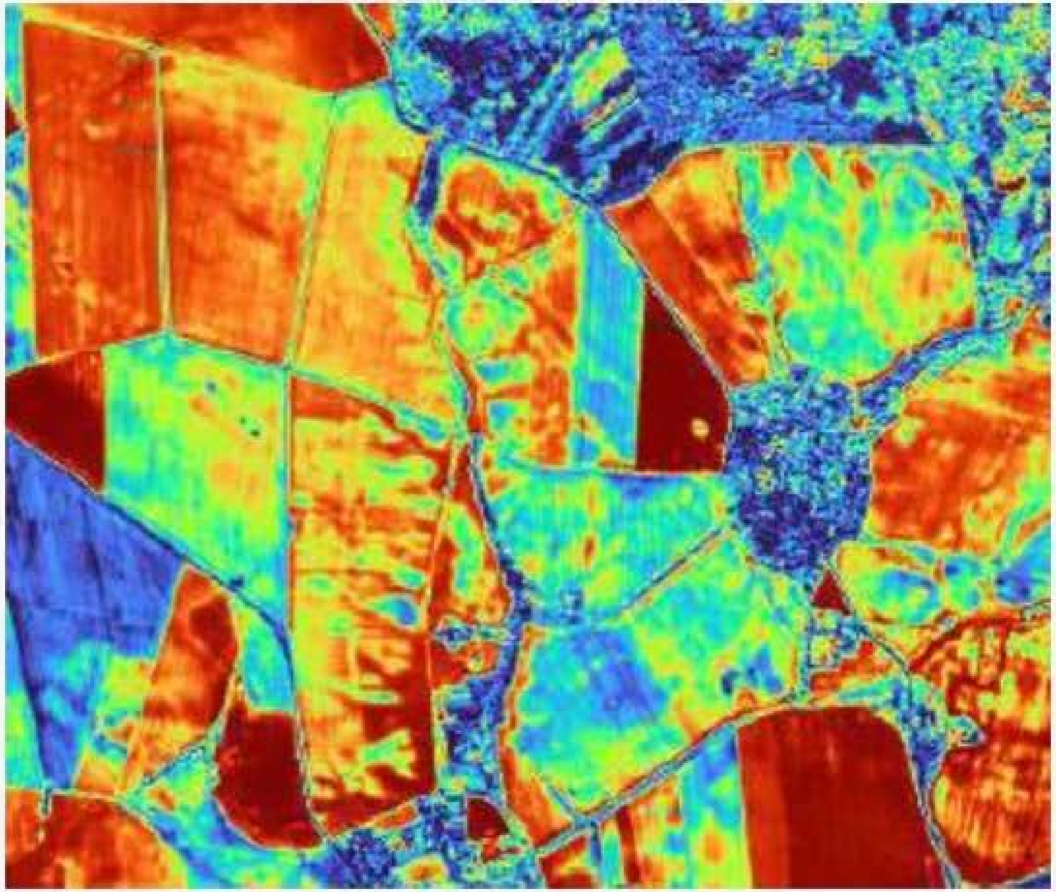
All accepted images between 2017 and 2021 Bands 2-3-4-8, Sentinel-2

Values: 0.0 … 0.46 (Blue … Red)



Functional patterns

Raster-Indicator "Variance" → Plant as proxy of soil characteristics (soil moisture)



Yearly Change as Variance

Variance of the yearly brightness for 5 years

All accepted images between 2017 - 2021
Bands 2-3-4-8, Sentinel-2

ESIS - EcoSystem Integrity – Conclusions!

1. **Traits/Trait variation** of **Geo-& Vegetationsdiversity** can be monitored with **RS**
2. **Trait/Trait variation exist on all spatio-temporal scale**
3. **ESIS Tool - derived genesis, structural, taxonomic, functional & temporal patterns/traits of Geo- & vegetations diversity as inputs for ecological modeling**
4. **Combining – In-Situ and RS-Approaches for monitoring EcoSystem Integrity**

ESIS - Requirements

- **Standardisability**
- **Scalen invariance**
- **Transferability to other regions**
- **Modularity (all RS methods can be combined modularly in ESIS)**
- **Sensor-independent (RGB, MSP, HSP, Radar, TIR, LiDAR)**
- **Coupling RS indicators & quantification, & ecological modelling in one tool (ESIS)**

Lausch - References

- **Lausch, A**., Bannehr, L., Berger, S.A., Borg, E., Bumberger, J., Hacker, J.M., Heege, T., Hupfer, M., Jung, A., Kuhwald, K., Oppelt, N., Pause, M., Schrodt, F., Selsam, P., von Trentini, F., Vohland, M., Glässer, C., 2024. **Monitoring Water Diversity and Water Quality with Remote Sensing and Traits**. Remote Sens. 16, 2425. https://doi.org/10.3390/rs16132425
- Selsam, P., Bumberger, J., Wellmann, T., Pause, M., Gey, R., Borg, E., **Lausch, A**., 2024. **Ecosystem Integrity Remote Sensing—Modelling and Service Tool—ESIS/Imalys**. Remote Sens. 16, 1139. https://doi.org/10.3390/rs16071139
- **Lausch, A.,** Selsam, P., Pause, M., Bumberger, J., 2024. **Monitoring vegetation- and geodiversity with remote sensing and traits**. Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. 382. https://doi.org/10.1098/rsta.2023.0058
- Schrodt, F., et. al. 2024. **The status and future of essential geodiversity variables**. Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. 382. https://doi.org/10.1098/rsta.2023.0052
- **Lausch et al., 2022. Remote Sensing of Geomorphodiversity Linked to Biodiversity**—Part III: Traits, Processes and Remote Sensing Characteristics. Remote Sens. 2022, 14, 2279. https://doi.org/10.3390/rs14092279
- **Lausch, A.;** et al., **2020**. **Linking Remote Sensing and Geodiversity and Their Traits Relevant to Biodiversity**—Part II: **Geomorphology, Terrain and Surfaces**. Remote Sens. 12, 3690. https://doi.org/10.3390/rs12223690
- **Lausch, A.;** Baade, J.; Bannehr, L.; Borg, E.; Bumberger, J.; Chabrilliat, S.; Dietrich, P.; Gerighausen, H.; Glässer, C.; Hacker, J.M.; et al. **Linking Remote Sensing and Geodiversity** and Their Traits Relevant to Biodiversity—Part I: **Soil Characteristics**. *Remote Sens.* **2019**, *11*, 2356. https://doi.org/10.3390/rs11202356
- **Lausch, A.;** Borg, E.; Bumberger, J.; Dietrich, P.; Heurich, M.; Huth, A.; Jung, A.; Klenke, R.; Knapp, S.; Mollenhauer, H.; et al. Understanding **Forest Health with Remote Sensing**, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches. *Remote Sens.* **2018**, *10*, 1120
- **Lausch, A.;** Erasmi, S.; King, D.; Magdon, P.; Heurich, M. Understanding **Forest Health with Remote Sensing**-Part II—A Review of Approaches and Data Models. *Remote Sens.* **2017**, *9*, 129.
- **Lausch, A**.; Erasmi, S.; King, D.J.; Magdon, P.; Heurich, M. Understanding **Forest Health with Remote Sensing** -Part I—A Review of Spectral Traits, Processes and Remote-Sensing Characteristics. *Remote Sens.* **2016**, *8*, 1029.
- **Lausch, A**.; Bannehr, L.; Beckmann, M.; Boehm, C.; Feilhauer, H.; Hacker, J.M.; Heurich, M.; Jung, A.; Klenke, R.; Neumann, C.; et al. **Linking Earth Observation and taxonomic, structural and functional biodiversity**: Local to ecosystem perspectives. *Ecol. Indic.* **2016**, *70*, 317–339.
- Skidmore, A.K., … **Lausch, A**., … et al, **2021**. Priority list of biodiversity metrics to observe from space. Nature. Ecol. Evol. https://doi.org/10.1038/s41559-021-01451-x

Scholar profile:
http://scholar.google.de/citations?user=gWU0UO0AAAAJ&hl=de
Research gate:
https://www.researchgate.net/profile/Angela_Lausch/