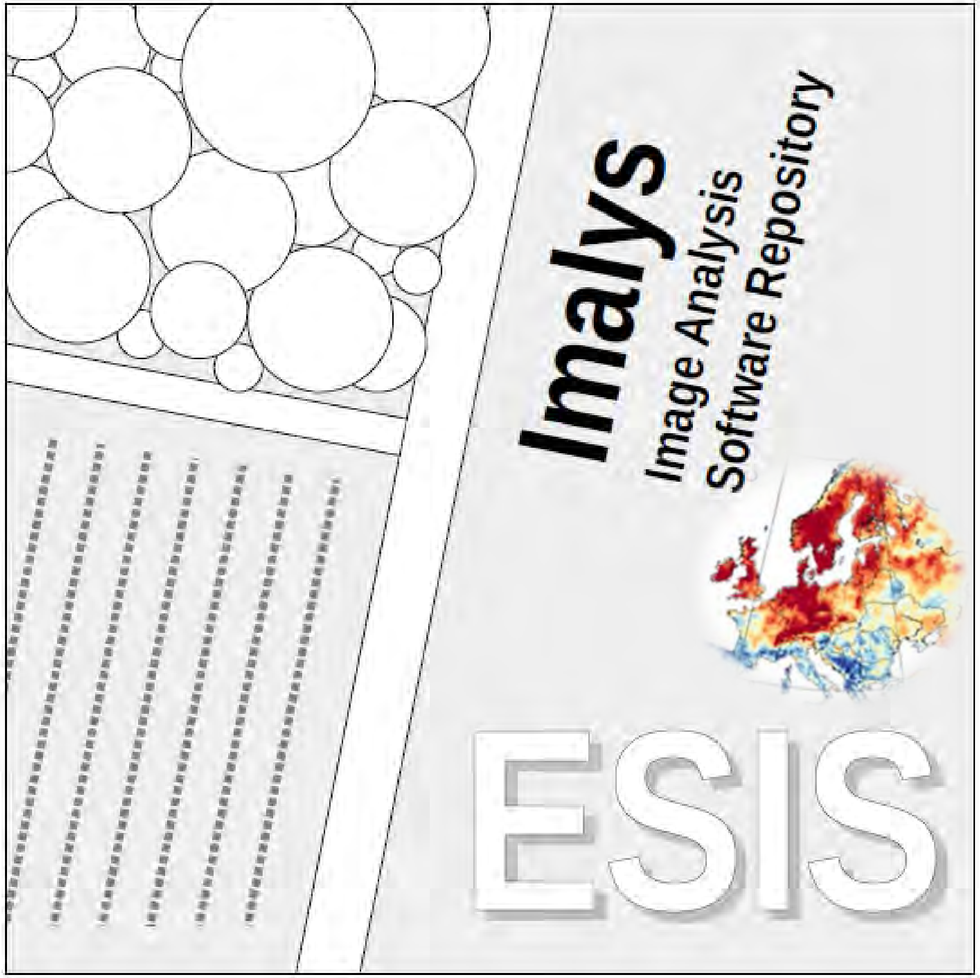
UFZ HELMHOLTZ Zentrum für Umweltforschung

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



Prof. Dr. habil. Angela Lausch
Dr. Jan Bumberger
Dr. Peter Selsam (Developer of ESIS)

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

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

Framework of Standard Observations

TERENO TERRESTRIAL ENVIRONMENTAL OBSERVATORIA

MOSES Modular Observation Solutions for Earth Systems

Concept of EcoSystem Integrity (Haase et al., 2018)

Abiotic Heterogeneity

Energy Budget

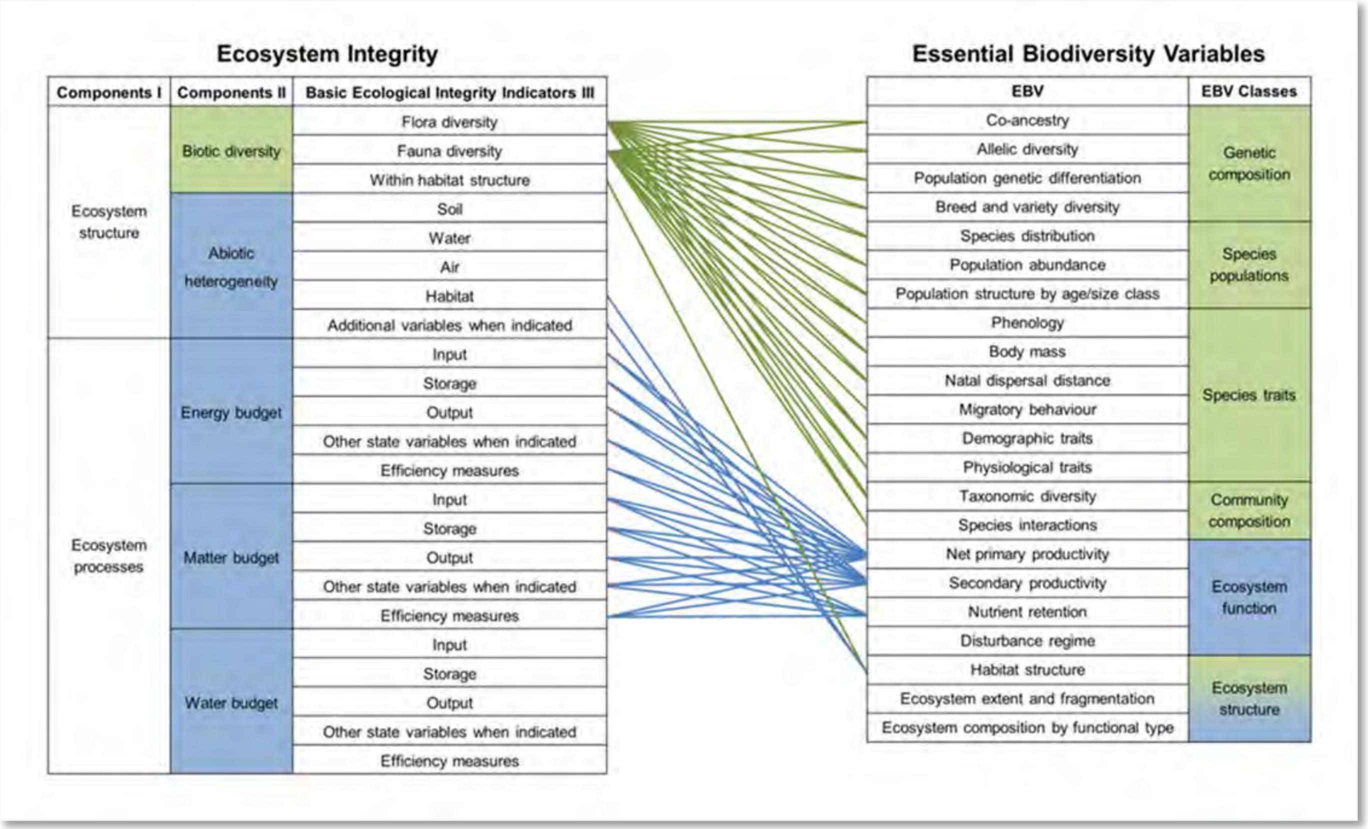
Water Budget

Biotic Diversity

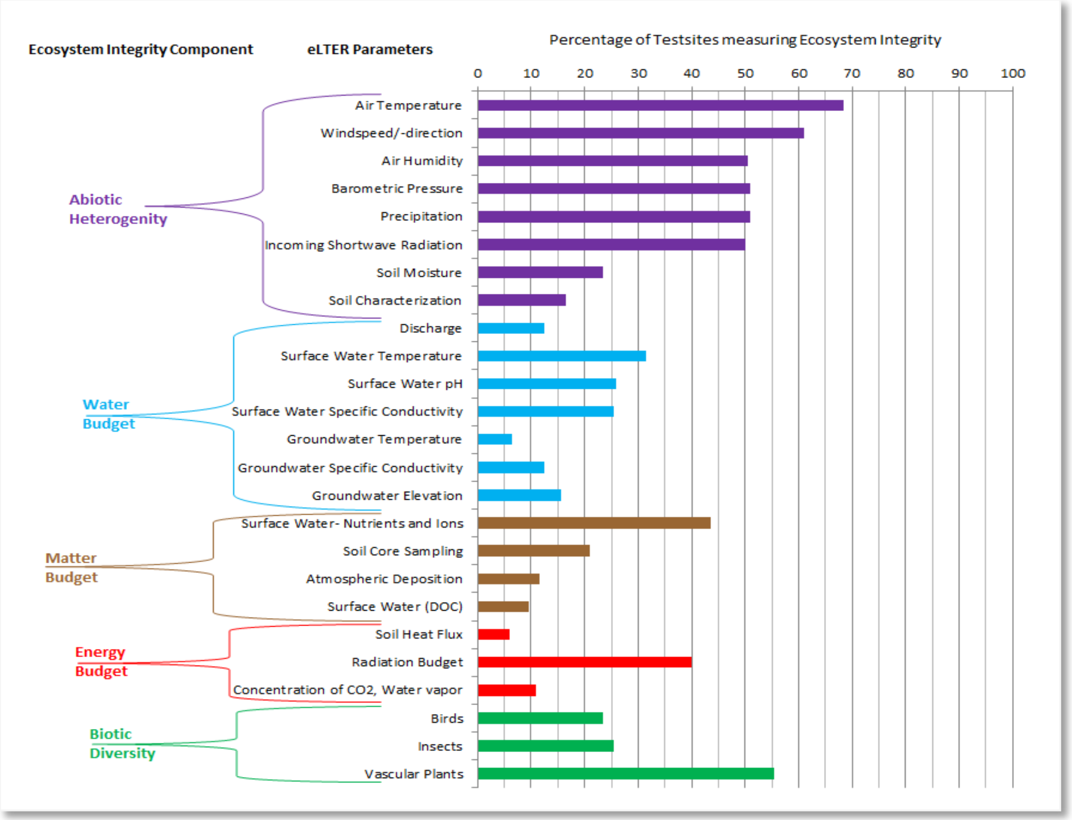
Matter Budget

Socio-Economy

Role of in-situ, Remote Sensing (RS), Traits to monitor EcoSystem Integrity



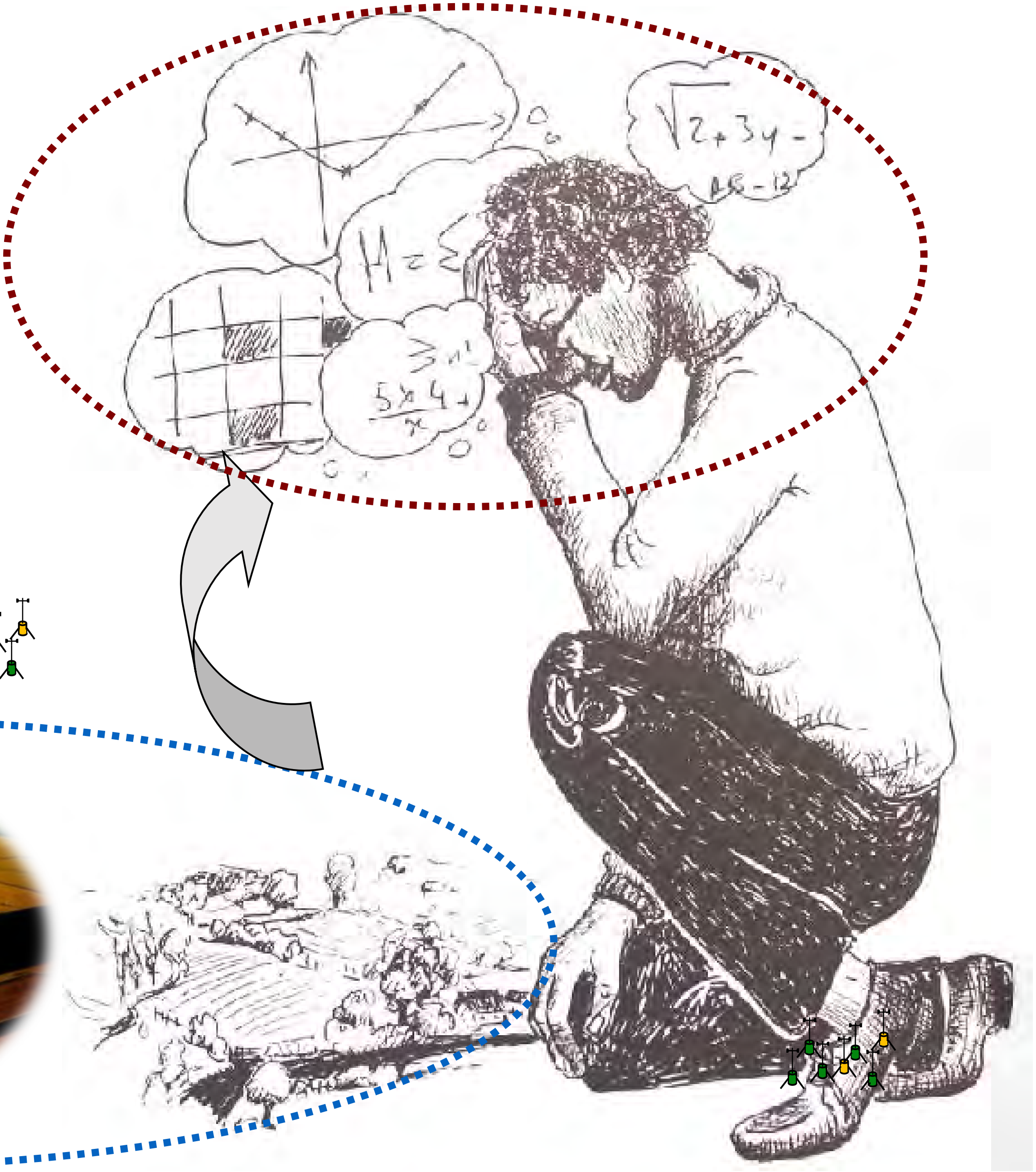
Haase, P., 2018. The next generation of site-based long-term ecological monitoring: Linking essential biodiversity variables and ecosystem integrity. Science of the Total Environment, 613, 1376-1384

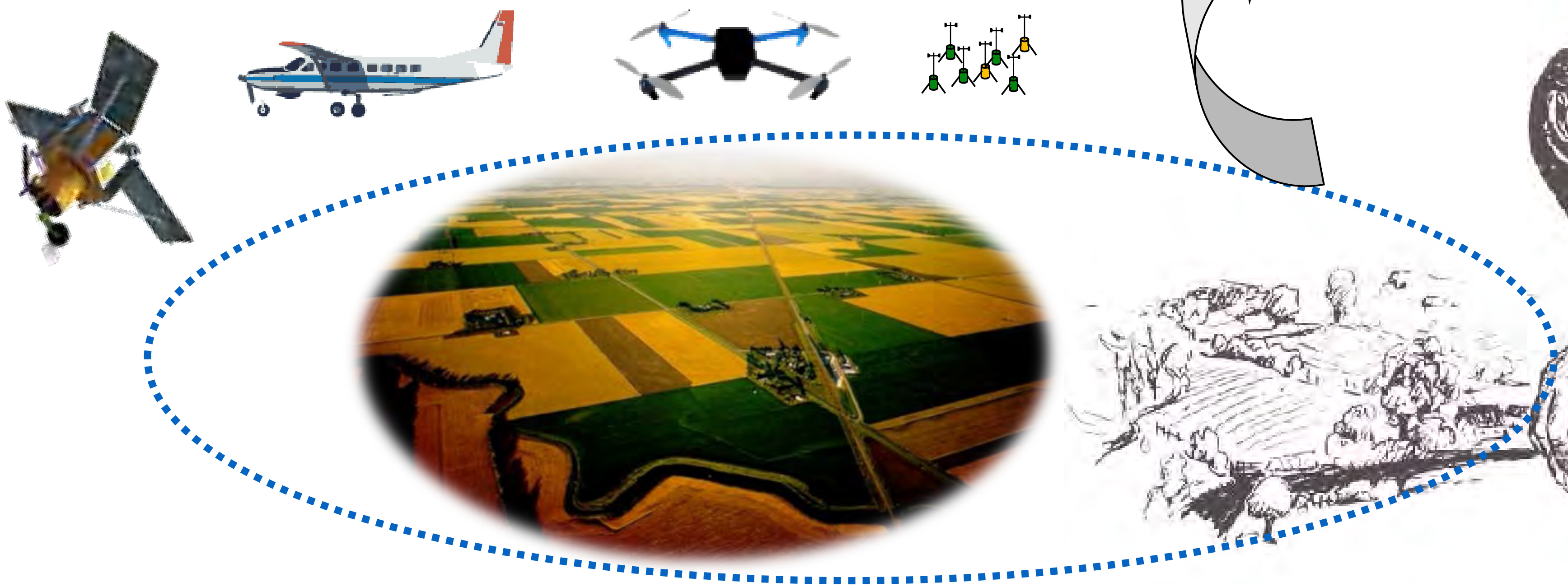


Mollenhauer, 2018 . Long-term *ecological monitoring systems in Europe–methods, scales, perspectives. Sci. Total Environ. 624, 968-978*

Zacharias, S., UFZ

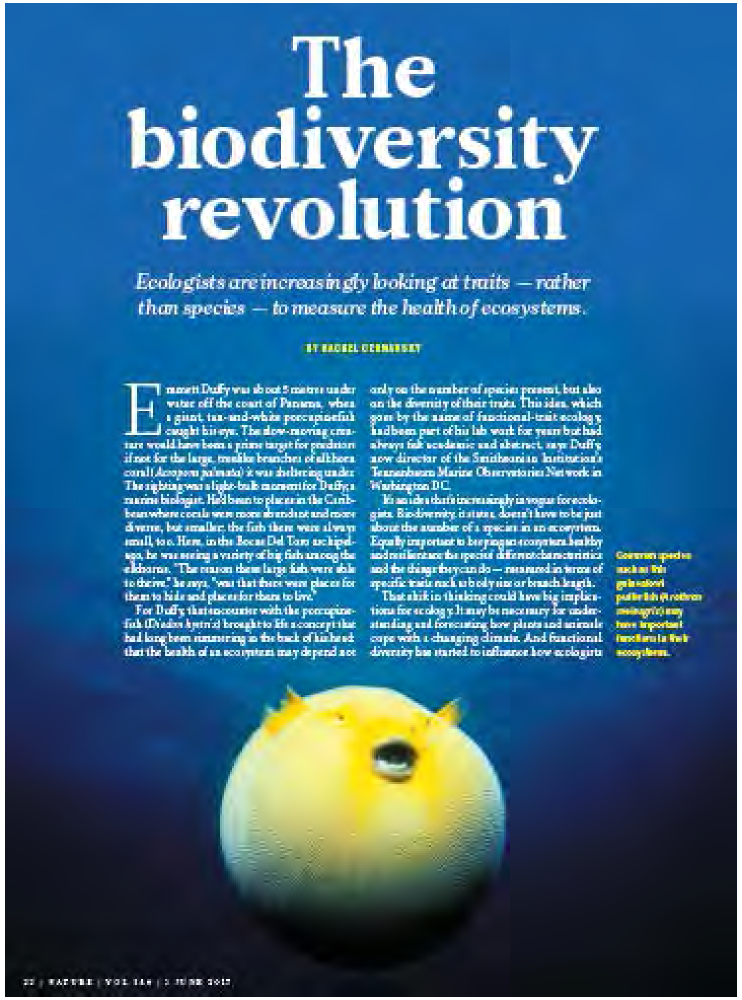
- How can we **monitor bio- & geodiversity & hazards** with **RS**?
- How can we **link in-situ (field) data with RS** approaches?
- How can we **model soil moisture?**





Approach: Trait concept

“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.

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 of Species

Species traits allowed us to go a "complete new way in understanding of fundamental questions of biodiversity"

(Green et al., 2008)

Traits help us to understand:

- **"Why organisms live where they do and how they will respond to environmental change"**

  (Green et al., 2008)

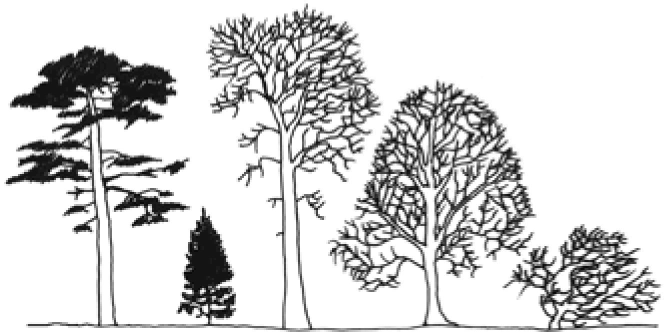
- **And how they interact to different stressors, disturbances, resource limitations and drivers**

Green, J.L.J.L., et al., 2008. Microbial biogeography: from taxonomy to traits. Science, 320, 1039–1043. doi:10.1126/science.1153475

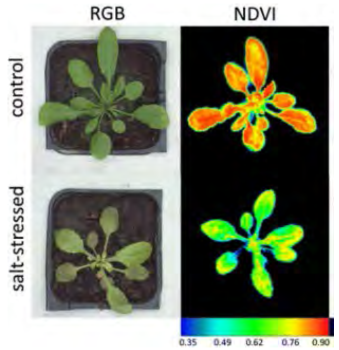
Approach: Trait concept – Plant species

➢**Plant traits → „Anatomical, morphological, biochemical, physiological, structural or phenological characteristics of individuals, plants, populations, communities …..“**
(modified after Kattge et al., 2011)

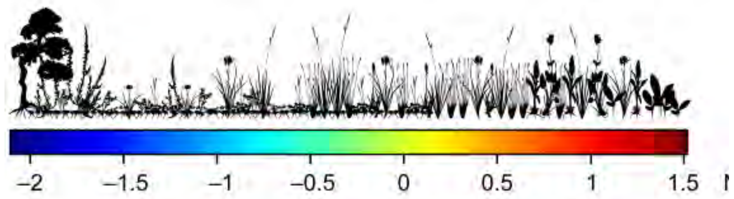
Growth-characteristics



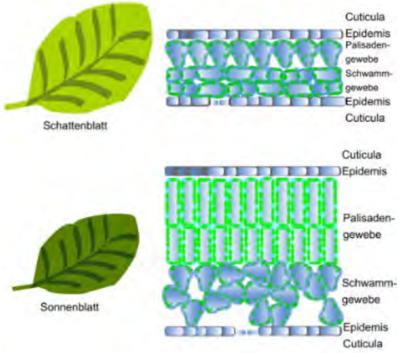
Leaf-biochemic traits



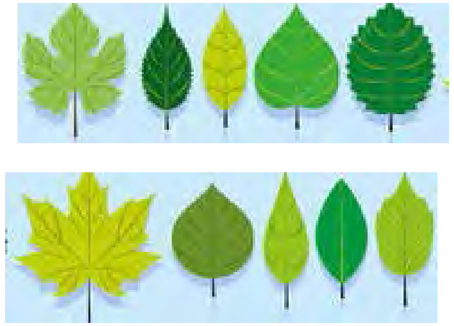
Flower-gradients



Leaf-morphology



Leaf-shape



Flower-shape

Flower-colour

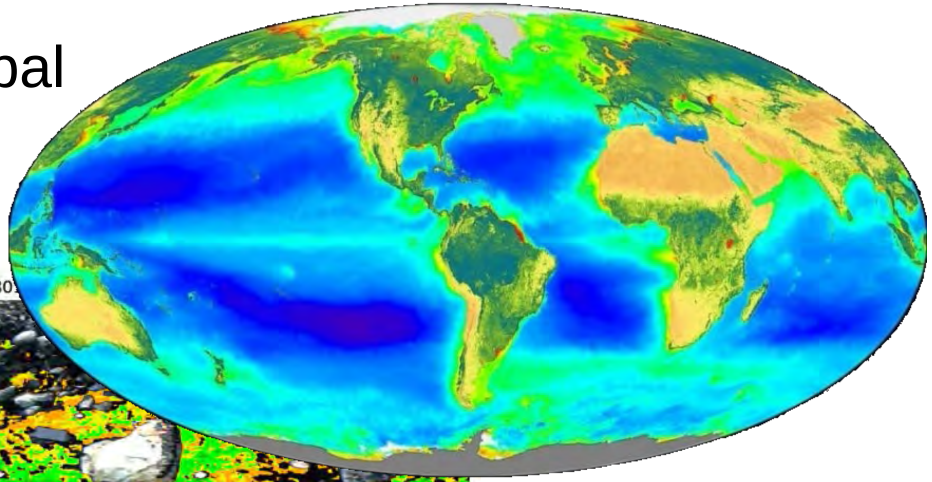
Kattge, J., et al.2011. TRY - a global database of plant traits. Glob. Chang. Biol. 17, 2905–2935. doi:10.1111/j.1365-2486.2011.02451.x

Approach: Trait concept – Plant species - Scaling

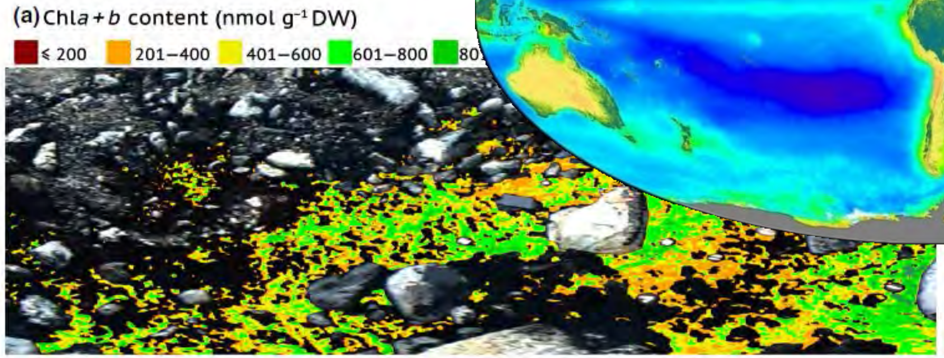
- Traits → exist on all spatial, temporal & directional scales
- Traits → important linking between scales

e.g. NDVI, Greeness

Global

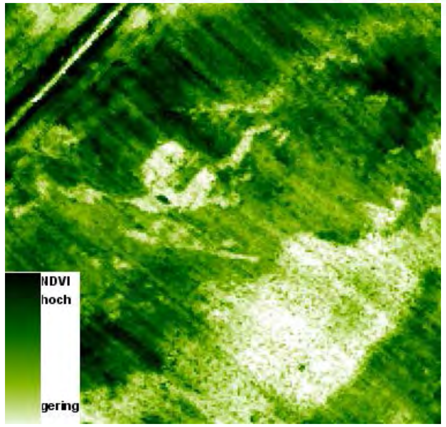


Local

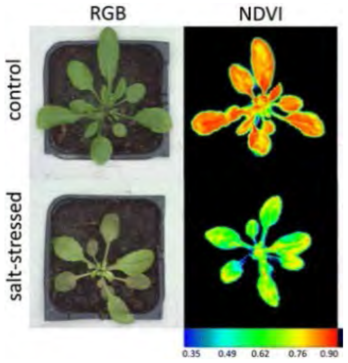


Malenovsky et al., 2015; https://upload.wikimedia.org

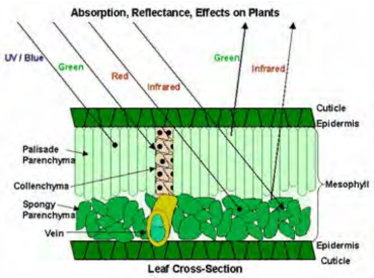
Plot



Individual



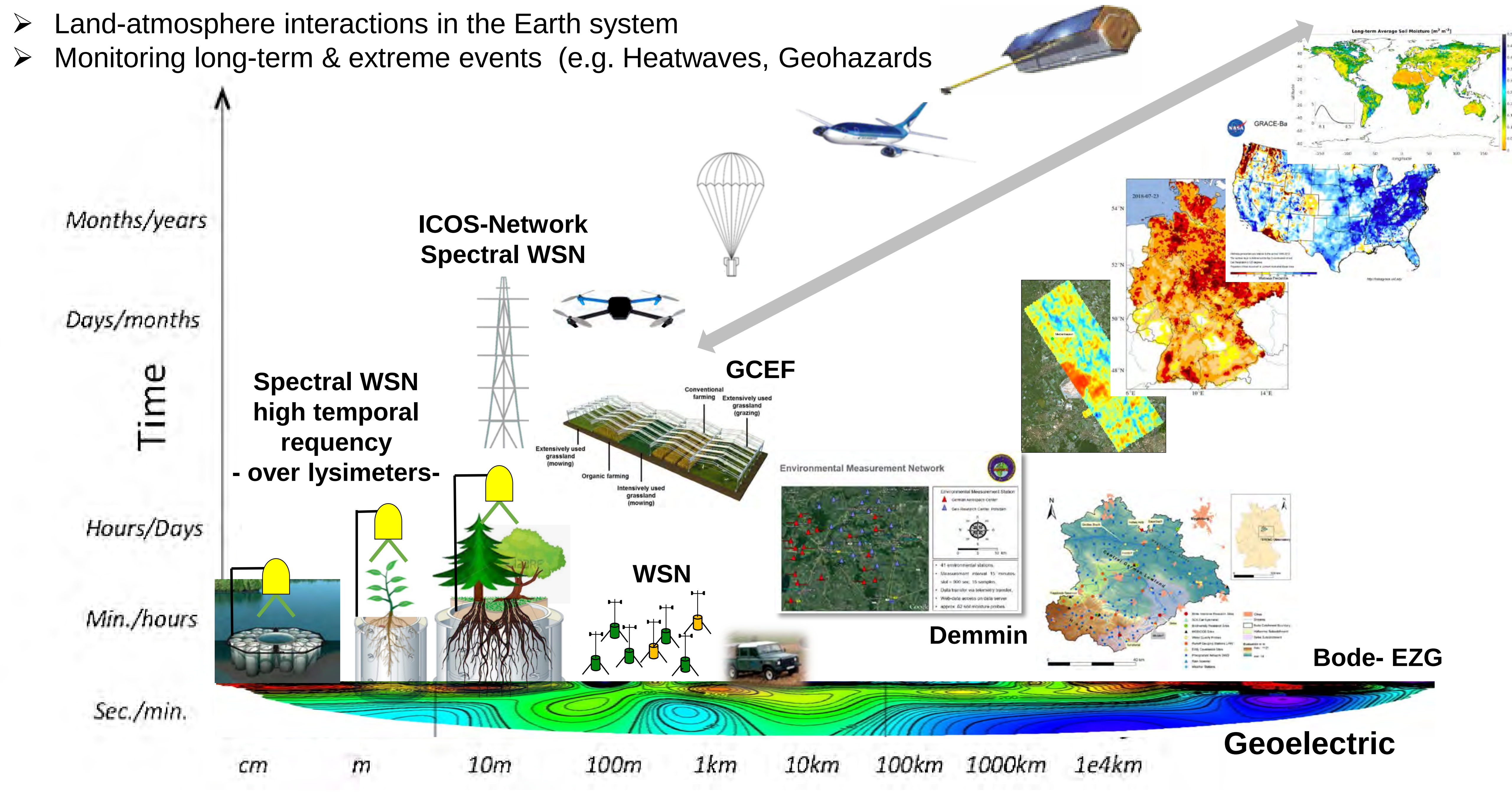
Cellular



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

Integrated Monitoring and Data Science – Linking Platforms, Approaches & Modelling

- Land-atmosphere interactions in the Earth system
- Monitoring long-term & extreme events (e.g. Heatwaves, Geohazards



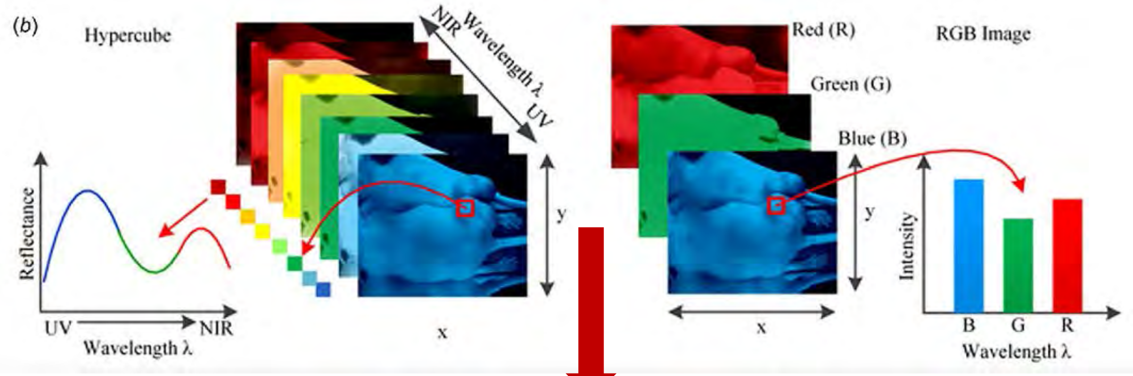
Approach: Remote Sensing to Monitor Biodiversity & Changes

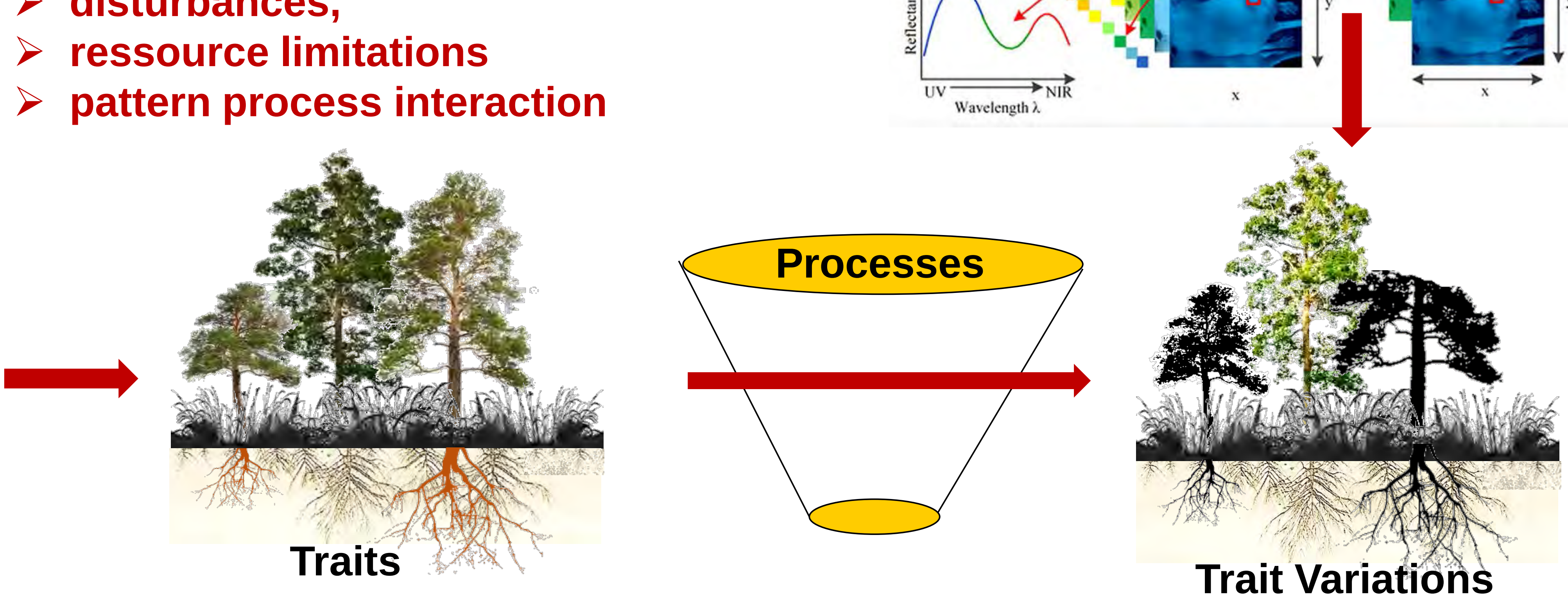
- Remote Sensing (RS) → Physical based system, but:
- RS records „Traits and Trait variations“ of
- surface, vegetation, soil, water …

- Bio-and Geodiversity and their interactions!

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

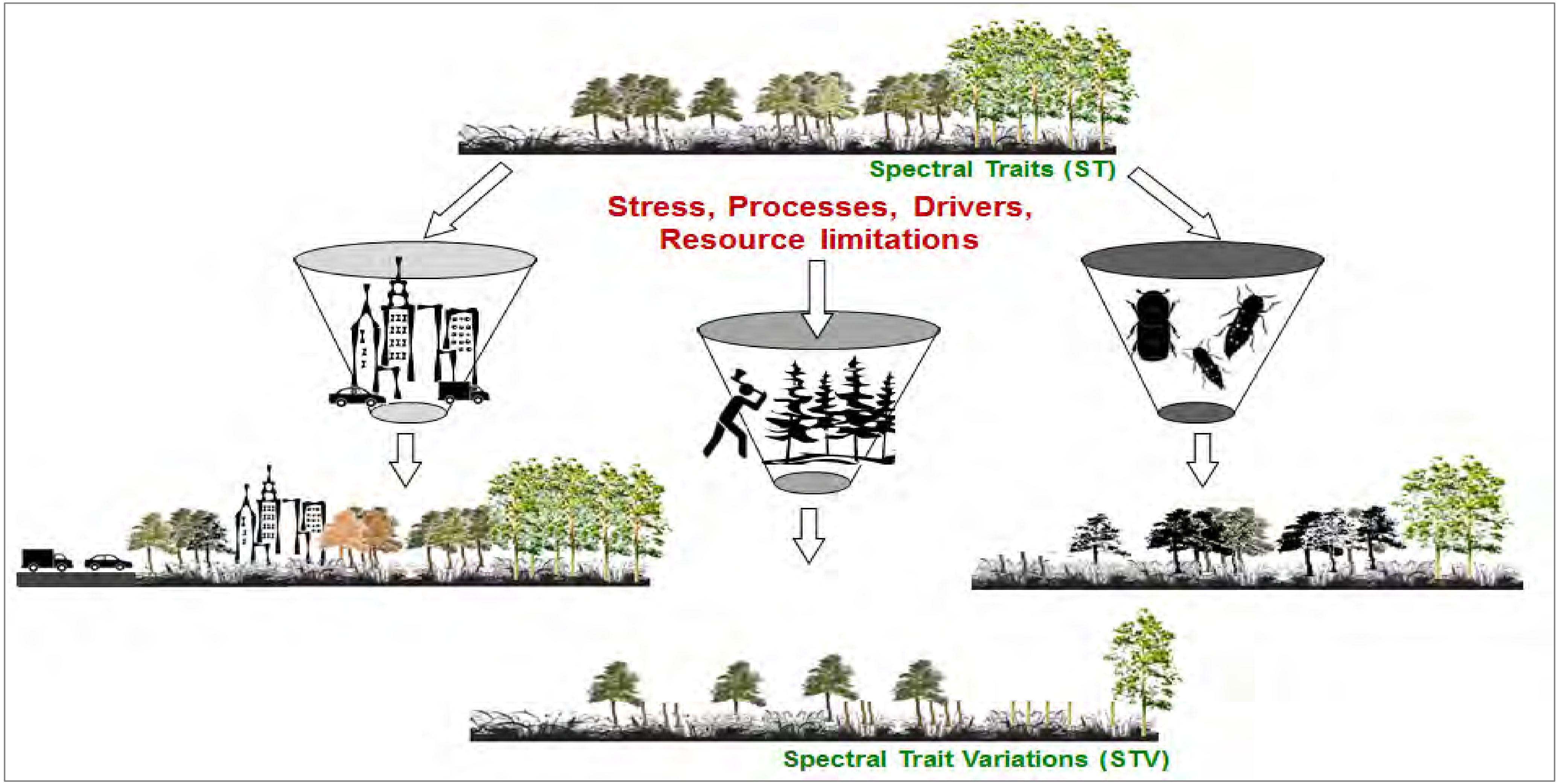
EnMAP



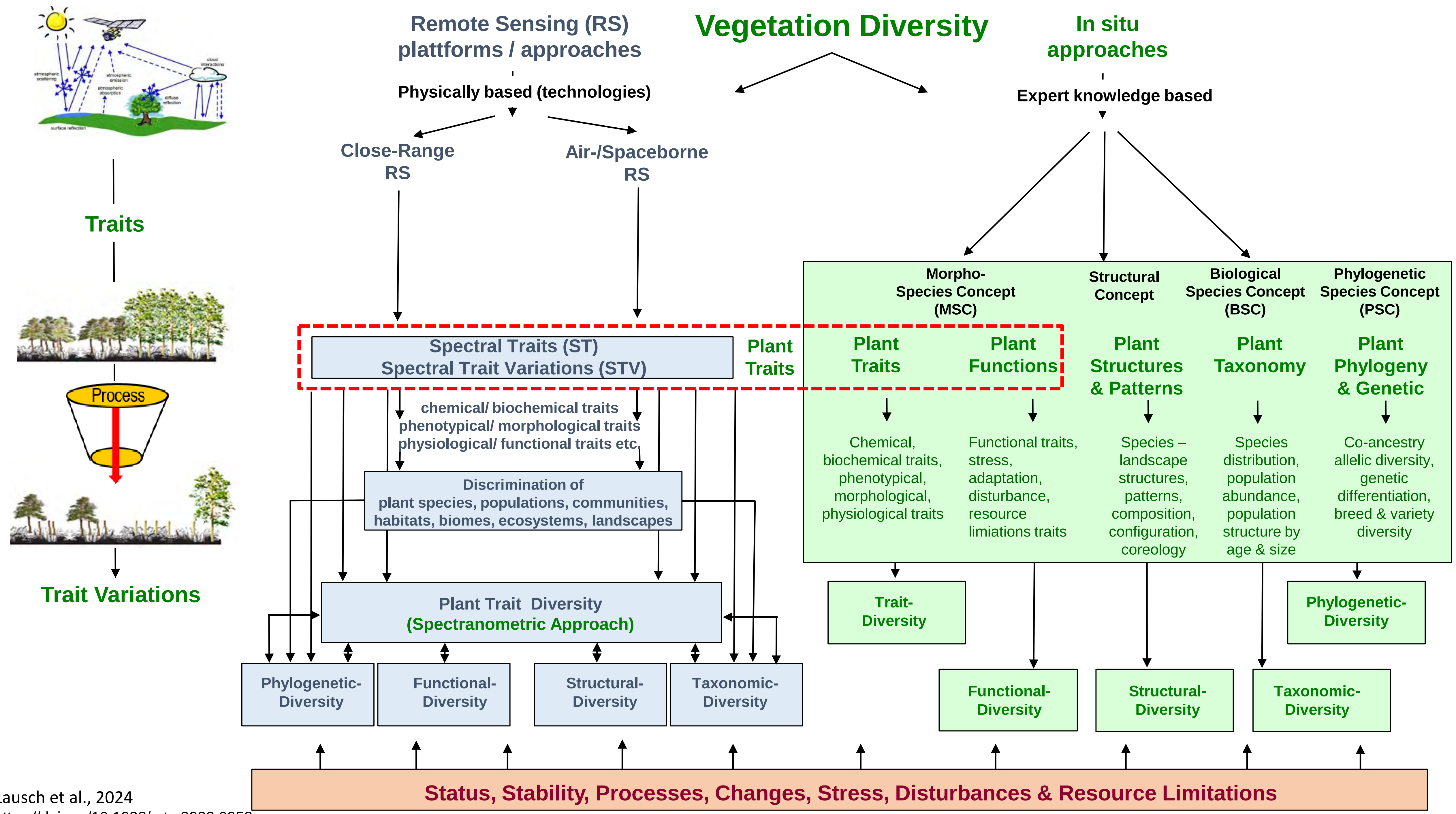


Approach: Trait concept – Plant Species

- **Traits & Trait Variations** → Filters of status, stress, processes, disturbances & resource limitations



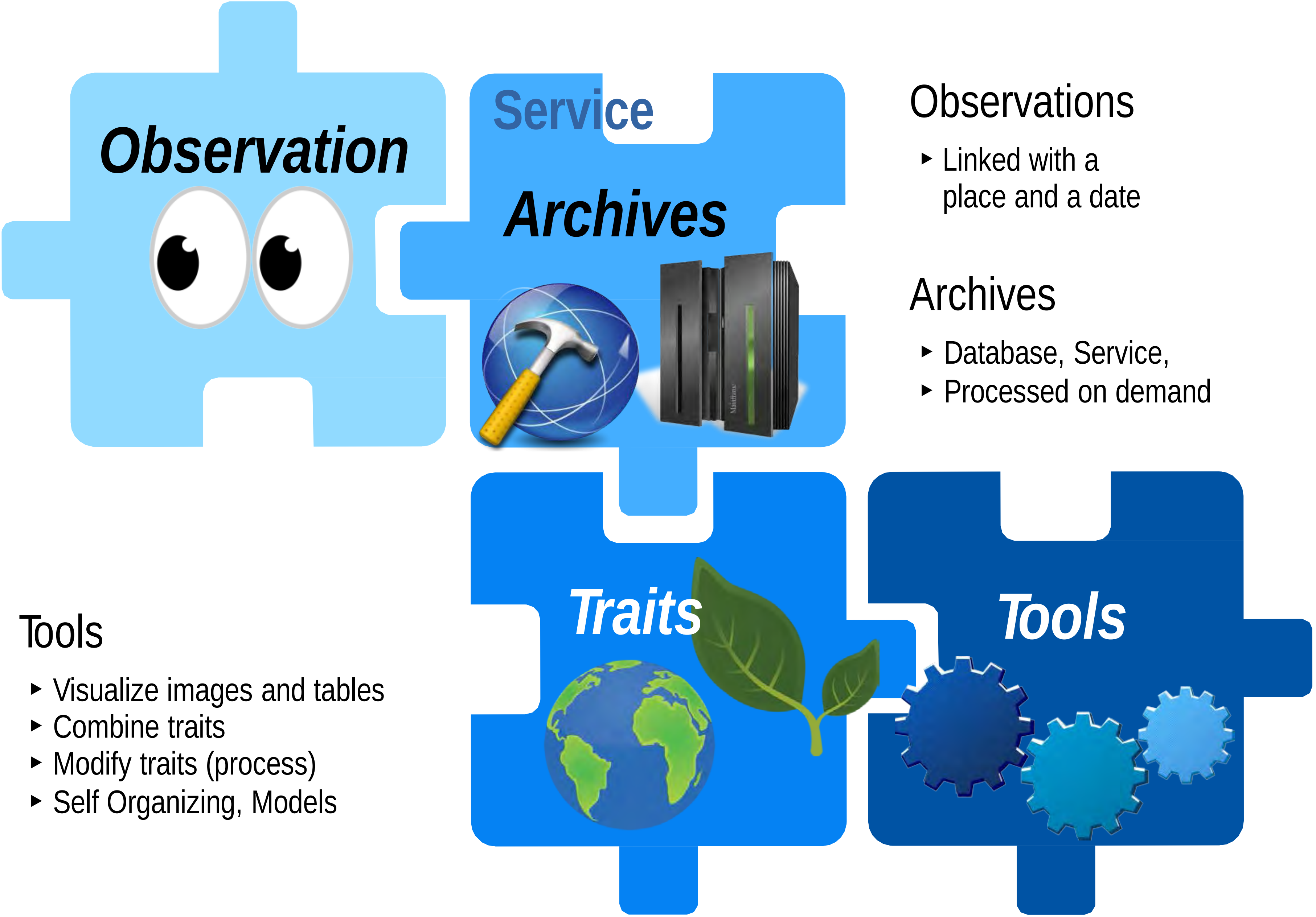
Lausch, A., et. al., 2016. Understanding Forest Health with Remote Sensing -Part I-A Review of Spectral Traits, Processes and Remote-Sensing Characteristics. Remote Sens. 2016, Vol. 8, Page 1029 8, 1029. doi:10.3390/RS8121029



Lausch et al., 2024
https://doi.org/10.1098/rsta.2023.0058

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

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



Observations

- Linked with a place and a date

Archives

- Database, Service,
- Processed on demand

Traits

- Meaningful properties
- Ready to use, FAIR*
- Quality selection
- Metadata, publications

Tools

- Visualize images and tables
- Combine traits
- Modify traits (process)
- Self Organizing, Models

* Findable, Accessible, Interoperable, Reusable

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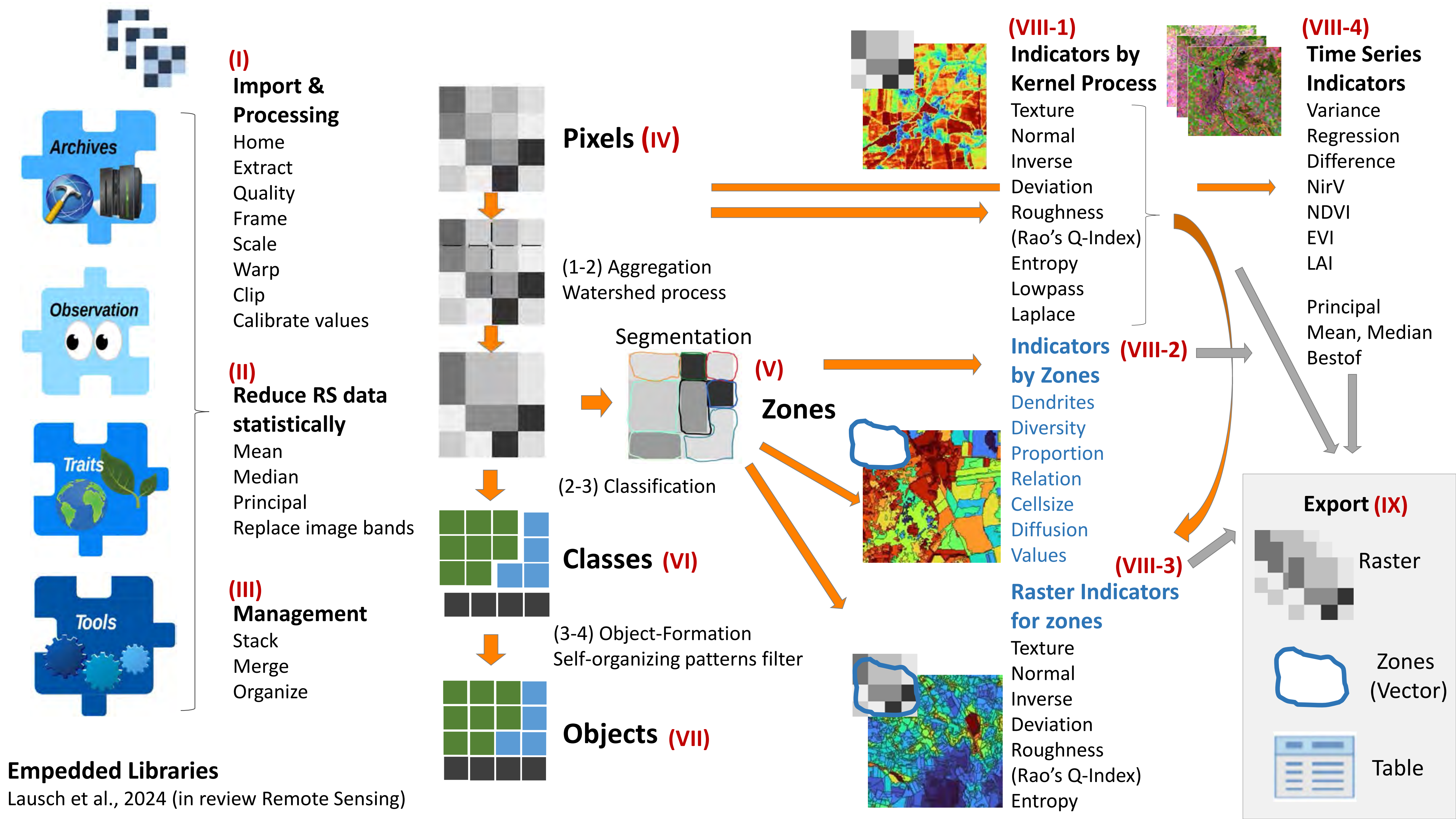
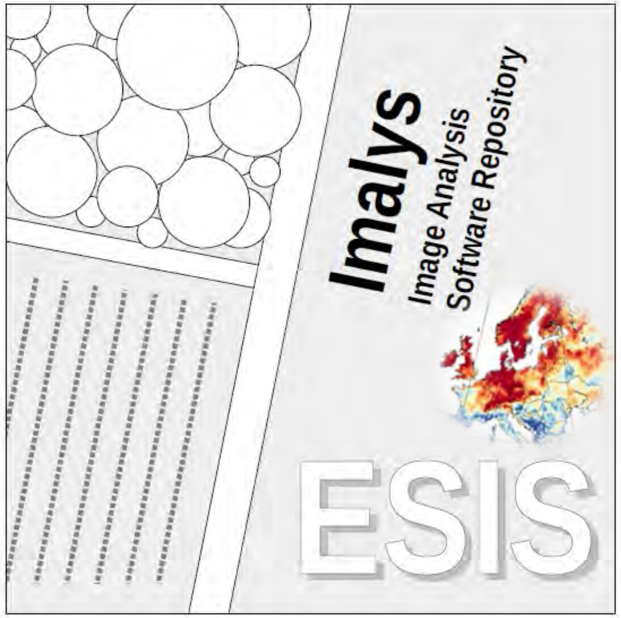


(I)
Import & Processing
Home
Extract
Quality
Frame
Scale
Warp
Clip
Calibrate values
(II)
Reduce RS data statistically
Mean
Median
Principal
Replace image bands
(III)
Management
Stack
Merge
Organize
Archives
Observation
Traits
Tools
Empedded Libraries
Lausch et al., 2024 (in review Remote Sensing)
Pixels (IV)
(1-2) Aggregation
Watershed process
Segmentation
(V)
Zones
(2-3) Classification
Classes (VI)
(3-4) Object-Formation
Self-organizing patterns filter
Objects (VII)
(VIII-1)
Indicators by Kernel Process
Texture
Normal
Inverse
Deviation
Roughness
(Rao's Q-Index)
Entropy
Lowpass
Laplace
Indicators by Zones
(VIII-2)
Dendrites
Diversity
Proportion
Relation
Cellsize
Diffusion
Values
(VIII-3)
Raster Indicators for zones
Texture
Normal
Inverse
Deviation
Roughness
(Rao's Q-Index)
Entropy
(VIII-4)
Time Series Indicators
Variance
Regression
Difference
NirV
NDVI
EVI
LAI
Principal
Mean, Median
Bestof
Export (IX)
Raster
Zones (Vector)
Table

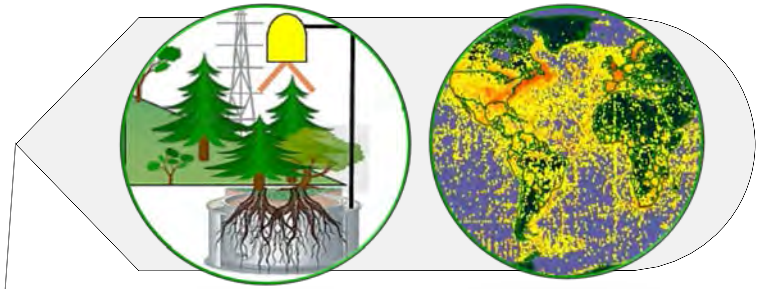
EcoSystem Integrity – RS/Modelling – Service – (ESIS)

- https://zenodo.org/record/7189794#.Y0bEz0pBwkI
- https://codebase.helmholtz.cloud/esis/Imalys



Remote Sensing
RGB, MSP, HSP, RADAR, GEDI-LiDAR, TIR
RS Data/RS Data Products

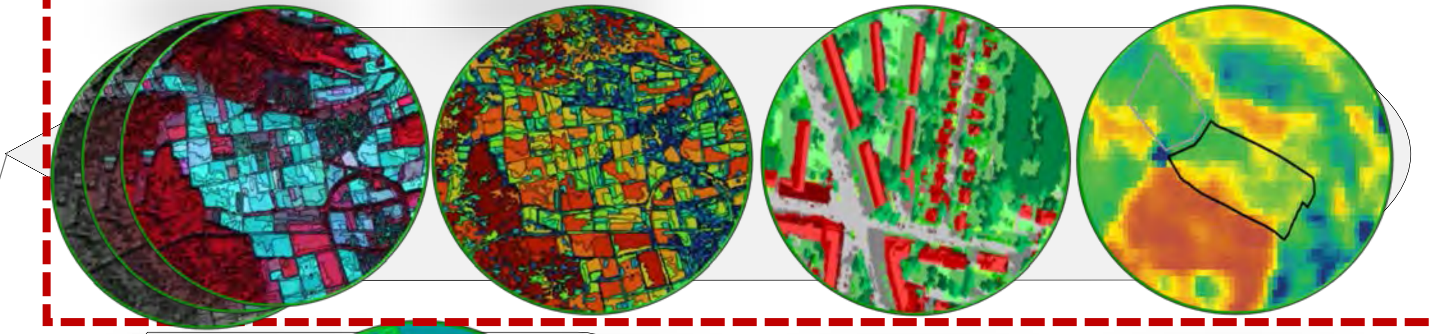
Species Distribution

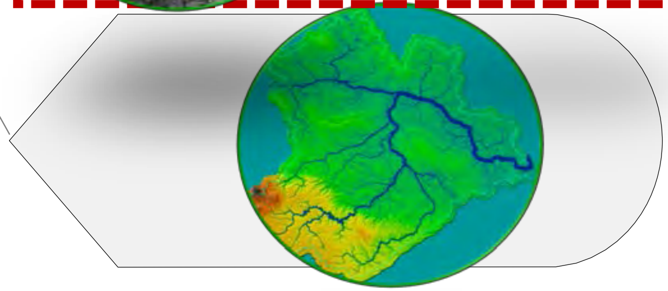


Basis for EcoSystem Modeling & Prediction

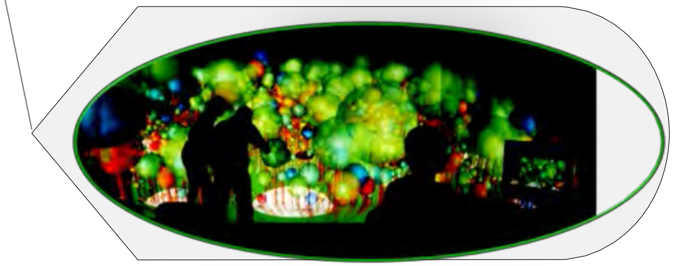
In-situ monitoring/ close range
Wireless-Sensor-Networks (WSN)
Databases
(Species distribution, traits, ..)

Temporal Patterns | Structural P. | Taxonomic P. | Functional P.





Hydrological Catchment Modelling

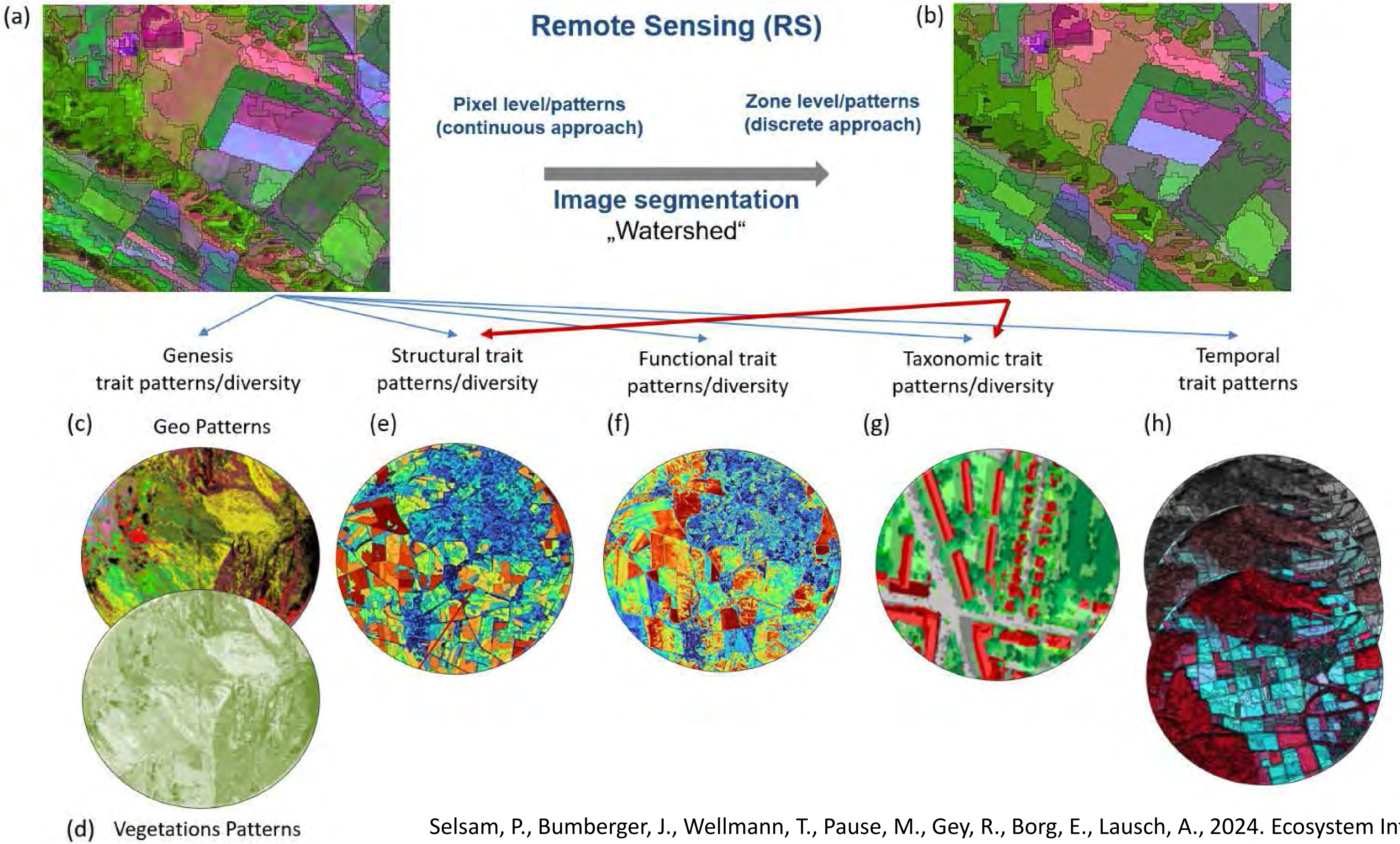


FORMIND
Individual-based forest Modeling (Rico Fischer)

....

1. Raster - Level

2. Zonal - Level

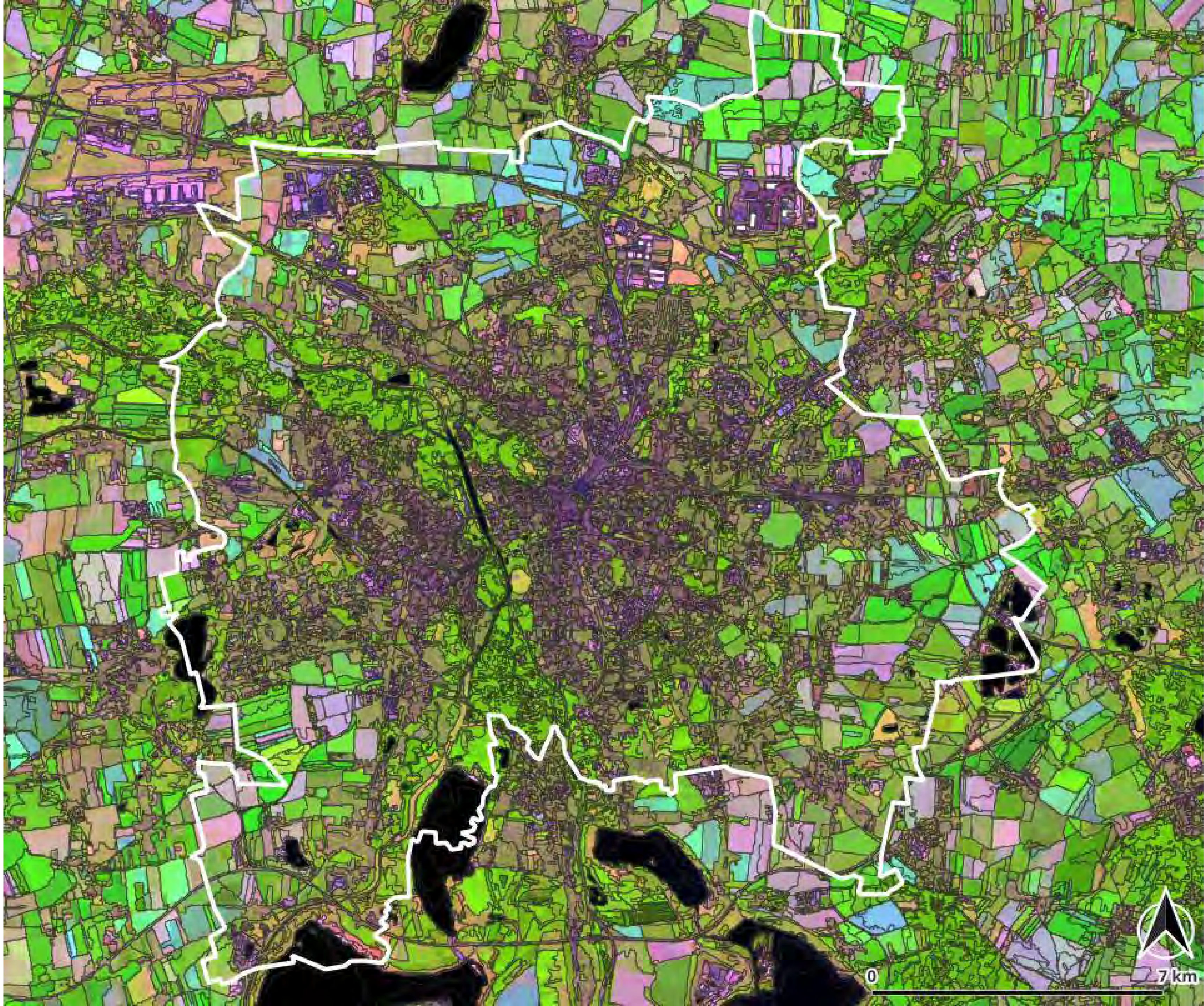


Selsam, P., Bumberger, J., Wellmann, T., Pause, M., Gey, R., Borg, E., Lausch, A., 2024. Ecosystem Integrity Remote Sensing—Modelling and Service Tool—ESIS/Imalys. Remote Sens. 16, 1139. https://doi.org/10.3390/rs16071139

Zones

Zones are delineated as regions with the smallest possible deviation within the zones compared with the mean deviation of the whole image. The process can be stopped at intermediate stages.

- Zones: Delineated landscape elements
- Image superimposed by zones borders
- Landsat 8/9
- Bands: 5 · 4 · 3
- Calibrated to TOA reflectance
- May … August, 2018 … 2023
- Median of all accepted images
- City of Leipzig, Germany

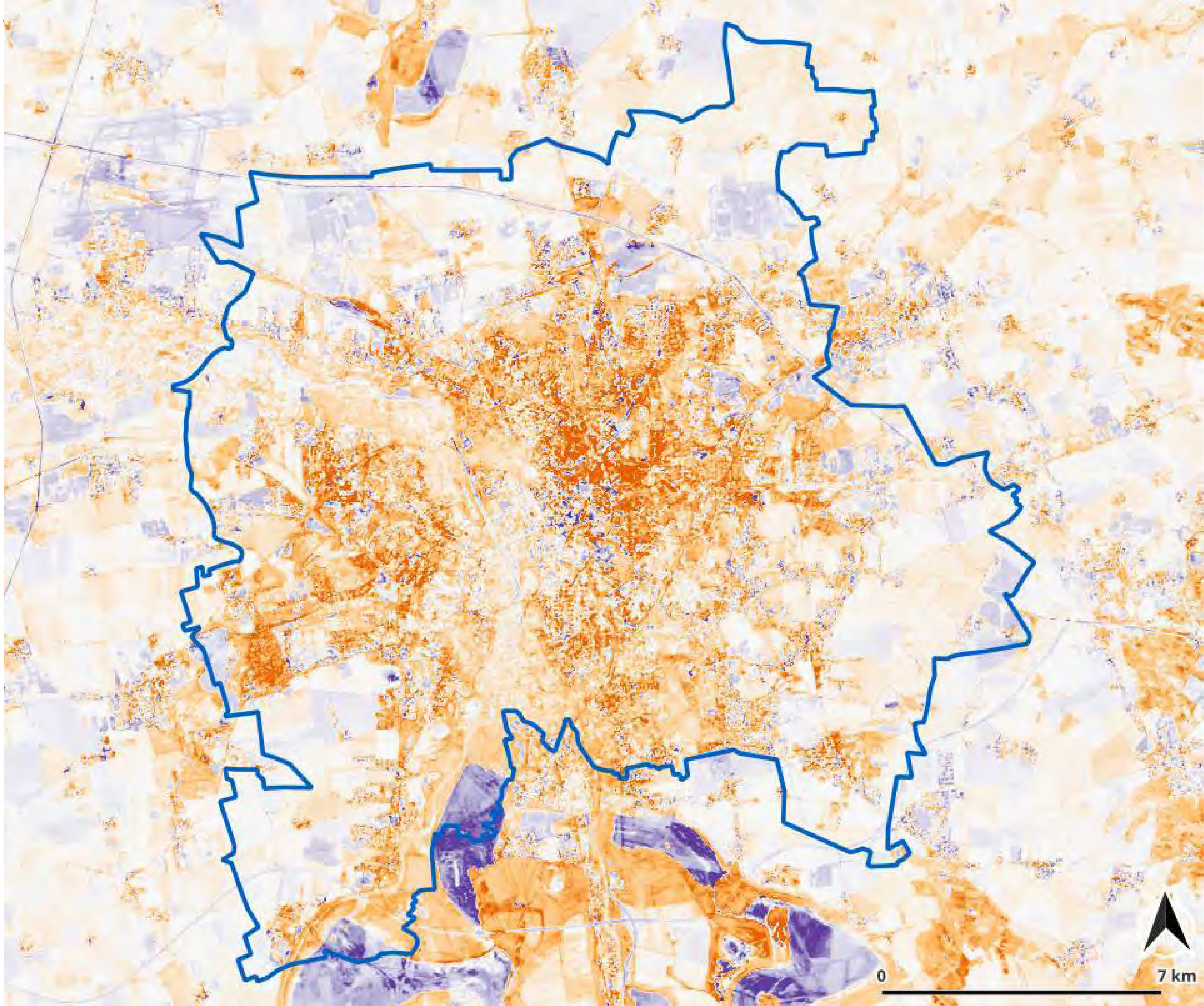


Selsam et. al. 2024

NIRv: Regression in Time

Regression is used to estimate dependencies between different parameters. In this case the NirV index shows a linear increase (orange) or decrease (blue) up to 0.2% a year.

- Time course 1984…2022
- NirV plant metabolism index
- Season: May…July
- Values: -0.002…………0.002
- Colors:
- Sensor Landsat 4/5…8/9
- Calibrated to TOA reflectance
- Region Leipzig, Germany

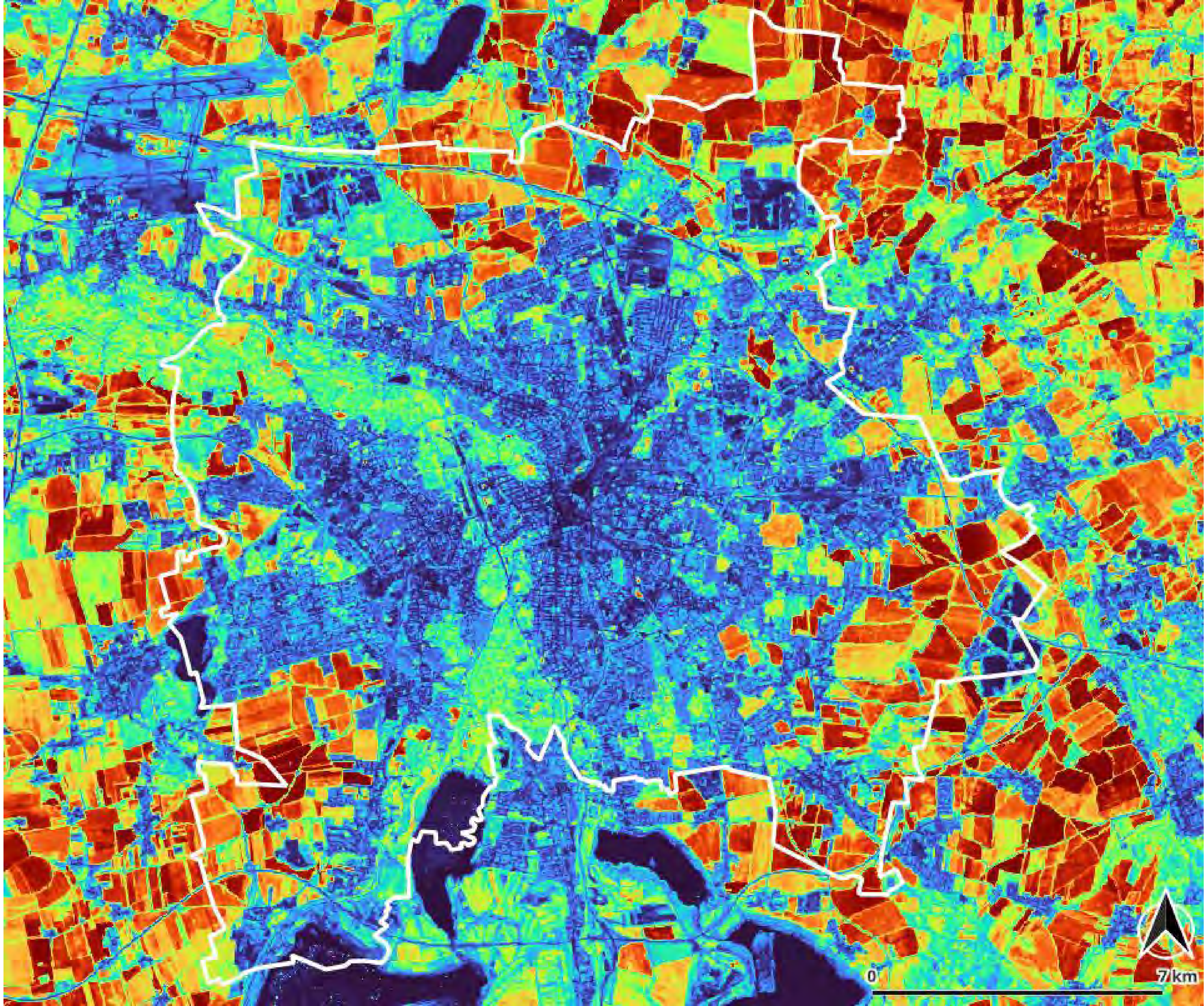


Selsam et. al. 2024

NIRv: Variance in Time

The square of the standard deviation is called "variance". In this case the variance in time reaches 0.02 or 45% deviation from the mean of the NirV index.

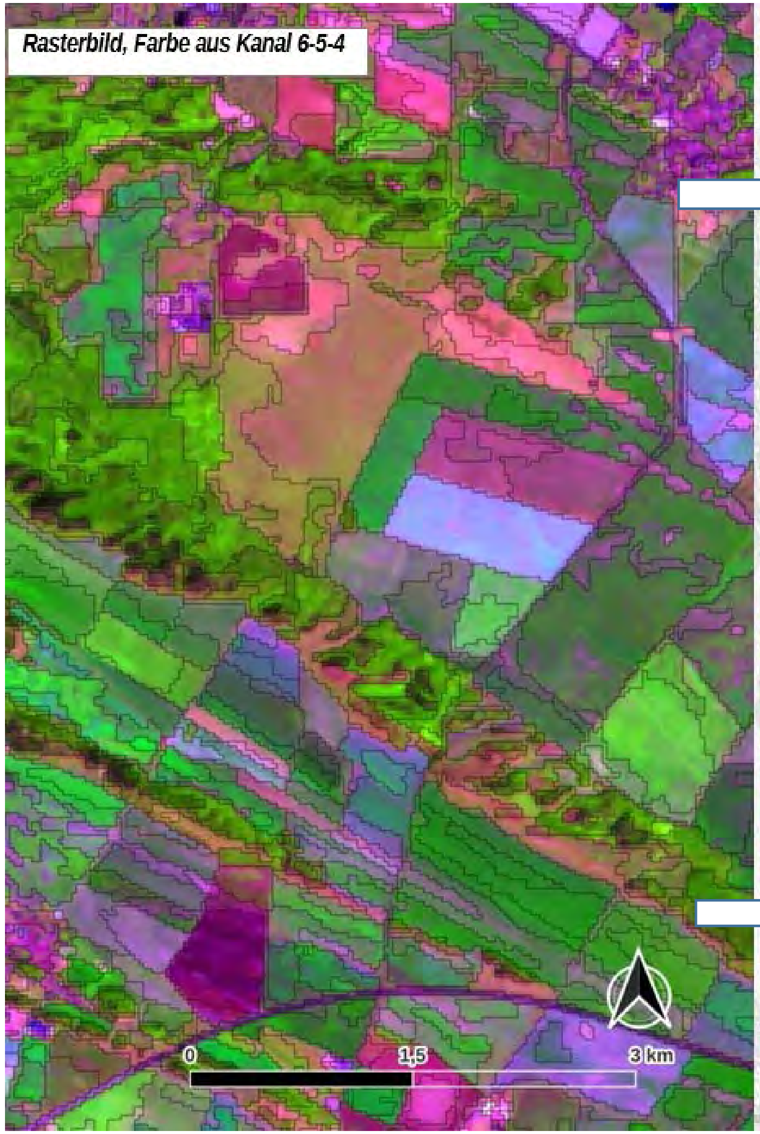
- Time course 2018…2023
- NirV plant metabolism index
- Season: May…October
- Values: 0.0……………0.032
- Colors:
- Sensor Landsat 8/9
- Calibrated to TOA reflectance
- City of Leipzig, Germany



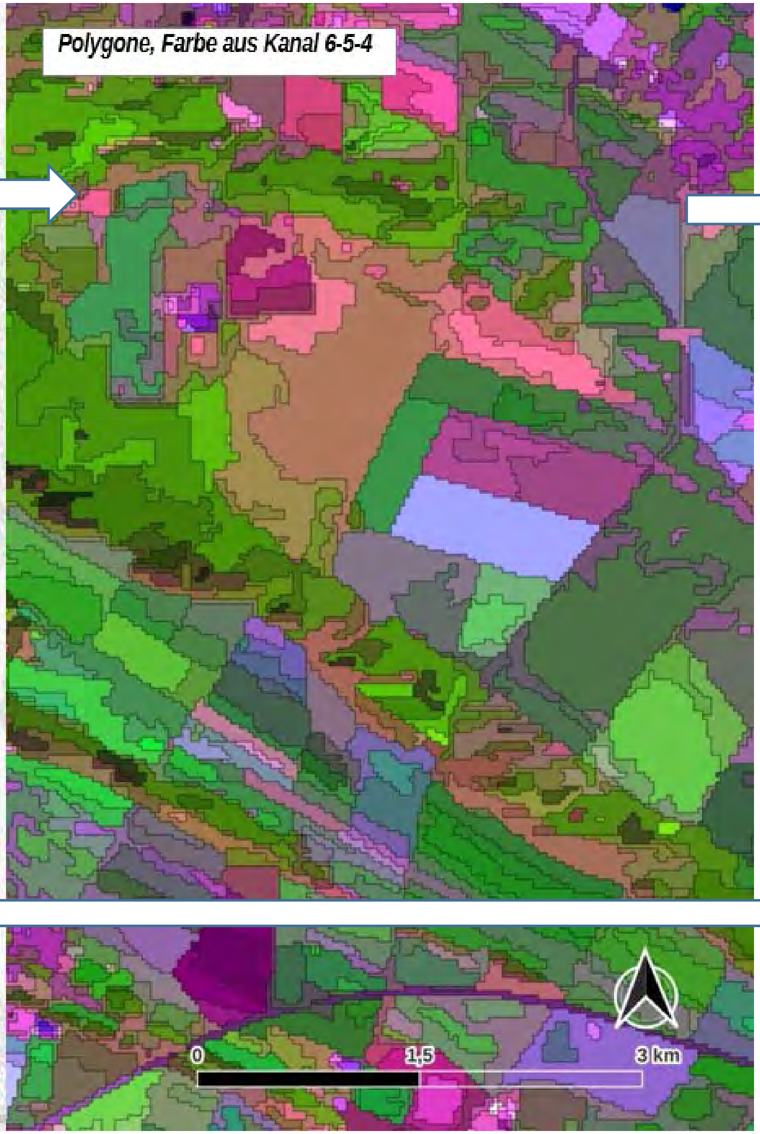
Selsam et. al. 2024

ESIS Approach: - 2. Zone Level (Segmentation)

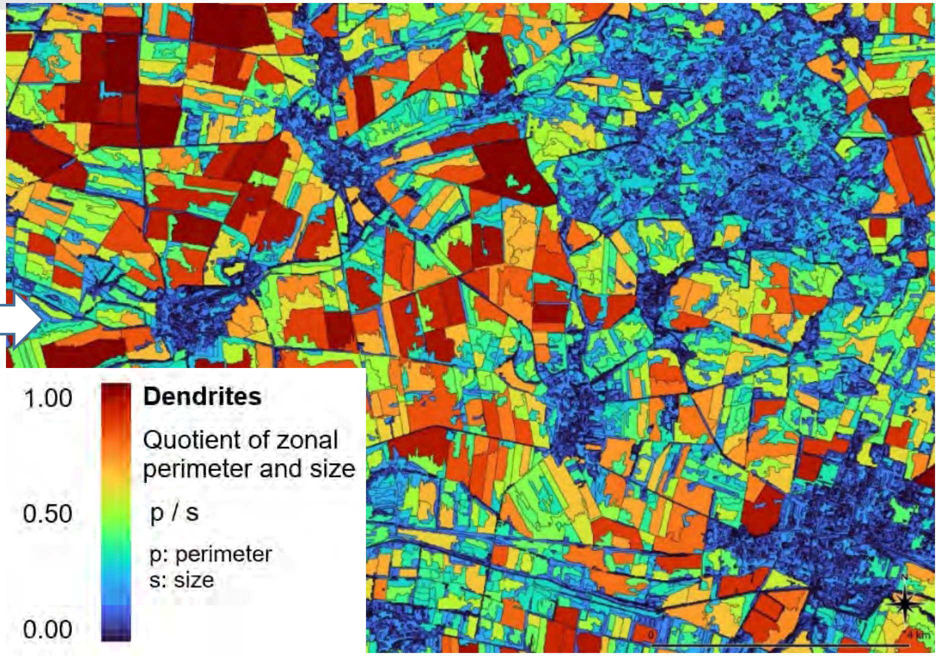
1. Spectral RS patterns



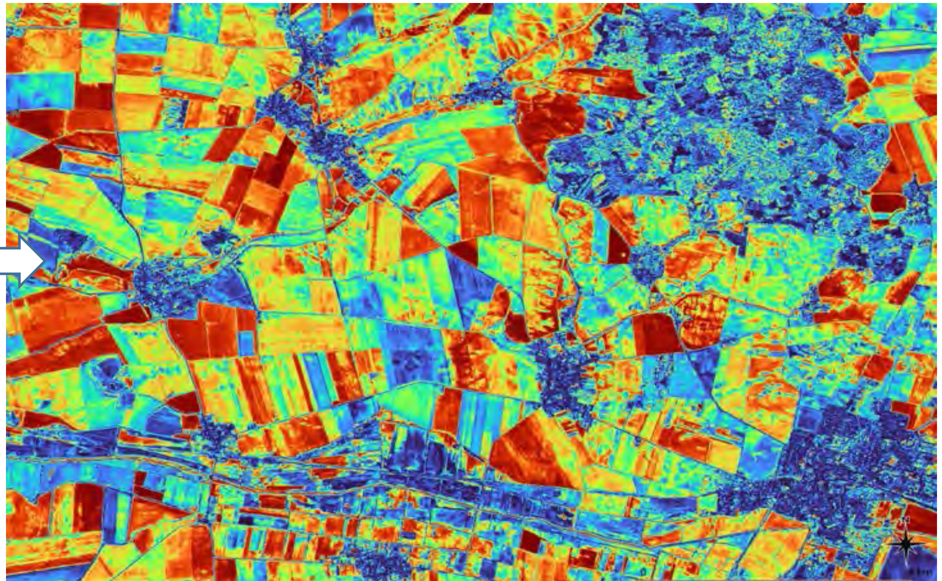
2. Zonal patterns



Zonal patterns (e.g. Dendrites)

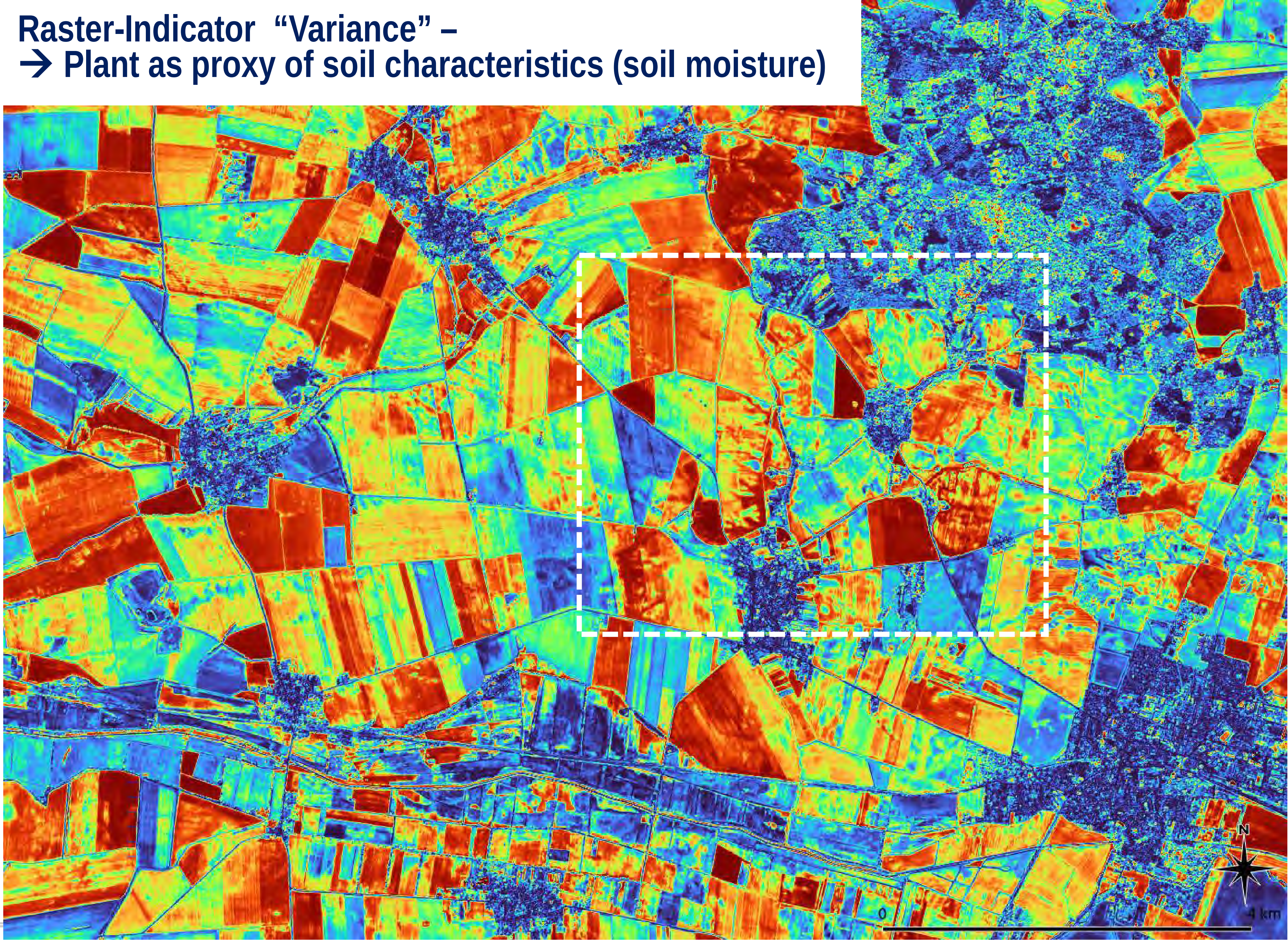


Spectral RS patterns



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

Raster-Indicator “Variance”



Yearly Change as Variance

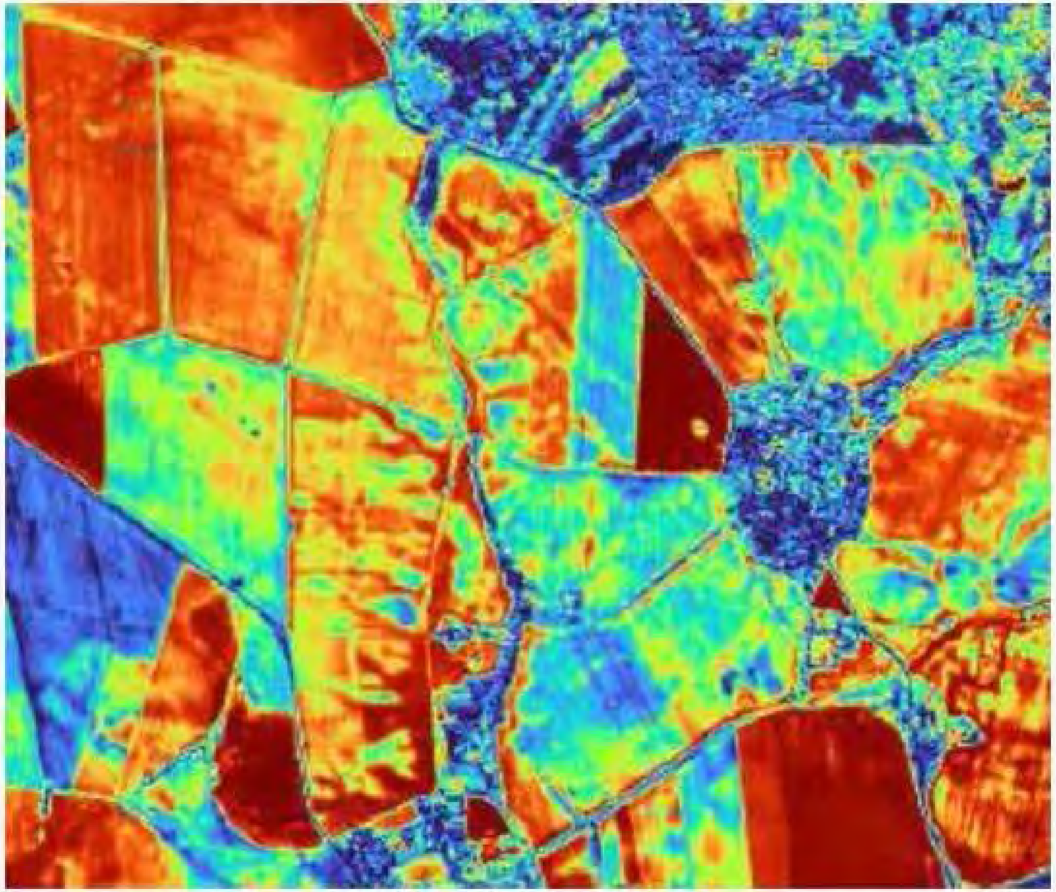
Variance of the yearly brightness for 5 years

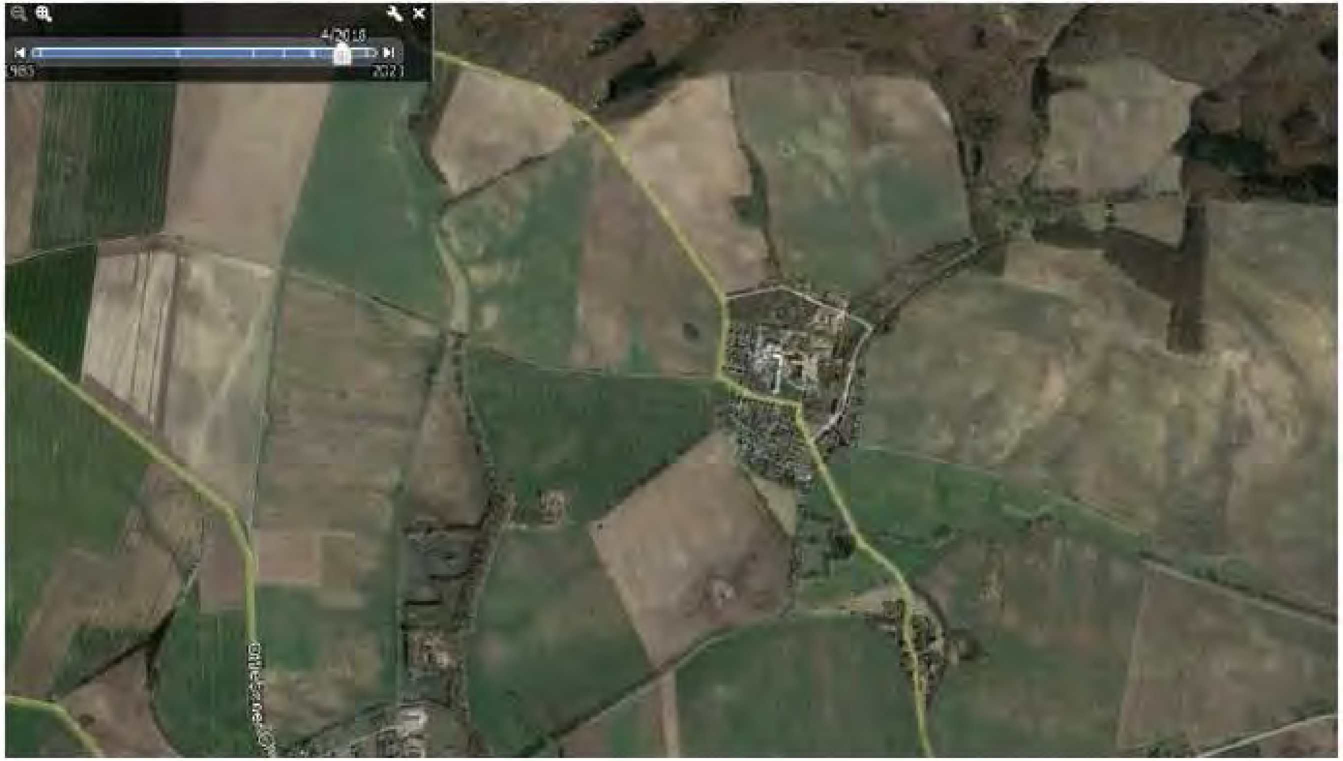
All accepted images between 2017 and 2021 Bands 2-3-4-8, Sentinel-2

Values: 0.0 … 0.46 (Blue … Red)

Functional patterns

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



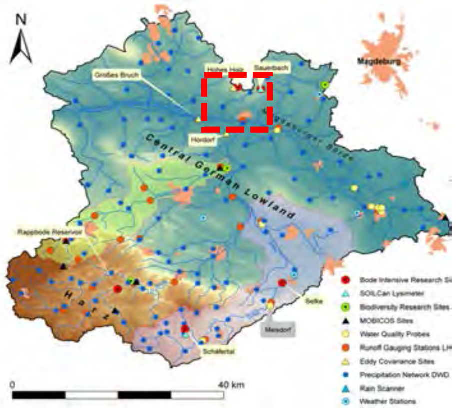


Yearly Change as Variance

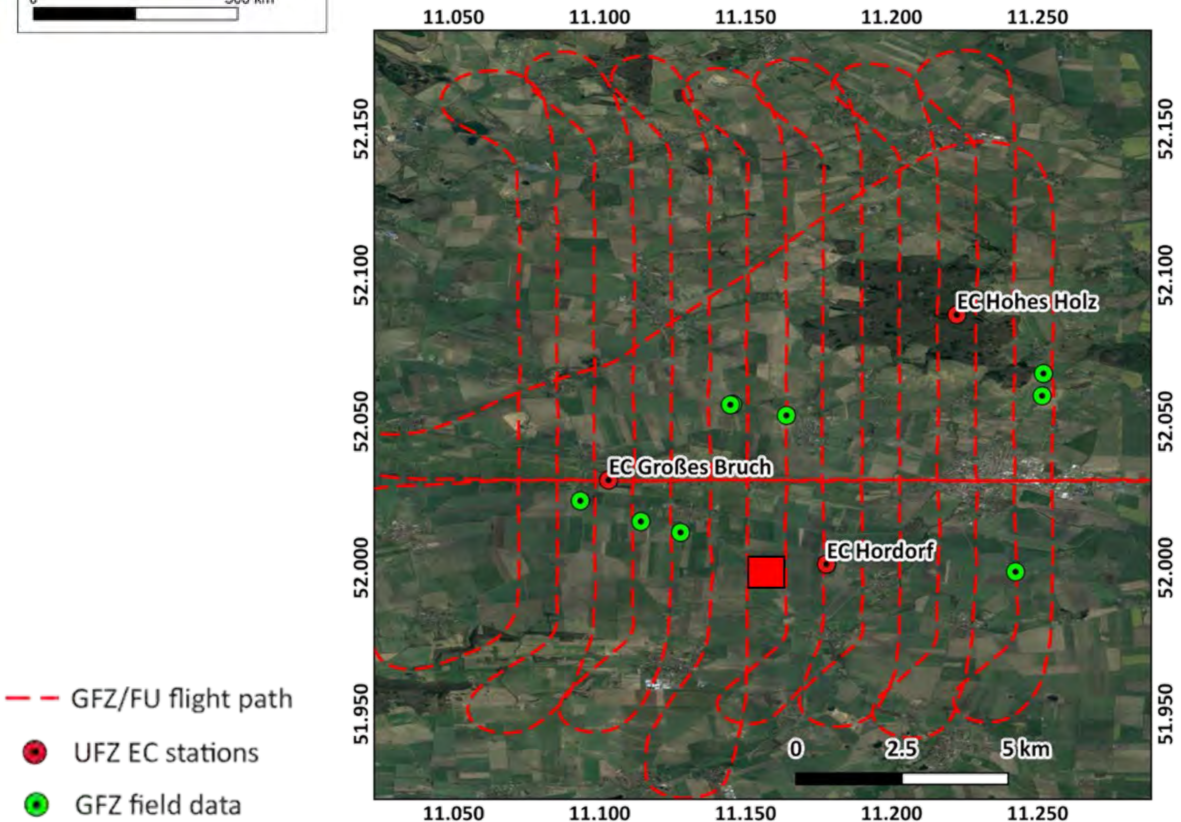
Variance of the yearly brightness for 5 years

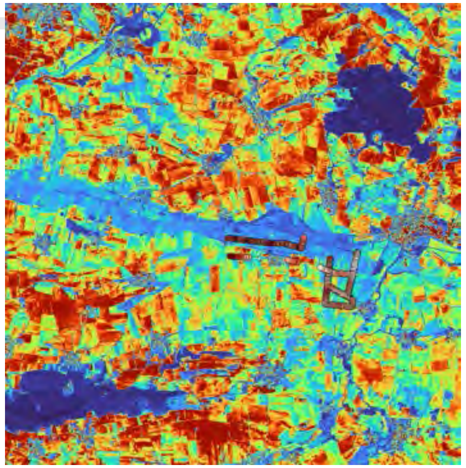
All accepted images between 2017 - 2021
Bands 2-3-4-8, Sentinel-2

Example – ESIS – RS Indicators to model/predict soil moisture (CNSR-Rover) - Germany



Bode Catchment, Germany





Spaceborne RS Data

Aircrafts

Mobiles ***Cosmic-Ray Neutron Sensing (CRNS)***

- Neutrons go through metals
  => CRNS by car, train, aircraft …

Drone

In-Situ Soil Moisture CRNS – Rover Data

Dr. Martin Schrön

Example – ESIS – RS Indicators to model/predict soil moisture (CNSR-Rover) - Germany

Mobiles ***Cosmic-Ray Neutron Sensing (CRNS)***

- ➢ Neutrons go through metals
  => CRNS by car, train, aircraft …

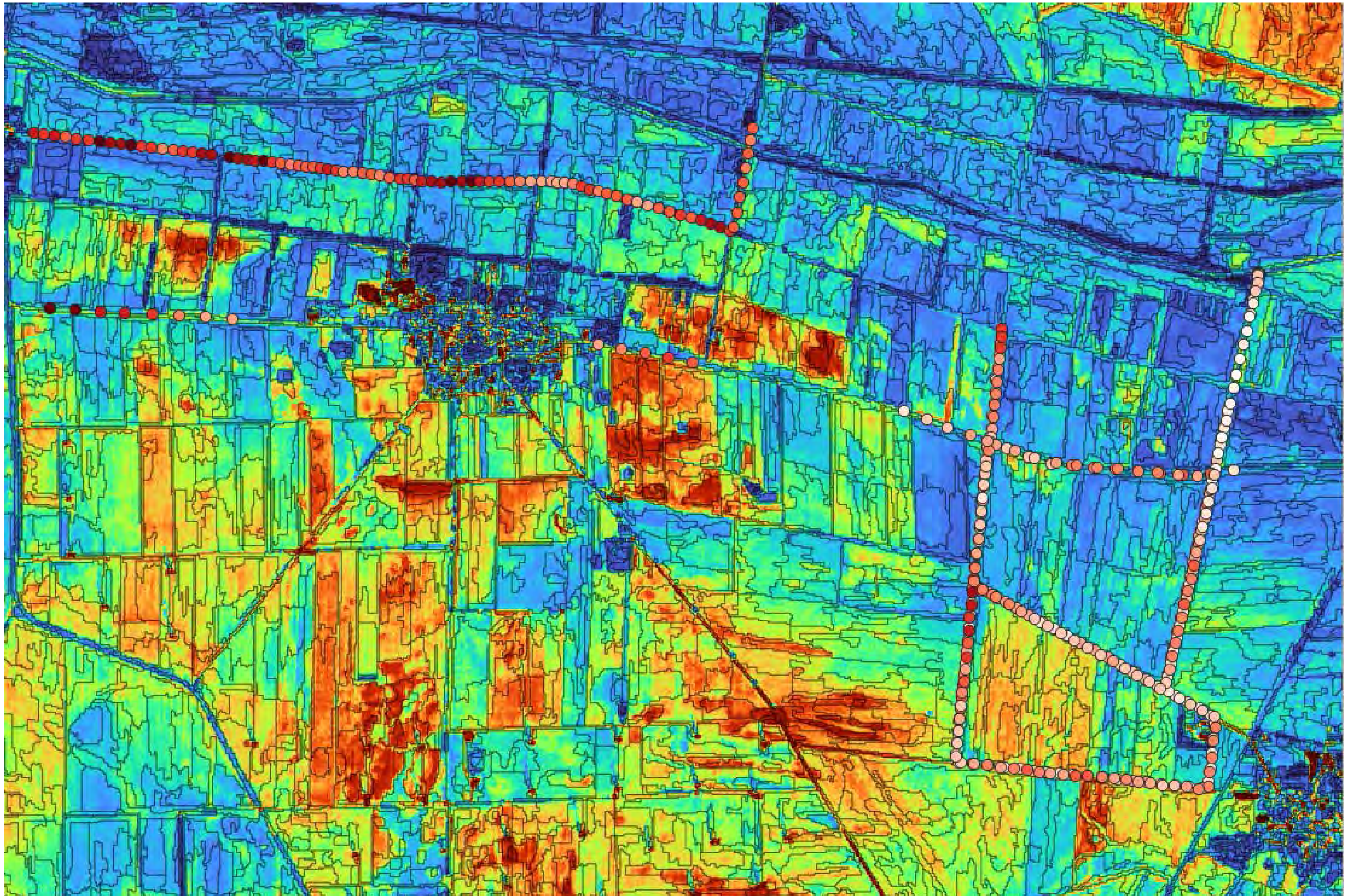
Soil Moisture
CRNS –
Rover Data [%]

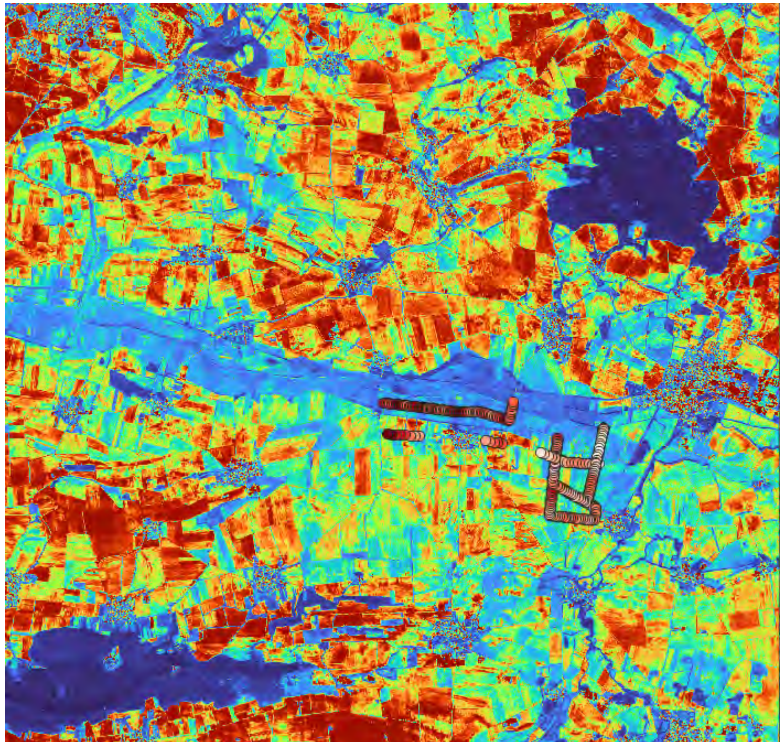
- 0 - 4.3
- 4.3 - 11.6
- 11.6 - 17.1
- 17.1 - 23.4
- 23.4 - 29.6
- 29.6 - 36.6
- 36.6 - 46.3
- 46.3 - 59.3
- 59.3 - 76
- 76 - 99.5

Dr. Martin Schrön, UFZ

Example – ESIS – RS Indicators to model/predict Soil moisture (CNSR-Rover) - Germany

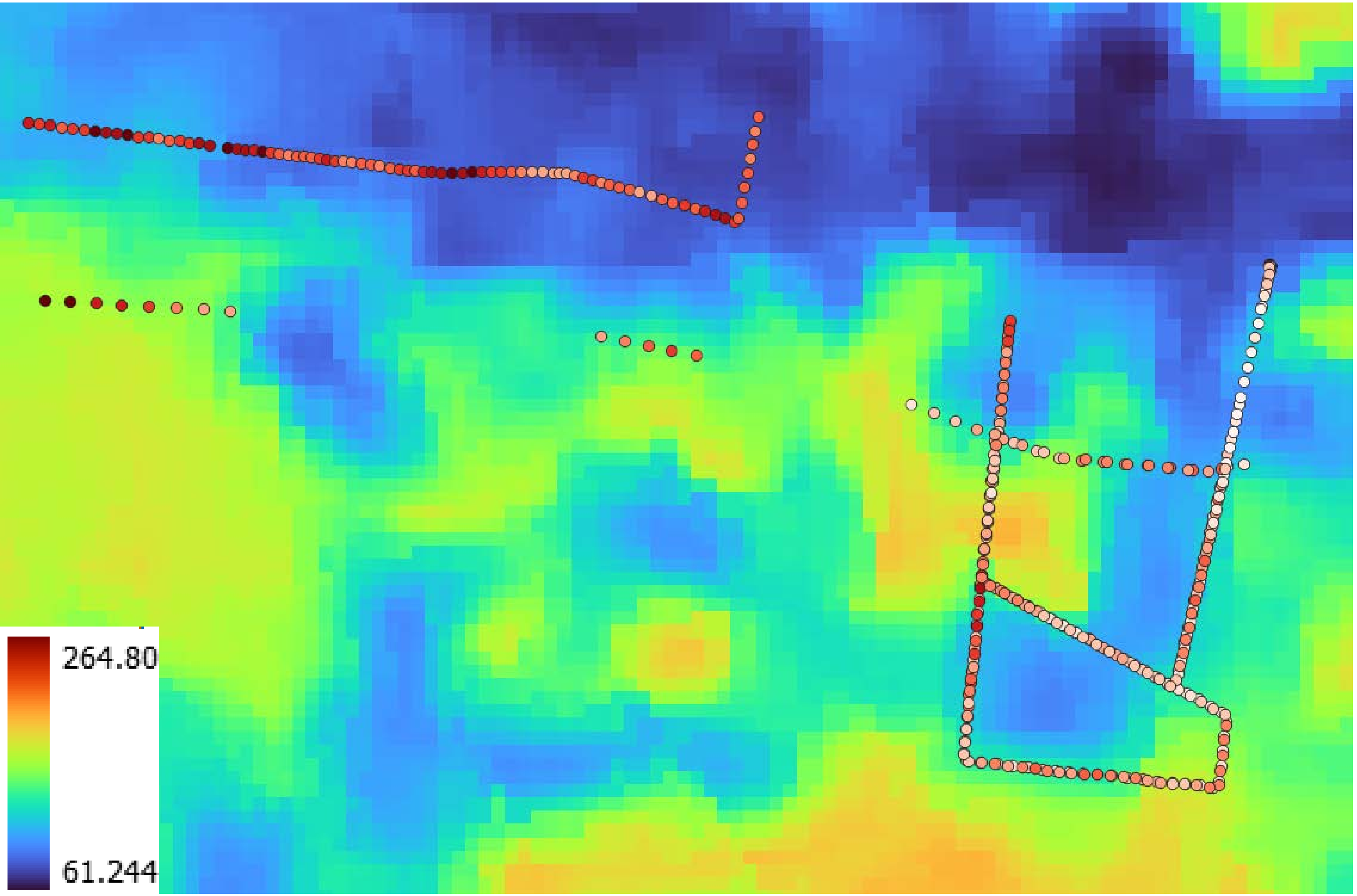
- Spectral Variance, 30 Sentinel 2 Data (2017-2021, Mai-July) + Zones (Segmentation)
- Source: ESIS – RS Raster Indicator, 10m/pixel

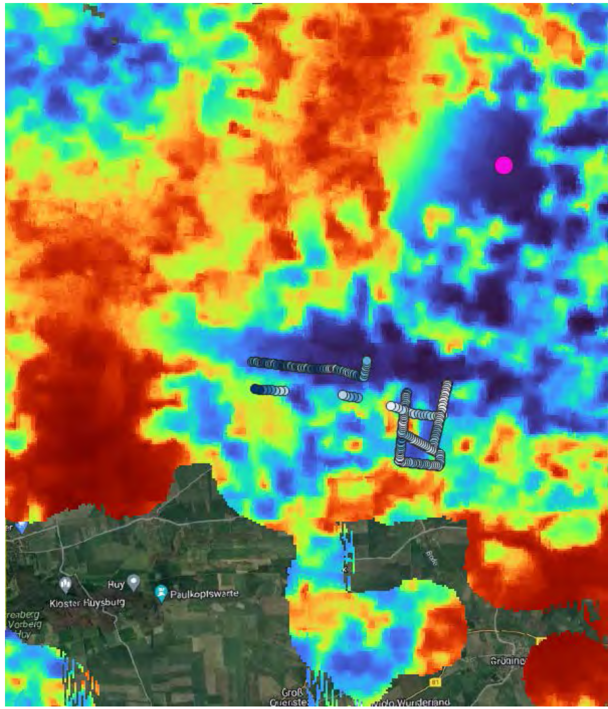




Example – ESIS – RS Indicators to model/predict Soil moisture (CNSR-Rover) - Germany

- EVAPOTRANSPIRATION_PT_JPL_Etdaily
- Source: Ecostress-RS Dataproduct, 60m/pixel





ESIS - EcoSystem Integrity – Conclusions!

1. **Traits/Traitvariation** of **Geo-& Vegetationsdiversity** can be monitored with **RS**
2. **Trait/Traitvariation exist on all spatio-temporal scale**
3. **ESIS - derived genesis, structural, taxonomic, functional & temporal patterns/traits of Geo- & Biodiversity as inputs for ecological modeling** and **predictions of climate change, land use intensity and soil moisture**
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

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