Monitoring Bio- Geodiversity and Ecosystem health by Traits, Remote Sensing (RS) and Data Science approaches

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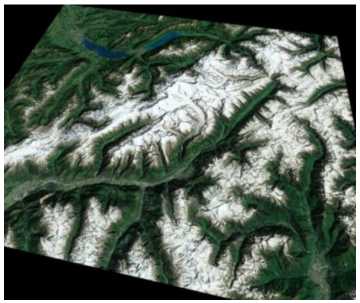
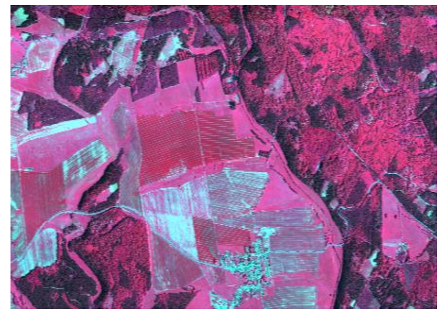
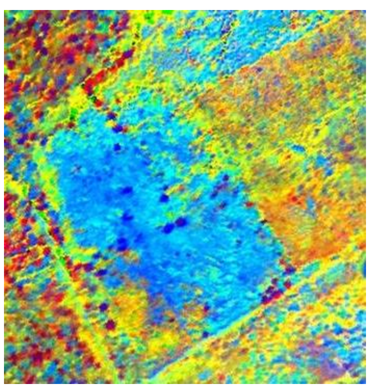
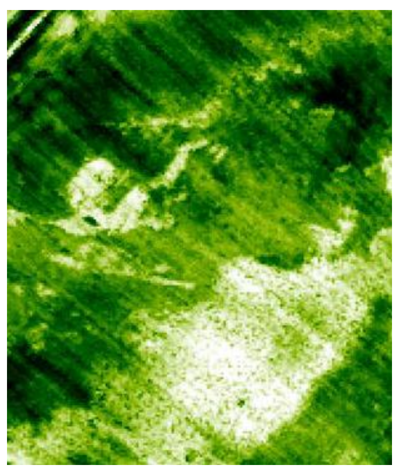
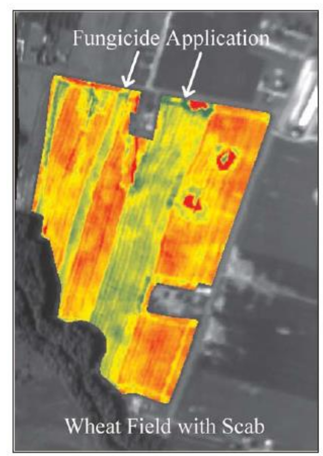
How can RS measure, assess Bio-and Geodiversity & and ESS?











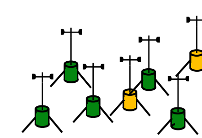
Spaceborne

Airborne

UAV - Drone

Camera trap

Wireless-Sensor-Network (WSN)



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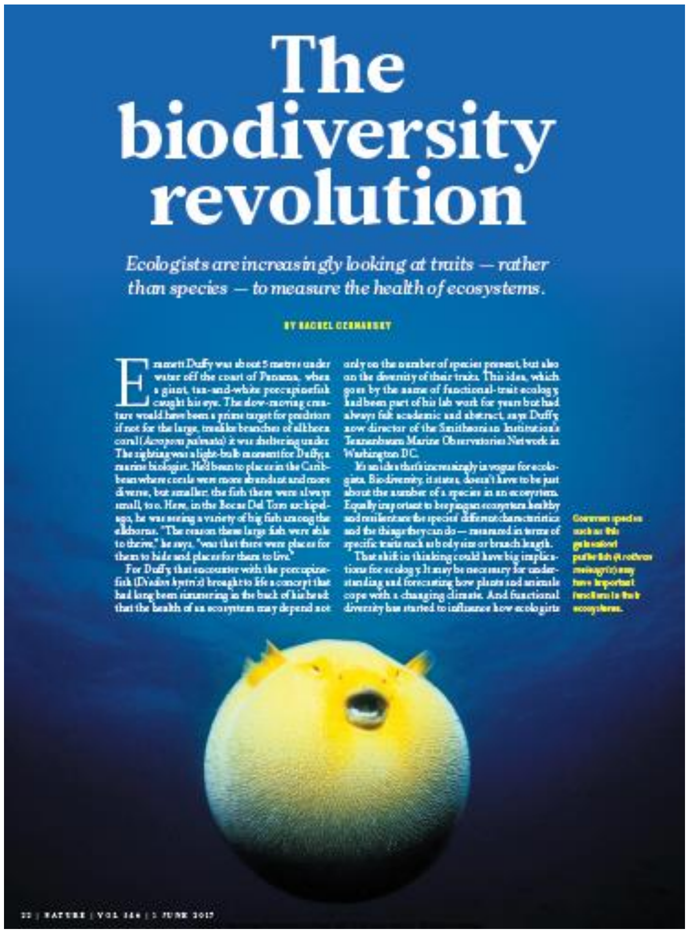
Trait concept of species – Indicators / Filters of stress

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



Traits

↓

Indicators of
Status
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"**

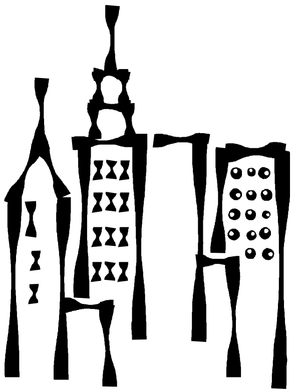
  (Green et al., 2008)

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

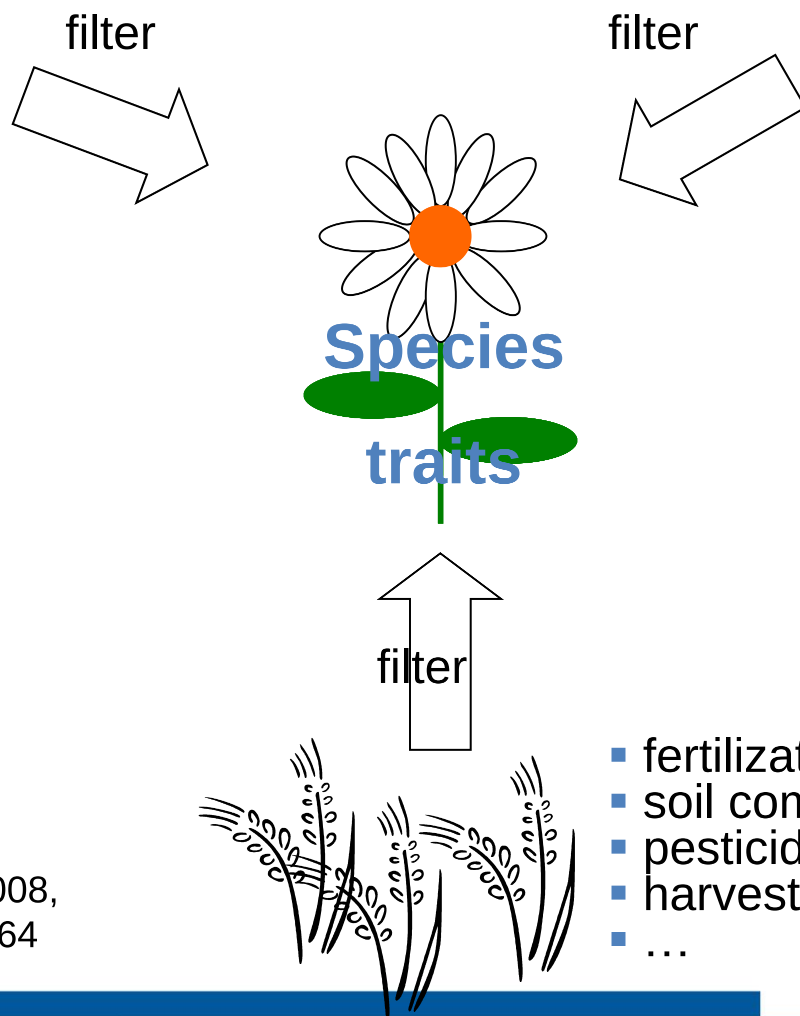
Green, J.L.J.L., et al., 2008. Microbial biogeography: from taxonomy to traits. Science, 320, 1039–1043. doi:10.1126/science.1153475

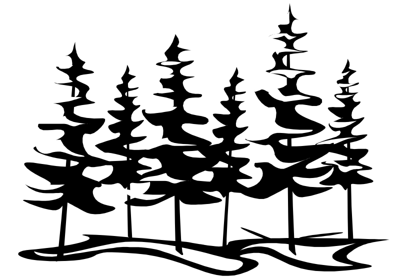
Approach: „In-situ-species traits“ - concept

Traits = Filters of status, stress, processes, disturbances and resource limitations



- heat island
- drought
- pollution
- paved surfaces
- …





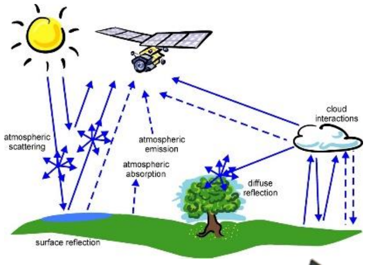
- nutrient deficiency
- forestry
- immissions
- …

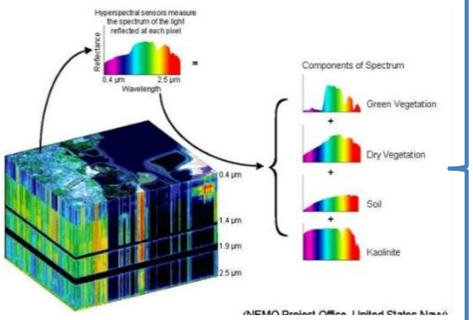
- fertilization
- soil compression
- pesticides
- harvest
- …

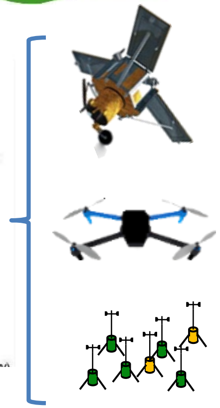
Drawn after Knapp, et al., 2008,
Ecology Letters 11: 1054-1064

Approach: Remote Sensing – Trait concept

- RS record „Traits and Trait variations“ of surface, vegetation, soil, water ..
- Bio-and Geodiversity and their interactions!
- Spectral answer, is a reaction on
  - status, process,
  - disturbances,
  - ressource limitations
  - pattern process interaction

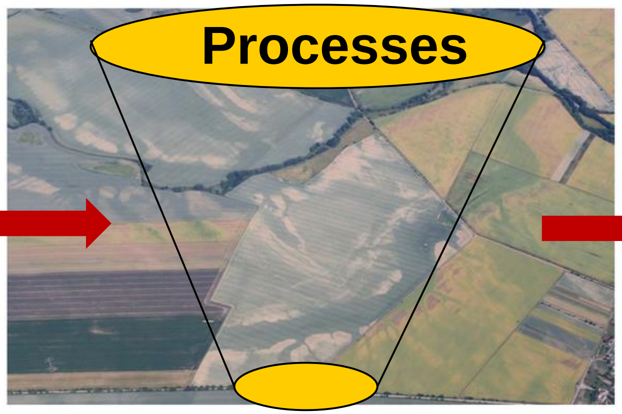


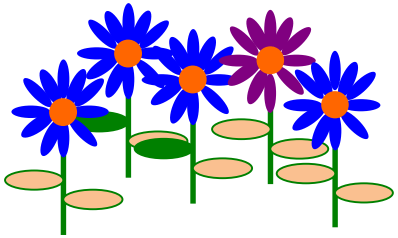




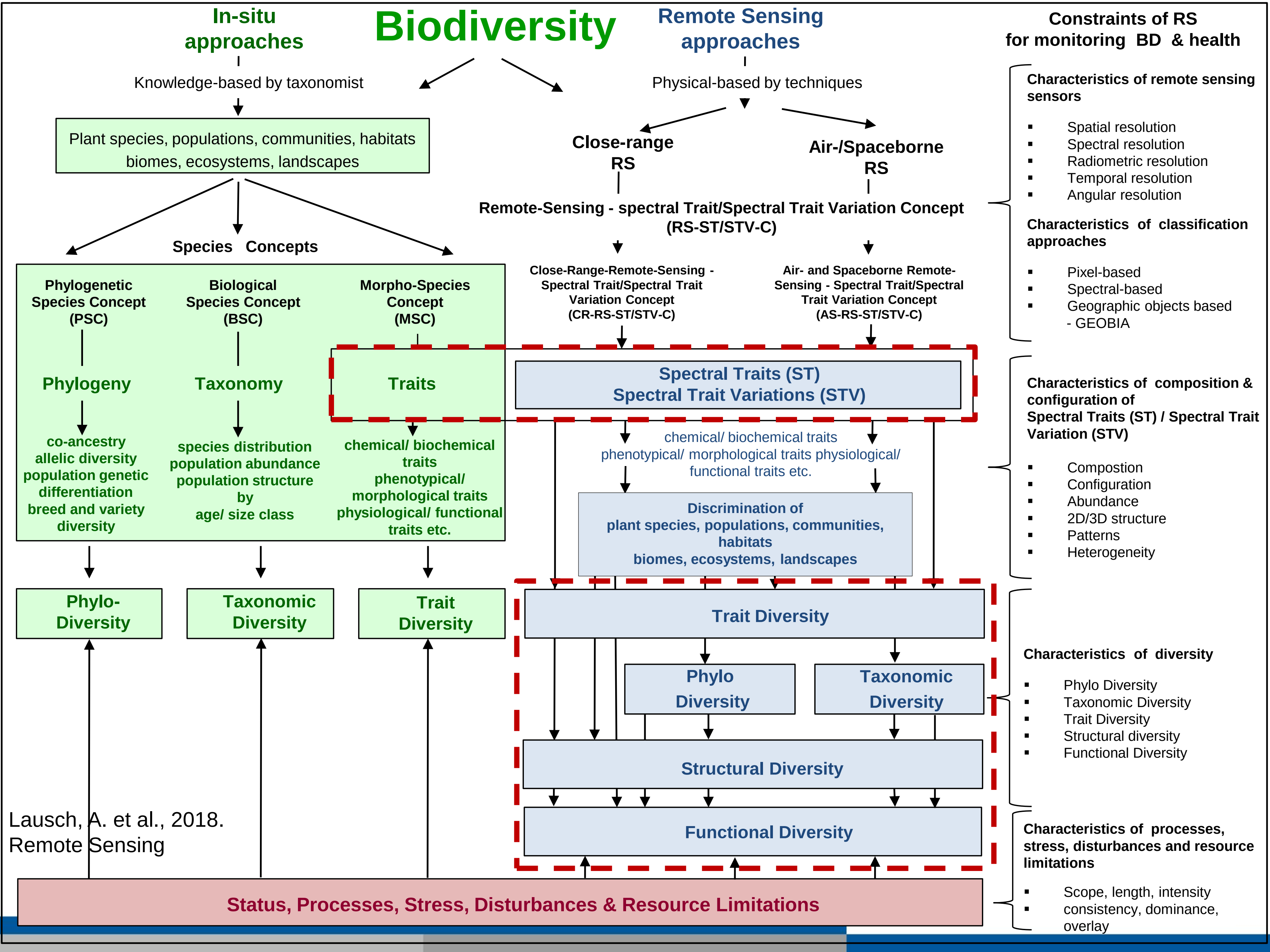
spectral answer by RS

Traits



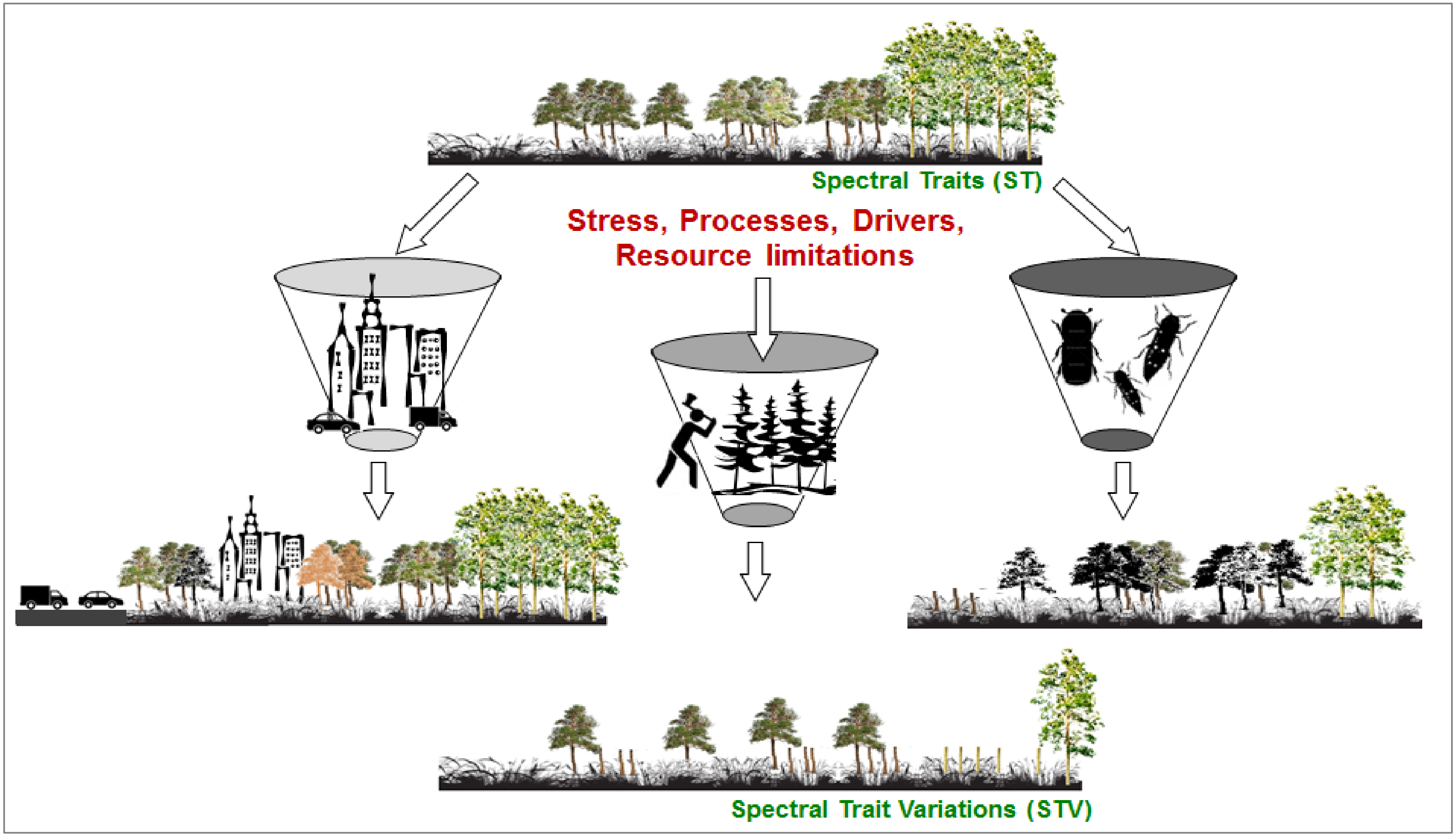


Trait-variation

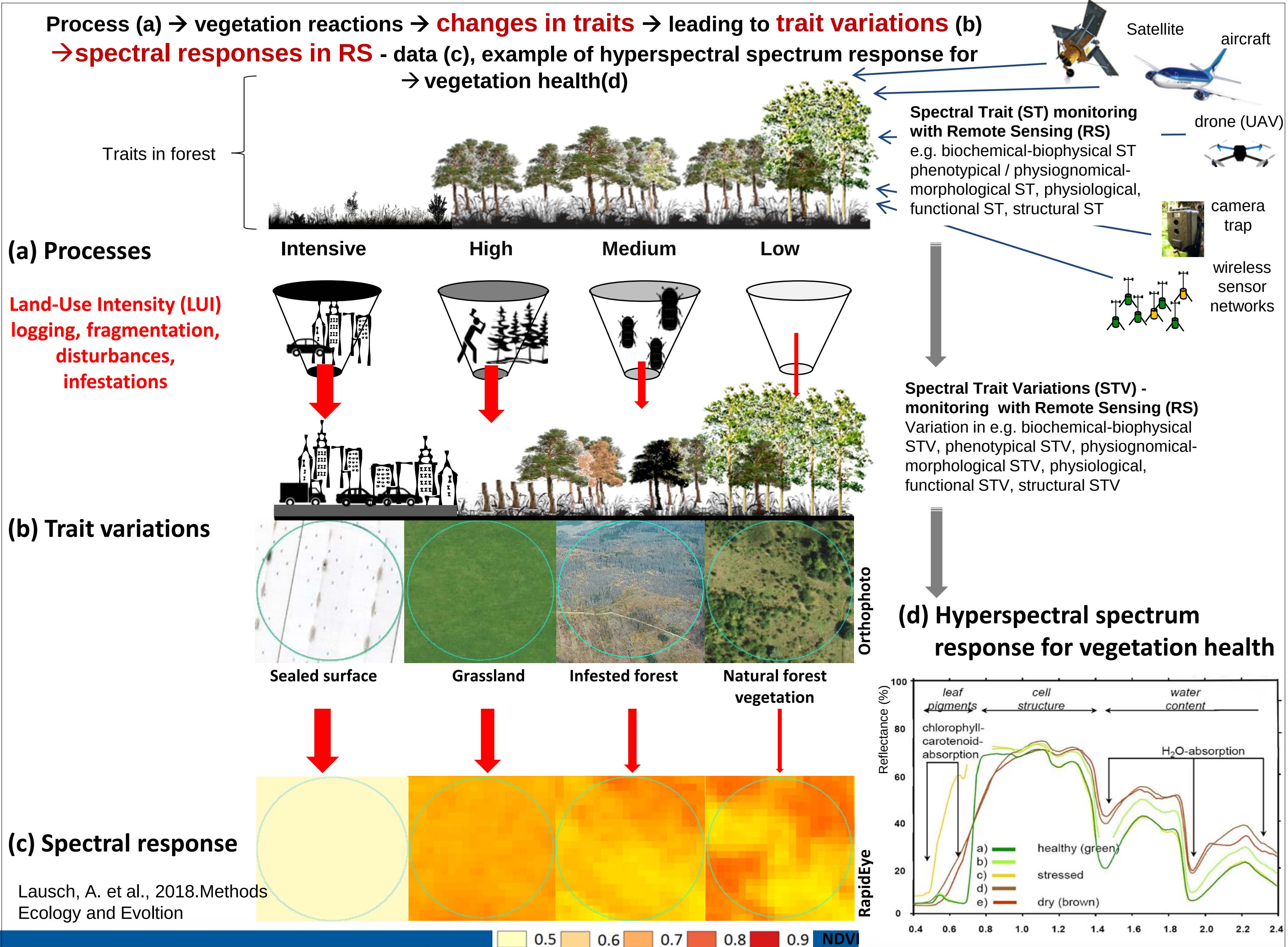

In-situ approaches
Biodiversity
Remote Sensing approaches
Constraints of RS for monitoring BD & health
Knowledge-based by taxonomist
Physical-based by techniques
Plant species, populations, communities, habitats biomes, ecosystems, landscapes
Close-range RS
Air-/Spaceborne RS
Remote-Sensing - spectral Trait/Spectral Trait Variation Concept (RS-ST/STV-C)
Species Concepts
Phylogenetic Species Concept (PSC)
Biological Species Concept (BSC)
Morpho-Species Concept (MSC)
Close-Range-Remote-Sensing - Spectral Trait/Spectral Trait Variation Concept (CR-RS-ST/STV-C)
Air- and Spaceborne Remote-Sensing - Spectral Trait/Spectral Trait Variation Concept (AS-RS-ST/STV-C)
Phylogeny
Taxonomy
Traits
Spectral Traits (ST)
Spectral Trait Variations (STV)
co-ancestry allelic diversity population genetic differentiation breed and variety diversity
species distribution population abundance population structure by age/ size class
chemical/ biochemical traits phenotypical/ morphological traits physiological/ functional traits etc.
chemical/ biochemical traits phenotypical/ morphological traits physiological/ functional traits etc.
Discrimination of plant species, populations, communities, habitats biomes, ecosystems, landscapes
Phylo-Diversity
Taxonomic Diversity
Trait Diversity
Trait Diversity
Phylo Diversity
Taxonomic Diversity
Structural Diversity
Functional Diversity
Lausch, A. et al., 2018. Remote Sensing
Status, Processes, Stress, Disturbances & Resource Limitations
Characteristics of remote sensing sensors
Spatial resolution
Spectral resolution
Radiometric resolution
Temporal resolution
Angular resolution
Characteristics of classification approaches
Pixel-based
Spectral-based
Geographic objects based - GEOBIA
Characteristics of composition & configuration of Spectral Traits (ST) / Spectral Trait Variation (STV)
Compostion
Configuration
Abundance
2D/3D structure
Patterns
Heterogeneity
Characteristics of diversity
Phylo Diversity
Taxonomic Diversity
Trait Diversity
Structural diversity
Functional Diversity
Characteristics of processes, stress, disturbances and resource limitations
Scope, length, intensity
consistency, dominance, overlay

Trait concept – Indicators / Filters of stress

Traits = Filters for stress, processes, disturbances and 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

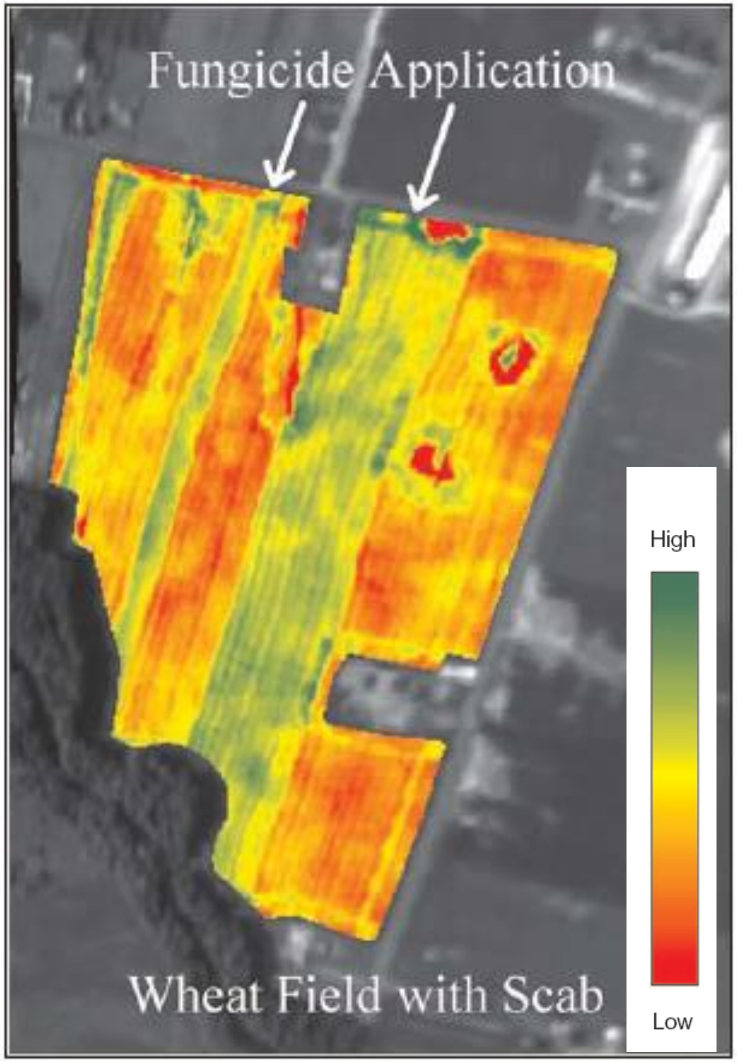


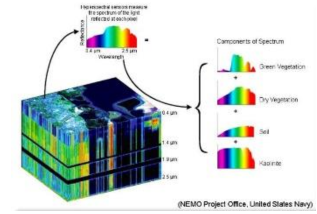
Lausch, A. et al., 2018.Methods Ecology and Evoltion

Trait concept - Understanding - Processes – Pattern – Interaction

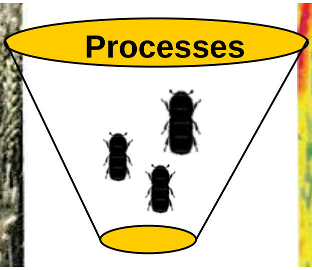
Monitoring and quantification of fungicid, pesticide applications

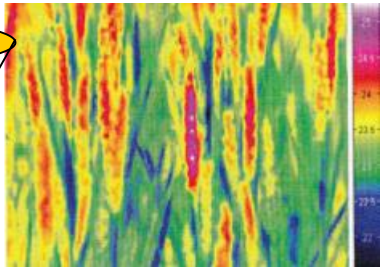
- **Healthy status of vegetation**
- **Changes of plant traits based on human pressures**





spectral answer by RS





Traits → **Trait-variation**

Wheat – Infection by phytopathogens
(Fusarium head scab.)

Trait concept of species -Traits - Animals

Opinion

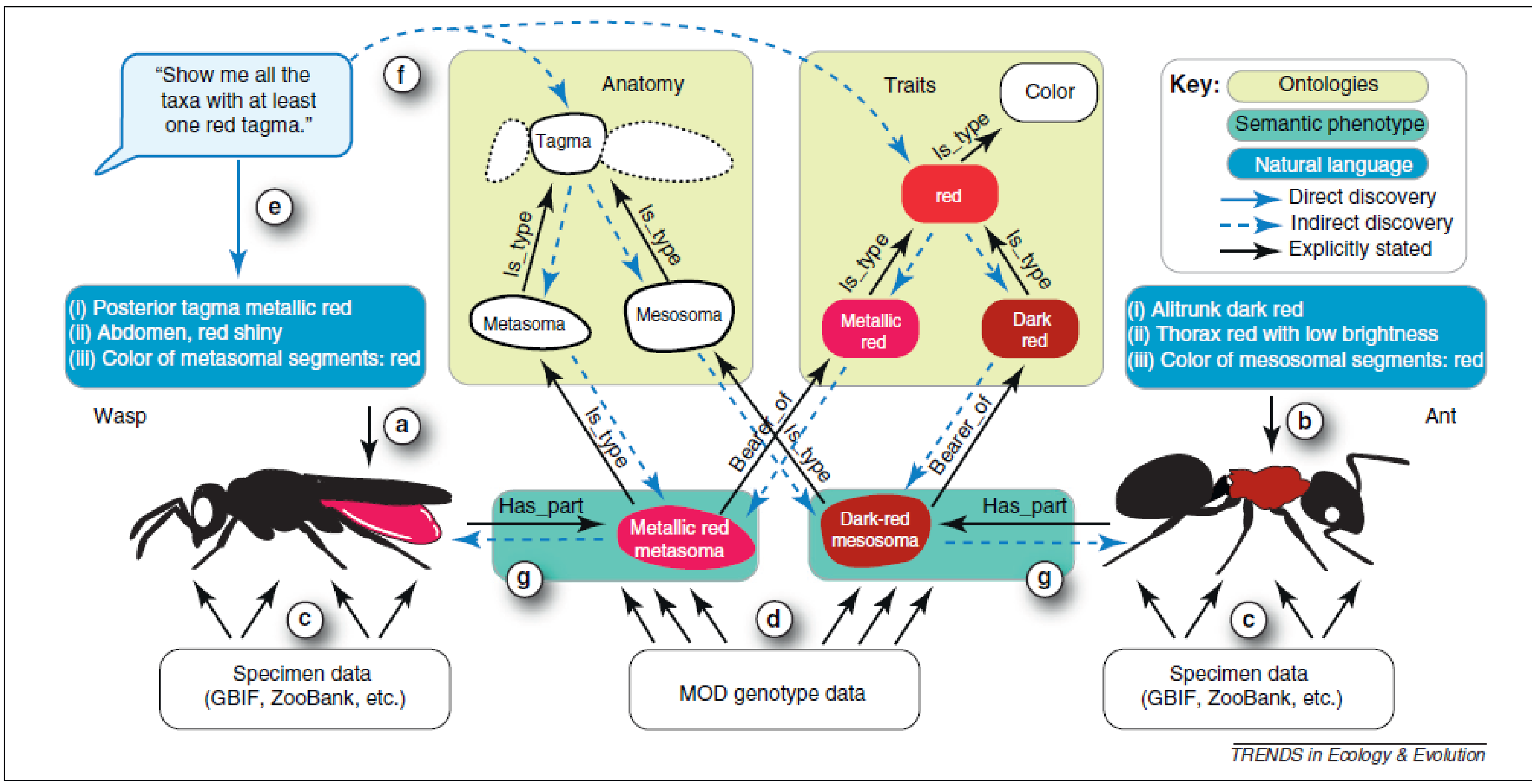
Special Issue: Ecological and evolutionary informatics

Time to change how we describe biodiversity

Andrew R. Deans[1], Matthew J. Yoder[1] and James P. Balhoff[2,3]

[1] Department of Entomology, North Carolina State University, Raleigh, NC 27695, USA
[2] National E
[3] Departmer

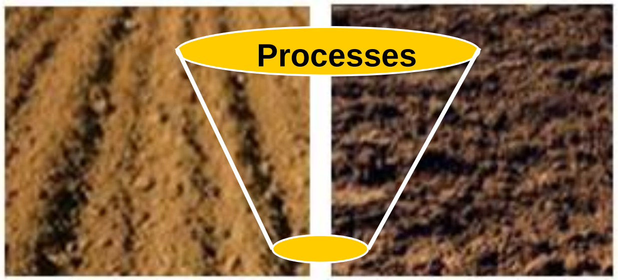
→ Semantic Web/ Linked Open Data



Deans, A.R., Yoder, M.J., Balhoff, J.P., 2012. Time to change how we describe biodiversity. Trends Ecol. Evol. 27, 78–84.

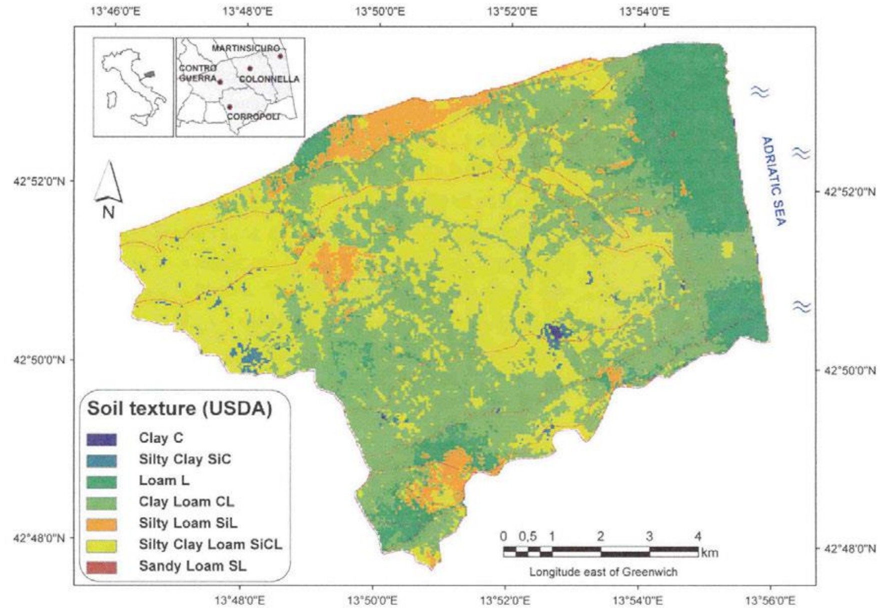
Trait concept – Traits of Geodiversity

Soil texture

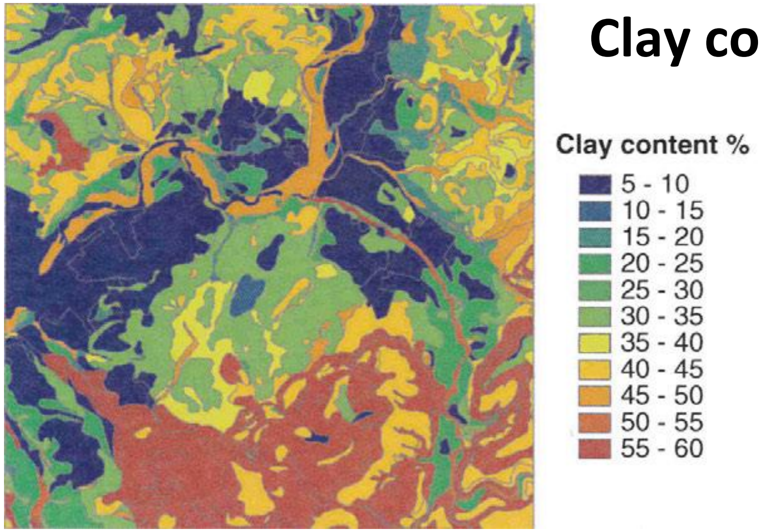


Soil management

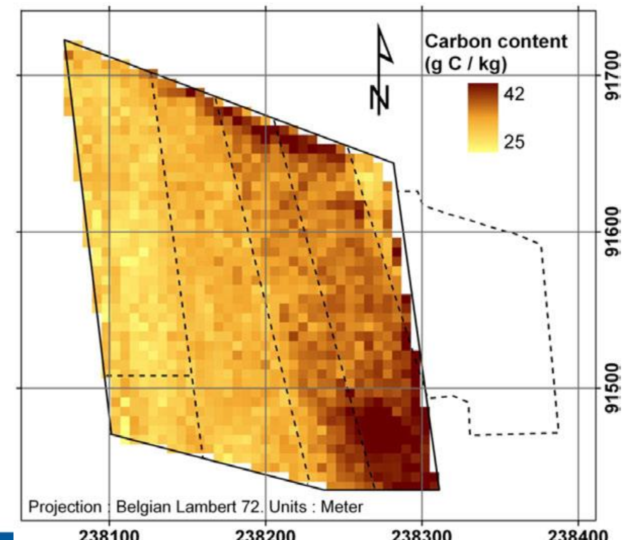
Soil texture



Clay content



Carbon content

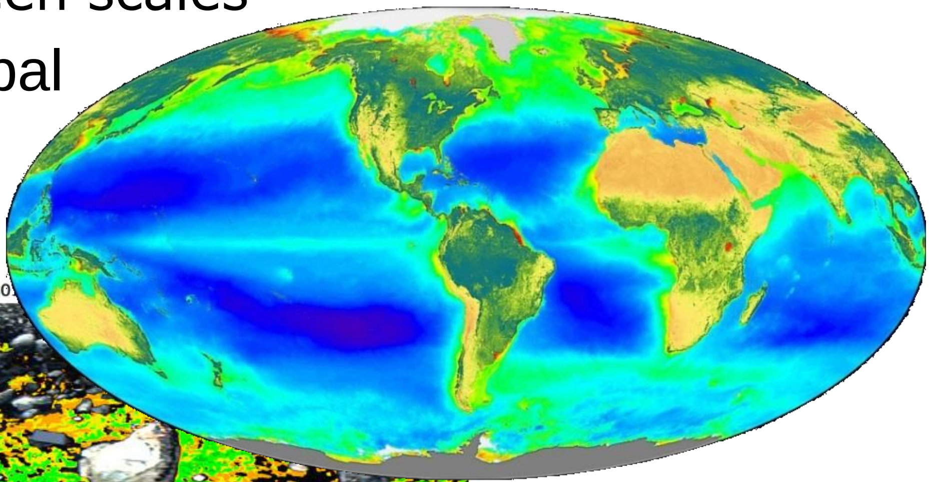


Wulf, H., Mulder, T., Schaepman, M. E., Keller, A., & Jörg, P. (2014). Remote Sensing of Soils. *Zurich, Switzerland*, 71.

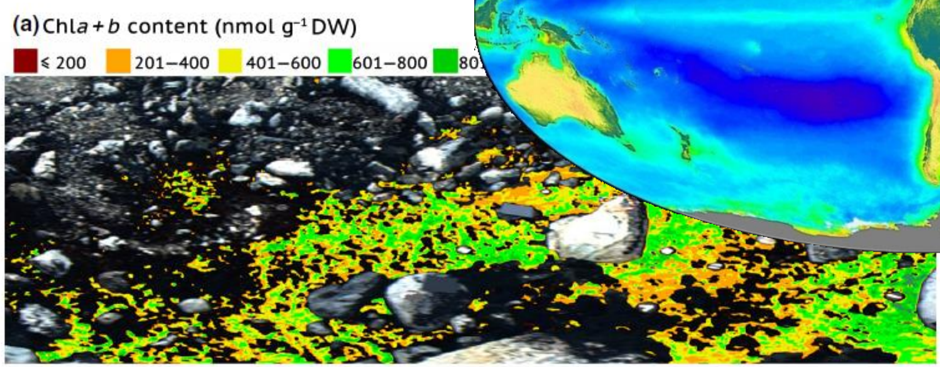
Trait concept - Understanding - Processes – Pattern – Interaction

- Traits → Exist on all spatial and temporal scales
- Imortant: Linking of traits between scales

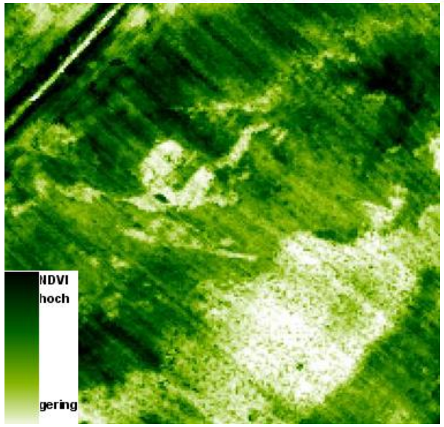
Global



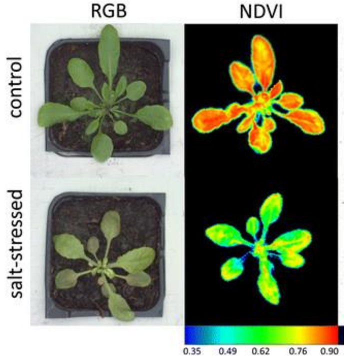
Local



Plot



Individual

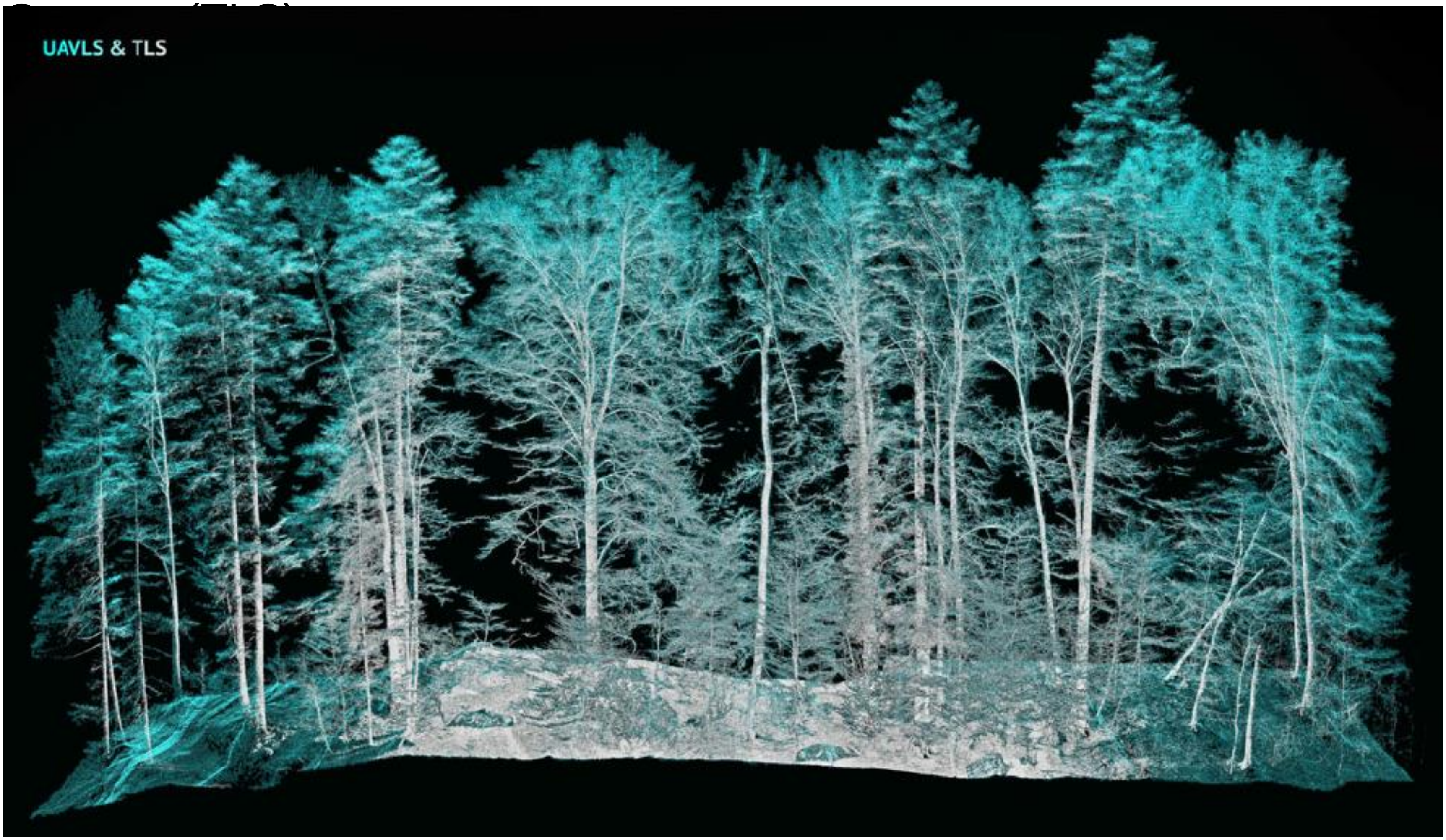


Chlorophyll-Concentration

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

Ecosystem health by RS 2-4D Structural Diversity

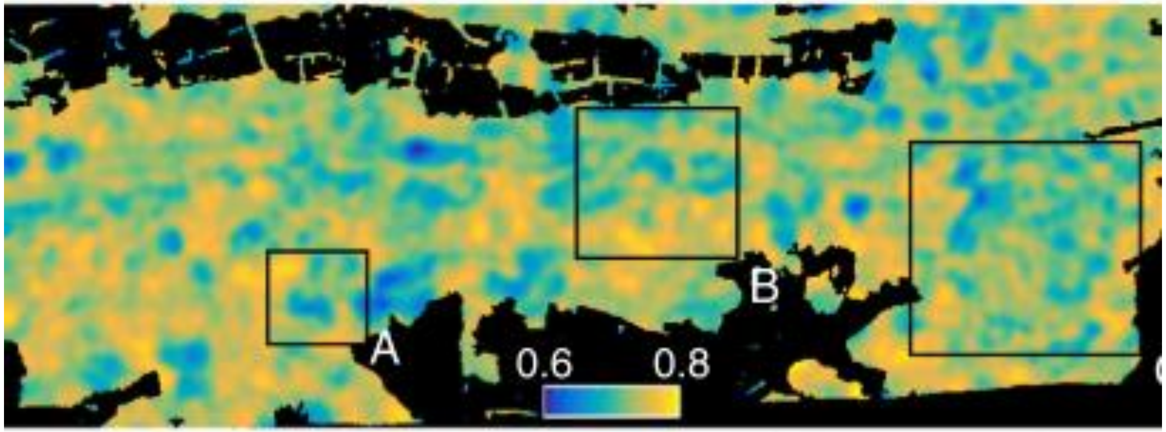
Coupling - Laserscanning (UAVLS) & Terrestrial Laser



Laegeren Forest, Switzerland

Morsdorf, F., Kükenbrink, D., Schneider, F.D., Abegg, M., Schaepman, M.E., 2018. Close-range laser scanning in forests: towards physically based semantics across scales. Interface Focus 8, 20170046. doi:10.1098/rsfs.2017.0046

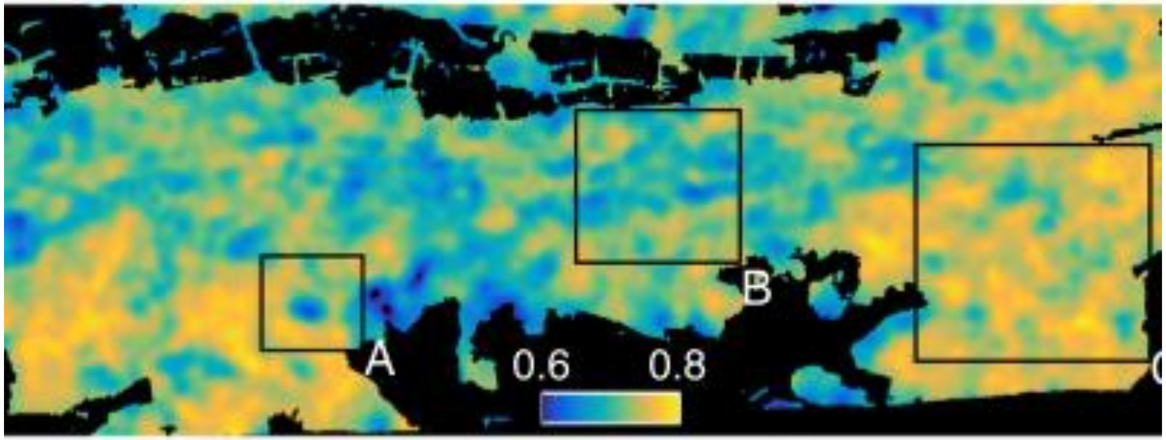
Ecosystem health by RS – Structural & Functional Diversity



Morphological forest traits

Plant area index (PAI, blue),
Canopy height (CH, red)
Foliage height diversity (FHD, green)

→Morphological Evenness



Physiological forest traits

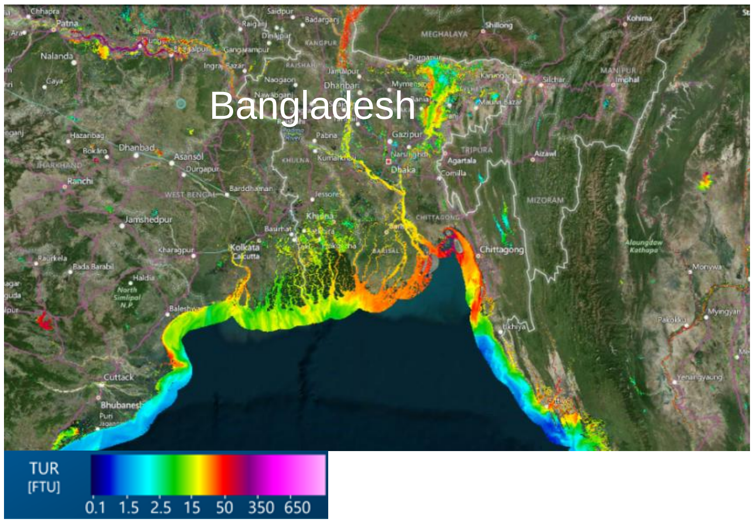
Water thickness (EWT, blue)
Carotenoids (CAR, red)
Chlorophyll (CHL, green)

→Physiological Evenness

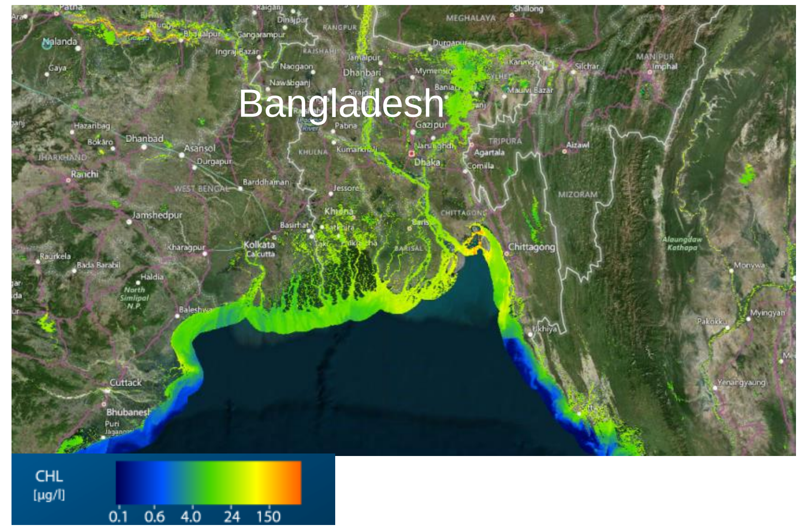
Schneider, F.D., Morsdorf, F., Schmid, B., Petchey, O.L., Hueni, A., Schimel, D.S., Schaepman, M.E., 2017. Mapping functional diversity from remotely sensed morphological and physiological forest traits. Nat. Commun. doi:10.1038/s41467-017-01530-3

Ecosystem health by RS – Water characteristics and water quality indicator

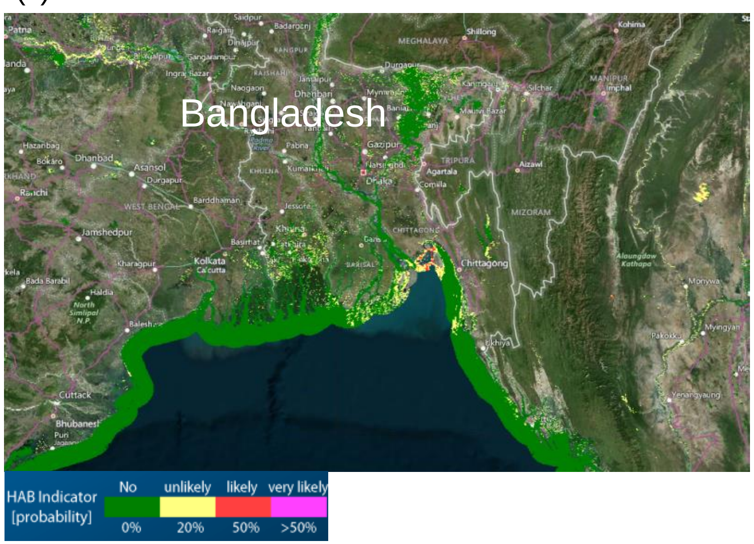
(a)



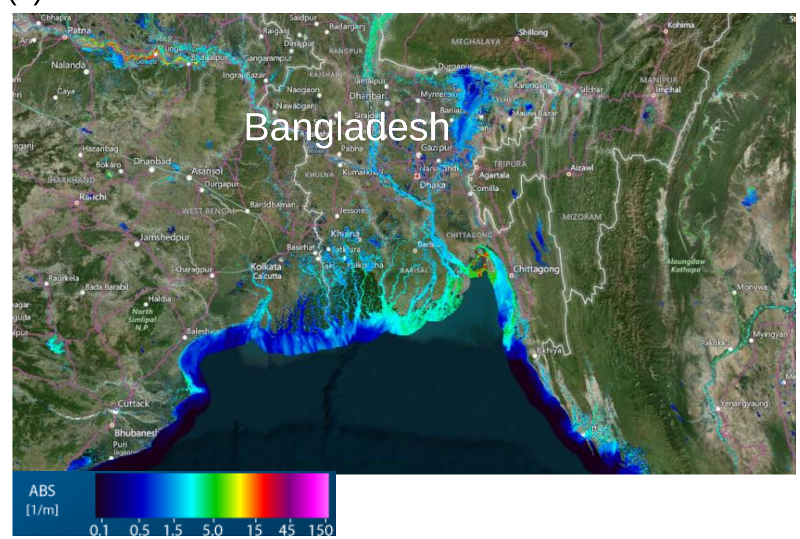
(b)



(c)



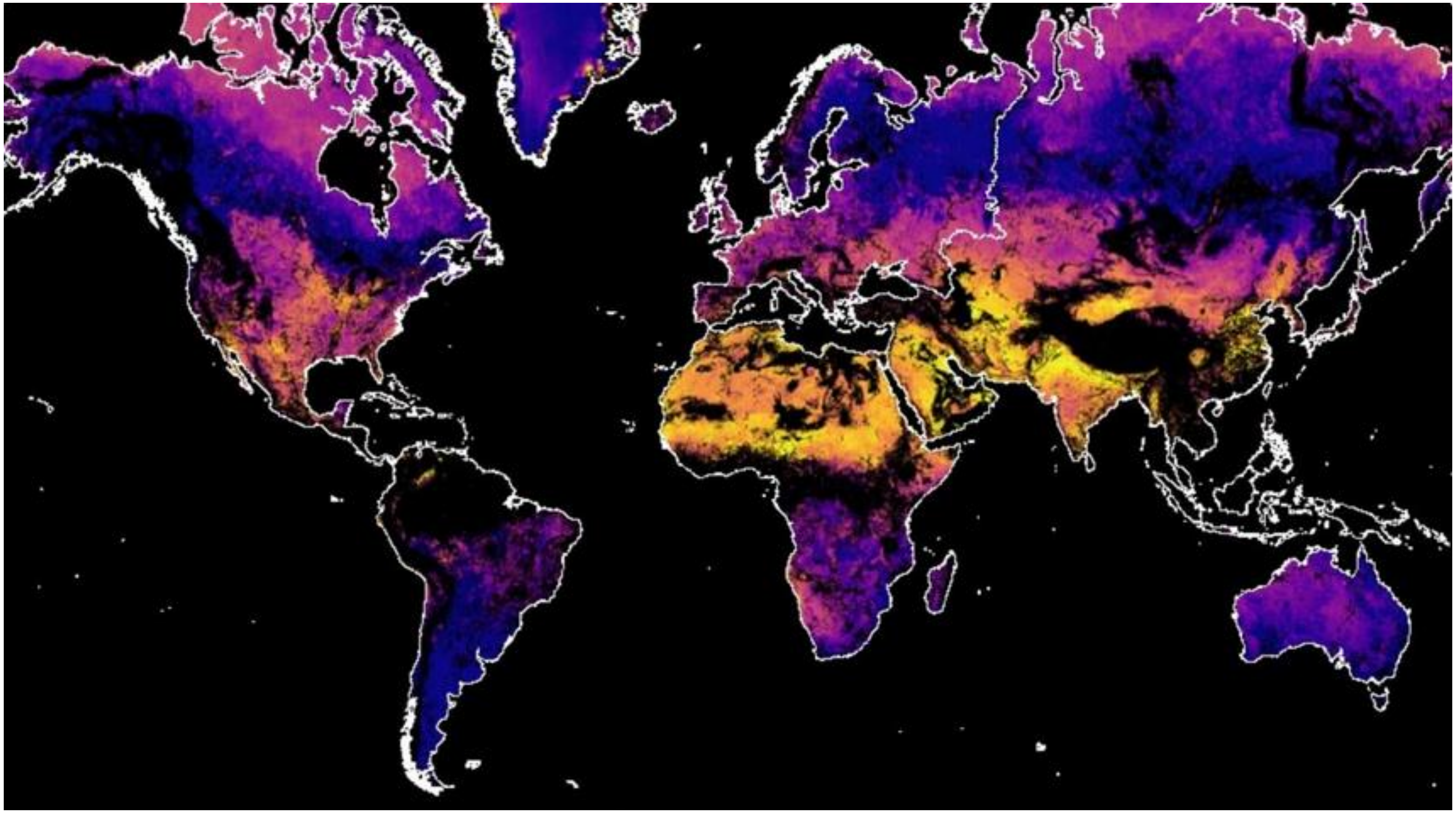
(d)



http://www.worldwaterquality.org/

Earth Engine Data Catalog - Atmospheric methane (CH_4) concentration

Earth Engine's public data archive **includes more than forty years of historical imagery** and scientific datasets, updated and expanded daily.

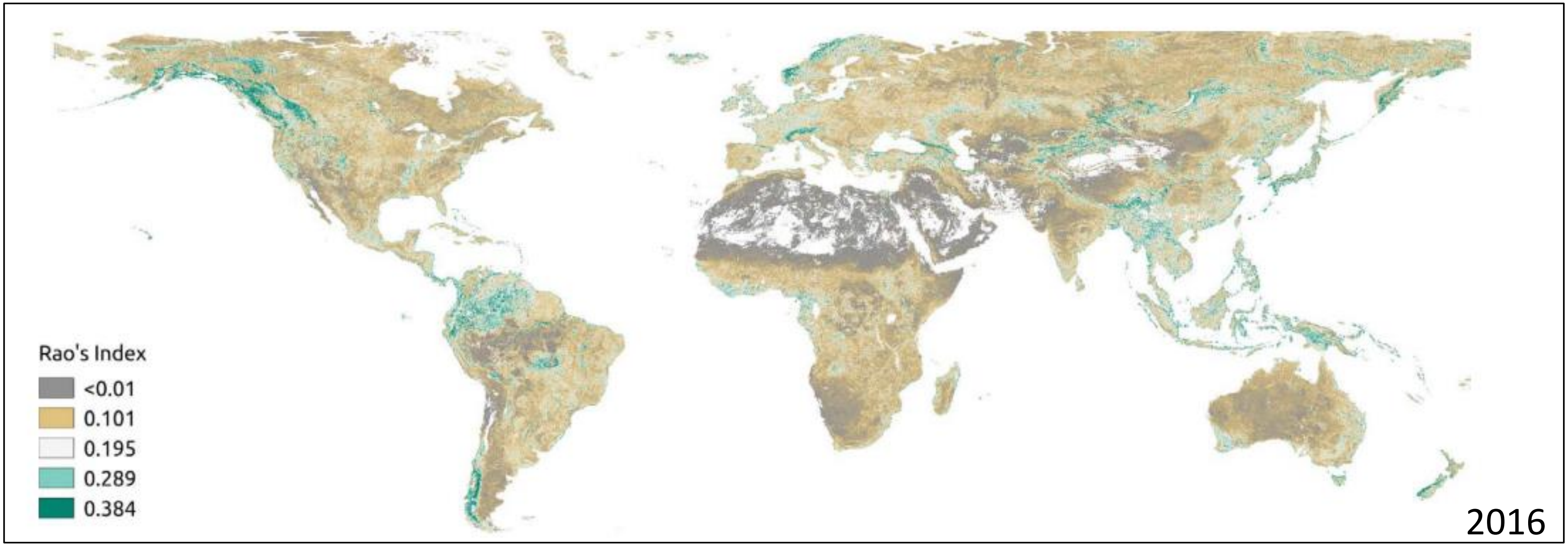


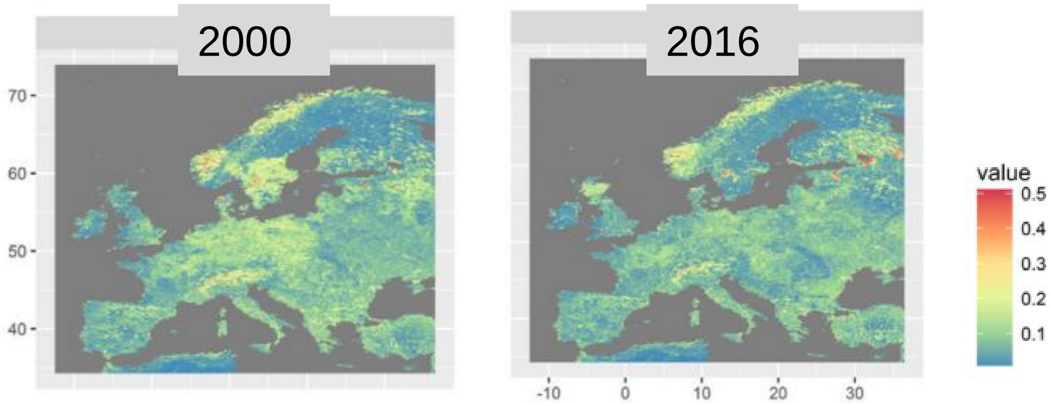
Sentinel-5P Methane
Atmospheric methane (CH_4) concentration. After carbon dioxide (CO_2), it is the most important contributor to the anthropogenically enhanced greenhouse effect. It enters Earth's atmosphere through both natural and anthropogenic processes, though the majority is of anthropogenic origin.
Dataset availability: 2019-02-08 – Present

https://developers.google.com/earth-engine/datasets

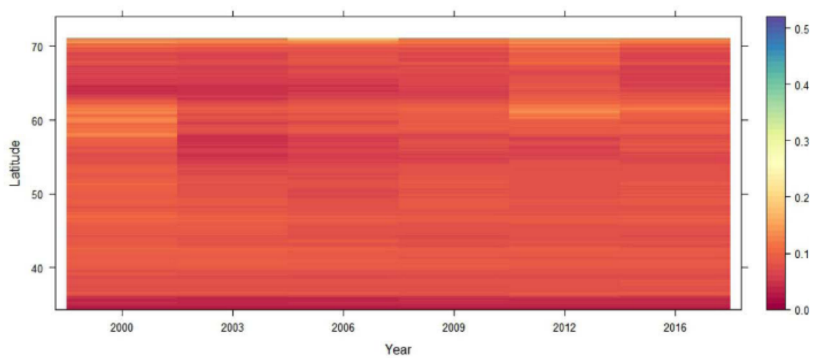
Ecosystem health by RS – Rao's quadratic diversity metric

Rao's quadratic diversity metric - **NDVI** map of the world
2016 - http://land.copernicus.eu/global/products/ndvi





2000 → 2016

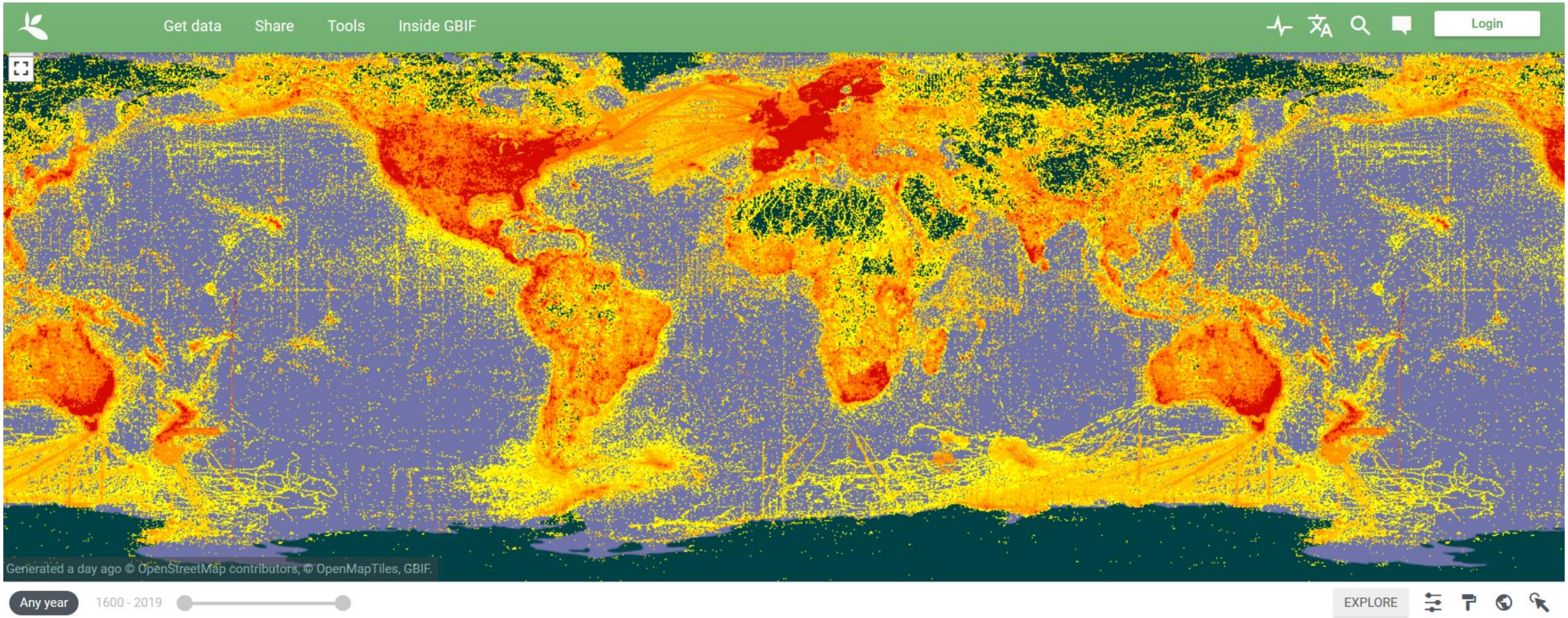


Rocchini, D., et al., 2018. Remotely sensed spatial heterogeneity as an exploratory tool for taxonomic and functional diversity study. Ecol. Indic. 85, 983–990. https://doi.org/10.1016/j.ecolind.2017.09.055

GBIF—the Global Biodiversity Information Facility

https://www.gbif.org/

—is an **international network** and research infrastructure funded by the world's governments and aimed at providing anyone, anywhere, **open access** to data about all types of life on Earth.



GBIF—the Global Biodiversity Information Facility

And what is the problem –
in Monitoring Bio- Geodiversity and ESS ?

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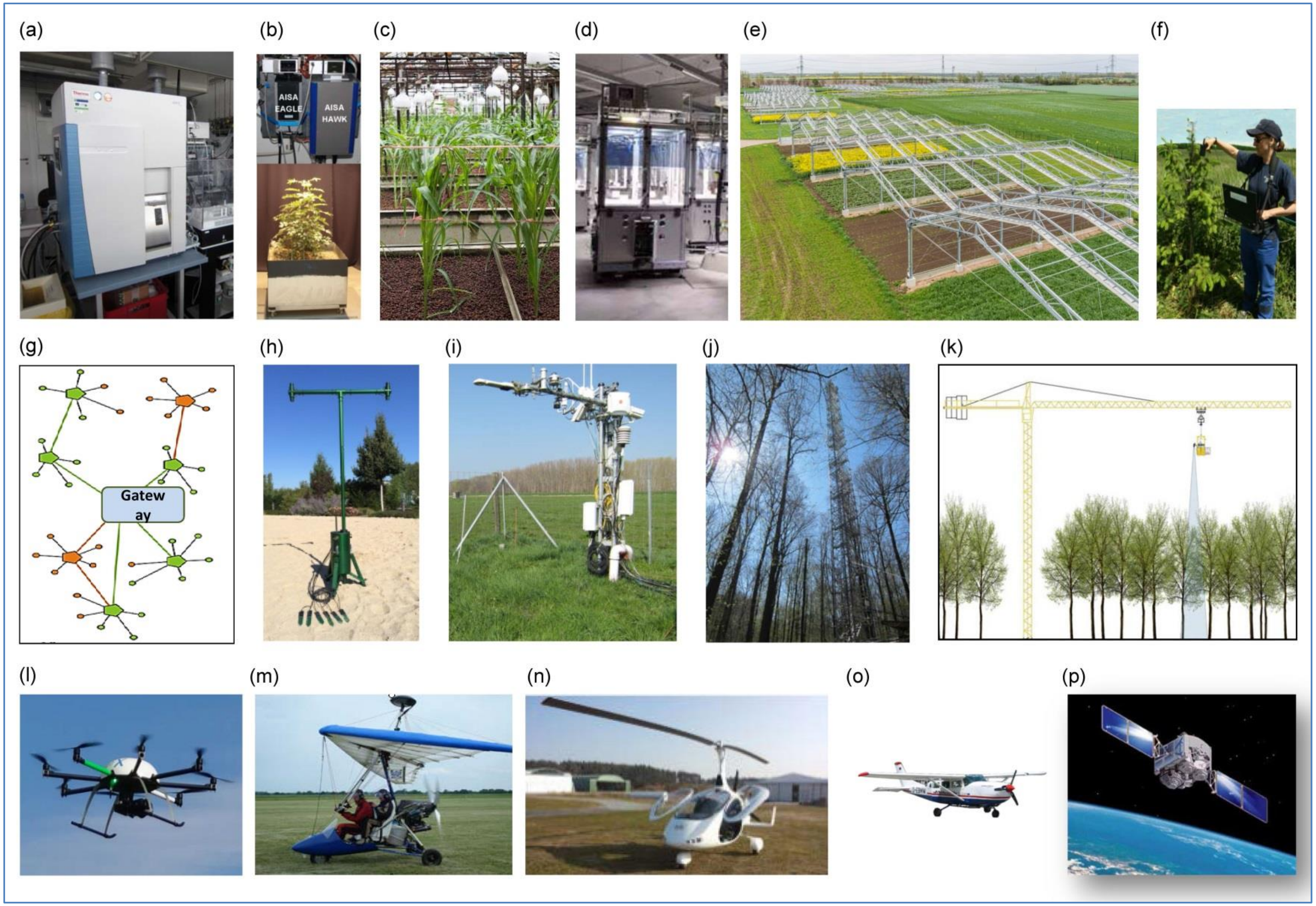
Data Science for Bio-Geodiversity - Challenges

- Landscapes, Ecology, Bio-and Geodiversity, Processes & Functions are:
  Complex, multidimensional, multi-scale and mostly non-linear

- **Not one** monitoring approach, monitoring platform, model, space-time scale, tool or data **alone is sufficient to explain the complexity** of landscapes, processes or functions

- We have to look for necessary **requirements** – dealing of **Complexity, Multidimensionality …,**

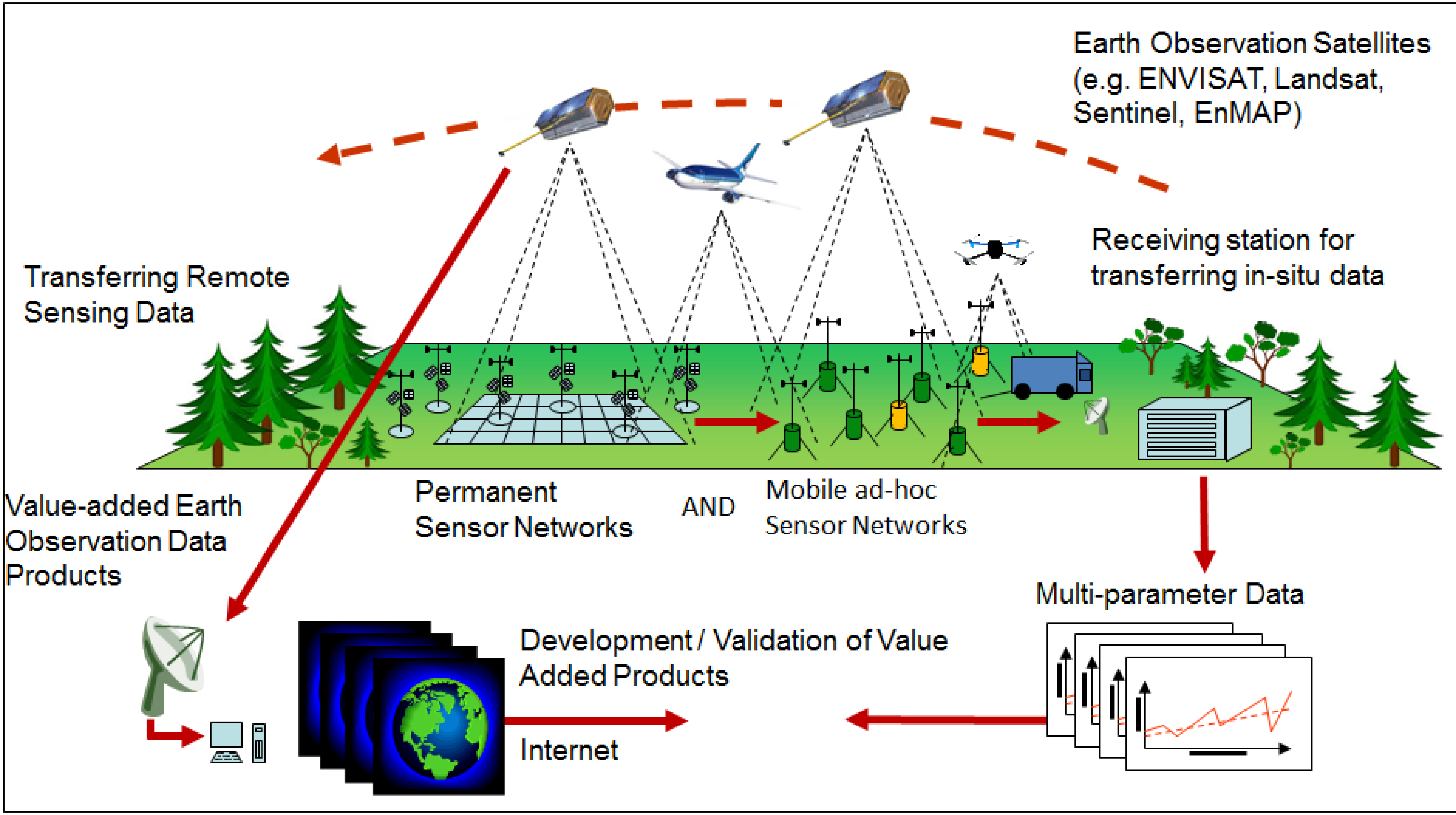
Data Science – Requirement – Remote Sensing



use & couple different plattforms

Lausch et al., 2020. A range of Earth Observation techniques for assessing plant diversity Jeannine Cavender-Bares, John Gamon, Philip Townsend (eds): The nature of biodiversity: prospects for remote detection of genetic, phylogenetic, functional and ecosystem components and importance in managing Planet, Jeannine Cavender-Bares, John Gamon, Philip Townsend, Springer (in press)

Data Science – Requirement – Coupling RS Platforms



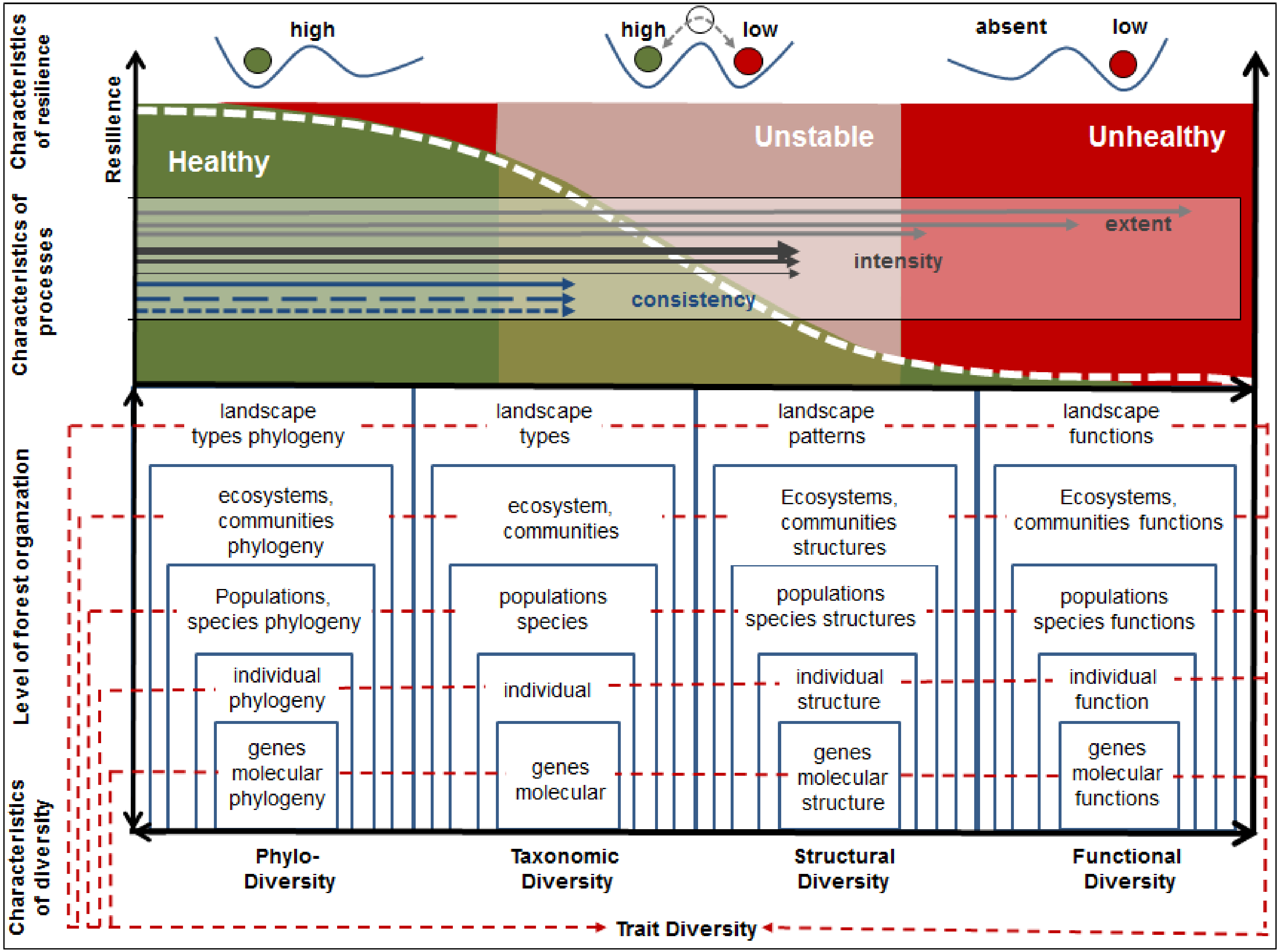
Lausch, A. et al., 2018. Understanding Forest Health with Remote Sensing, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches. Remote Sensing, 10, 1120

Approaches, scale, processes → Biodiversity and their resillience

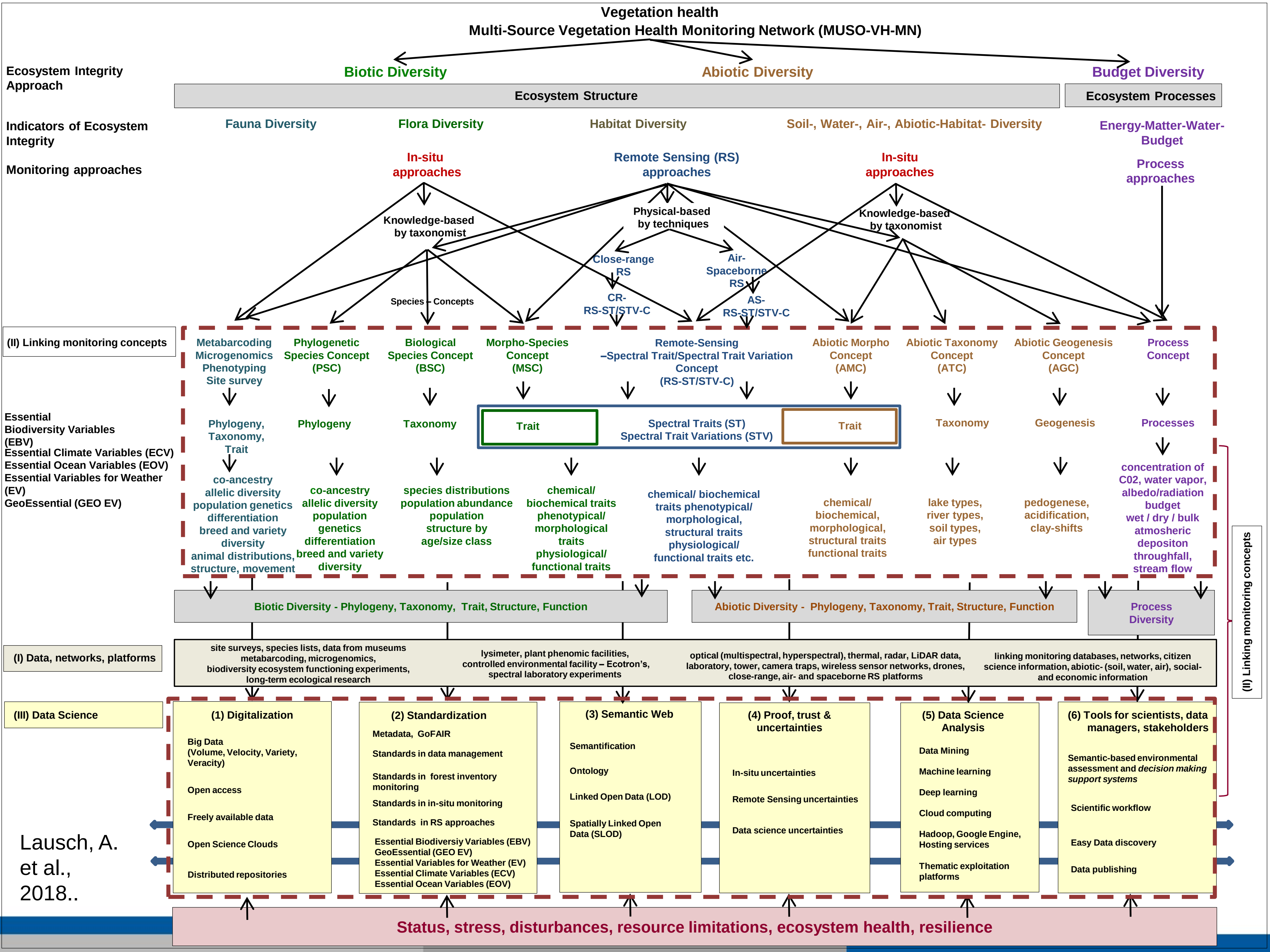
Processes

Scale (level of organization)

Approaches



Lausch, A. et al., 2018. Understanding Forest Health with Remote Sensing, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches. Remote Sensing, 10, 1120; doi:10.3390/rs10071120.


Vegetation health
Multi-Source Vegetation Health Monitoring Network (MUSO-VH-MN)
Ecosystem Integrity Approach
Biotic Diversity
Abiotic Diversity
Budget Diversity
Ecosystem Structure
Ecosystem Processes
Indicators of Ecosystem Integrity
Fauna Diversity
Flora Diversity
Habitat Diversity
Soil-, Water-, Air-, Abiotic-Habitat- Diversity
Energy-Matter-Water-Budget
Monitoring approaches
In-situ approaches
Remote Sensing (RS) approaches
In-situ approaches
Process approaches
Knowledge-based by taxonomist
Physical-based by techniques
Knowledge-based by taxonomist
Close-range RS
Air-Spaceborne RS
Species - Concepts
CR-RS-ST/STV-C
AS-RS-ST/STV-C
(II) Linking monitoring concepts
Metabarcoding Microgenomics Phenotyping Site survey
Phylogenetic Species Concept (PSC)
Biological Species Concept (BSC)
Morpho-Species Concept (MSC)
Remote-Sensing –Spectral Trait/Spectral Trait Variation Concept (RS-ST/STV-C)
Abiotic Morpho Concept (AMC)
Abiotic Taxonomy Concept (ATC)
Abiotic Geogenesis Concept (AGC)
Process Concept
Essential Biodiversity Variables (EBV)
Essential Climate Variables (ECV)
Essential Ocean Variables (EOV)
Essential Variables for Weather (EV)
GeoEssential (GEO EV)
Phylogeny, Taxonomy, Trait
Phylogeny
Taxonomy
Trait
Spectral Traits (ST) Spectral Trait Variations (STV)
Trait
Taxonomy
Geogenesis
Processes
co-ancestry allelic diversity population genetics differentiation breed and variety diversity animal distributions, structure, movement
co-ancestry allelic diversity population genetics differentiation breed and variety diversity
species distributions population abundance population structure by age/size class
chemical/ biochemical traits phenotypical/ morphological traits physiological/ functional traits
chemical/ biochemical traits phenotypical/ morphological, structural traits physiological/ functional traits etc.
chemical/ biochemical, morphological, structural traits functional traits
lake types, river types, soil types, air types
pedogenese, acidification, clay-shifts
concentration of C02, water vapor, albedo/radiation budget wet / dry / bulk atmosheric deposition throughfall, stream flow
Biotic Diversity - Phylogeny, Taxonomy, Trait, Structure, Function
Abiotic Diversity - Phylogeny, Taxonomy, Trait, Structure, Function
Process Diversity
(I) Data, networks, platforms
site surveys, species lists, data from museums metabarcoding, microgenomics, biodiversity ecosystem functioning experiments, long-term ecological research
lysimeter, plant phenomic facilities, controlled environmental facility – Ecotron's, spectral laboratory experiments
optical (multispectral, hyperspectral), thermal, radar, LiDAR data, laboratory, tower, camera traps, wireless sensor networks, drones, close-range, air- and spaceborne RS platforms
linking monitoring databases, networks, citizen science information, abiotic- (soil, water, air), social- and economic information
(III) Data Science
(1) Digitalization
Big Data (Volume, Velocity, Variety, Veracity)
Open access
Freely available data
Open Science Clouds
Distributed repositories
(2) Standardization
Metadata, GoFAIR
Standards in data management
Standards in forest inventory monitoring
Standards in in-situ monitoring
Standards in RS approaches
Essential Biodiversiy Variables (EBV) GeoEssential (GEO EV) Essential Variables for Weather (EV) Essential Climate Variables (ECV) Essential Ocean Variables (EOV)
(3) Semantic Web
Semantification
Ontology
Linked Open Data (LOD)
Spatially Linked Open Data (SLOD)
(4) Proof, trust & uncertainties
In-situ uncertainties
Remote Sensing uncertainties
Data science uncertainties
(5) Data Science Analysis
Data Mining
Machine learning
Deep learning
Cloud computing
Hadoop, Google Engine, Hosting services
Thematic exploitation platforms
(6) Tools for scientists, data managers, stakeholders
Semantic-based environmental assessment and decision making support systems
Scientific workflow
Easy Data discovery
Data publishing
(II) Linking monitoring concepts
Lausch, A. et al., 2018..
Status, stress, disturbances, resource limitations, ecosystem health, resilience

Data Science – Challenge - Digitalization

Ecology and Evolution

Open Access

The PREDICTS database: a global database of how local terrestrial biodiversity responds to human impacts

Lawrence N. Hudson[1]*, Tim Newbold[2,3]*, Sara Contu[1], Samantha L. L. Hill[1,2], Igor Lysenko[4], Adriana De Palma[1,4], Helen R. P. Phillips[1,4], Rebecca A. Senior[2], Dominic J. Bennett[4], Hollie Booth[2,5], Argyrios

Global Change Biology

Global Change Biology (2011) 17, 2905–2935, doi: 10.1111/j.1365-2486.2011.02451.x

TRY – a global database of plant traits

J. KATTGE*, S. DÍAZ†, S. LAVOREL‡, I. C. PRENTICE§, P. LEADLEY¶, G. BÖNISCH*, E. GARNIER||, M. WESTOBY§, P. B. REICH**, ††, I. J. WRIGHT§, J. H. C. CORNELISSEN‡‡

World database of protected areas (WDPA)

Movebank – For Animal Tracking data
www.movebank.org

Encyclopedia of life (EOL)

Contents lists available at ScienceDirect

Biological Conservation

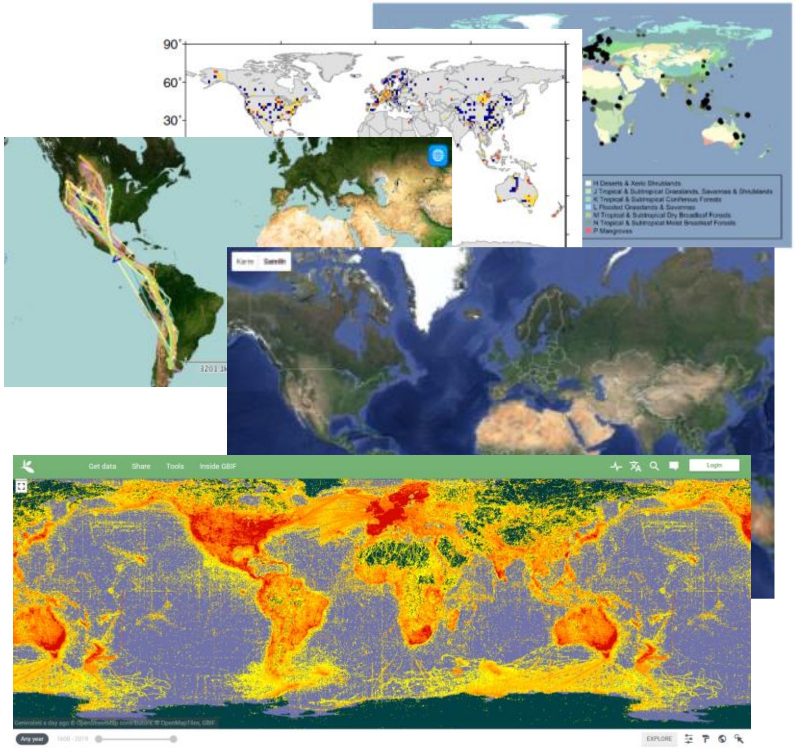
journal homepage: www.elsevier.com/locate/biocon

ELSEVIER

Perspective

Free and open-access satellite data are key to biodiversity conservation

W. Turner[a,*], C. Rondinini[b], N. Pettorelli[c], B. Mora[d], A.K. Leidner[a,e], Z. Szantoi[f], G. Buchanan[g],



Big Data

Free Data

Open Data

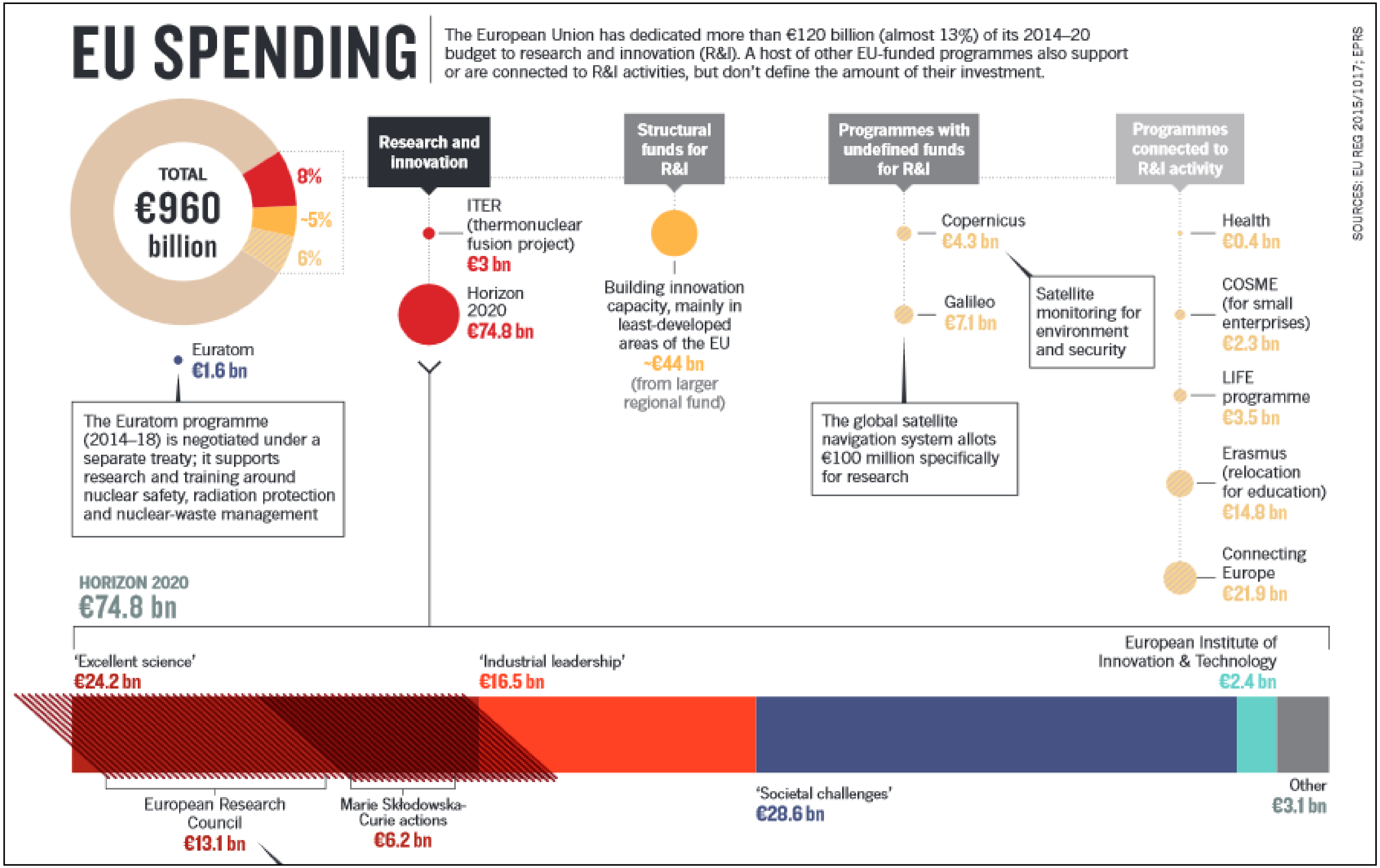
Complex Data

Data Science – Challenge - Digitalization

Roche, D.G., Lanfear, R., Binning, S.A., Haff, T.M., Schwanz, L.E., Cain, K.E., Kokko, H., Jennions, M.D., Kruuk, L.E.B., 2014. Troubleshooting Public Data Archiving: Suggestions to Increase Participation. PLoS Biol. 12. doi:10.1371/journal.pbio.1001779

Data Science – Challenge - Digitalization

Investitions/EU - Data-Generation 2014-2020 → 120B €



Abbott, A.; Butler, D.; Gibney, E.; Schiermeier, Q.; Van Noorden, R. Boon or burden: done for science? Nature 2016, 534, 307–309.

Data Science – Challenge - Digitalization

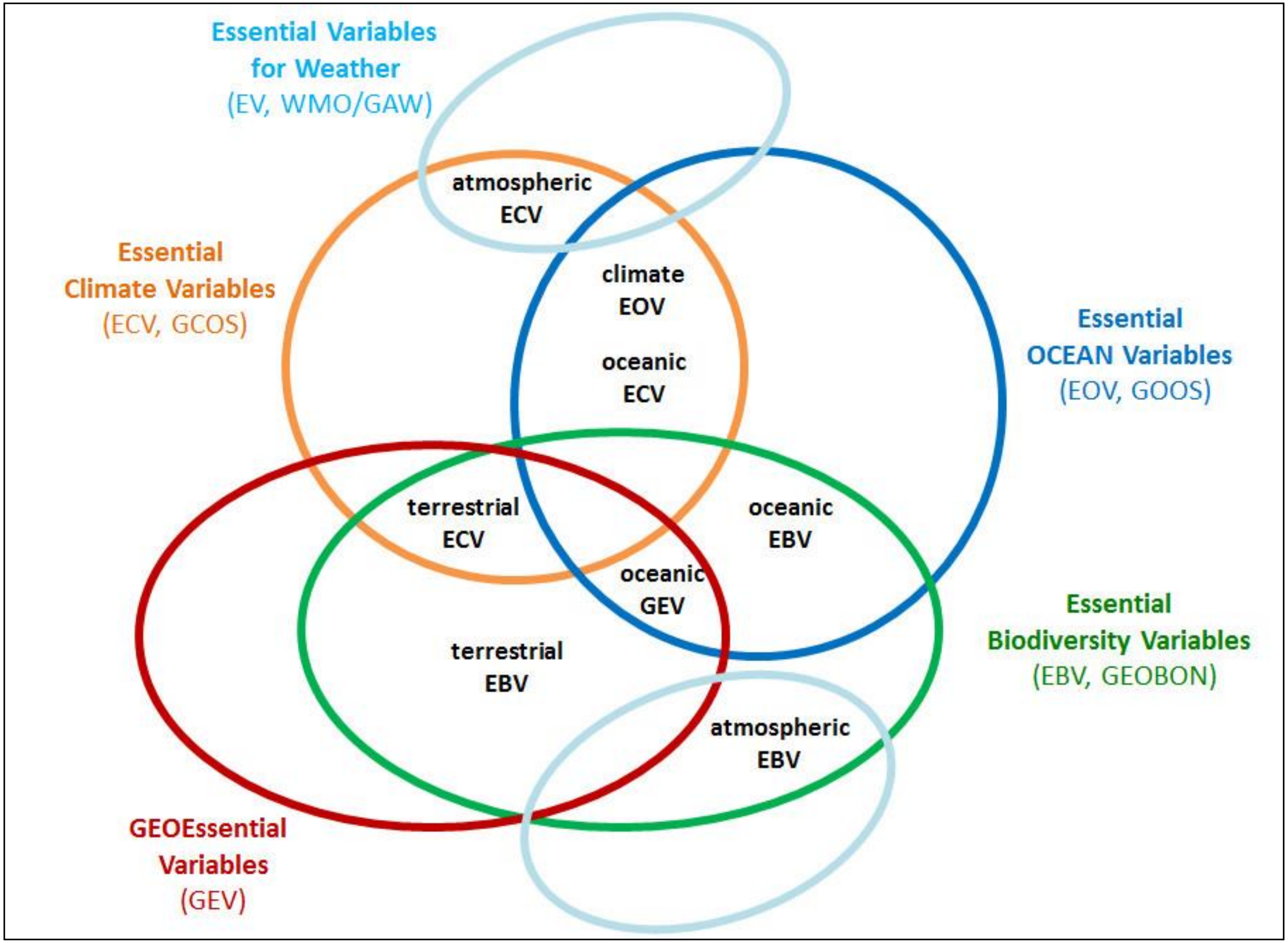
Although 90% of the world's data was generated over two years, around

→ "50% of all research and experiment data (= US$28B/year) are never found again !

→ and over 80% of it never makes it to a trusted and sustainable repository" (Ayris et al., 2016)

Ayris, P.; Berthou, J.-Y.; Bruce, R.; Lindstaedt, S.; Monreale, A.; Mons, B.; M. Tochtermann, K.;Wilkinson, R. Realising the European Open Science Cloud; Europe Brussels, Belgium, 2016.

Data Science – Standardization in Monitoring



Lausch, A. et al., 2018. Understanding Forest Health with Remote Sensing, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches. Remote Sensing, 10, 1120

Data Science – Requirement – Metadata/Data - FAIR

www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

Comment: The FAIR Guiding Principles for scientific data management and stewardship

Mark D. Wilkinson et al.*

Received: 10 December 2015
Accepted: 12 February 2016
Published: 15 March 2016

There is an urgent need to improve the infrastructure supporting the reuse of scholarly data. A diverse set of stakeholders—representing academia, industry, funding agencies, and scholarly publishers—have come together to design and jointly endorse a concise and measureable set of principles that we refer to as the FAIR Data Principles. The intent is that these may act as a guideline for those wishing to enhance the reusability of their data holdings. Distinct from peer initiatives that focus on the human scholar, the FAIR Principles put specific emphasis on enhancing the ability of machines to automatically find and use the data, in addition to supporting its reuse by individuals. This Comment is the first formal publication of the FAIR Principles, and includes the rationale behind them, and some exemplar implementations in the community.

Box 2 | The FAIR Guiding Principles

To be Findable:
F1. (meta)data are assigned a globally unique and persistent identifier
F2. data are described with rich metadata (defined by R1 below)
F3. metadata clearly and explicitly include the identifier of the data it d
F4. (meta)data are registered or indexed in a searchable resource

To be Accessible:
A1. (meta)data are retrievable by their identifier using a standardized c
A1.1 the protocol is open, free, and universally implementable
A1.2 the protocol allows for an authentication and authorization procedure, where necessary
A2. metadata are accessible, even when the data are no longer available

To be Interoperable:
I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
I2. (meta)data use vocabularies that follow FAIR principles
I3. (meta)data include qualified references to other (meta)data

To be Reusable:
R1. meta(data) are richly described with a plurality of accurate and relevant attributes
R1.1. (meta)data are released with a clear and accessible data usage license
R1.2. (meta)data are associated with detailed provenance
R1.3. (meta)data meet domain-relevant community standards

Findable

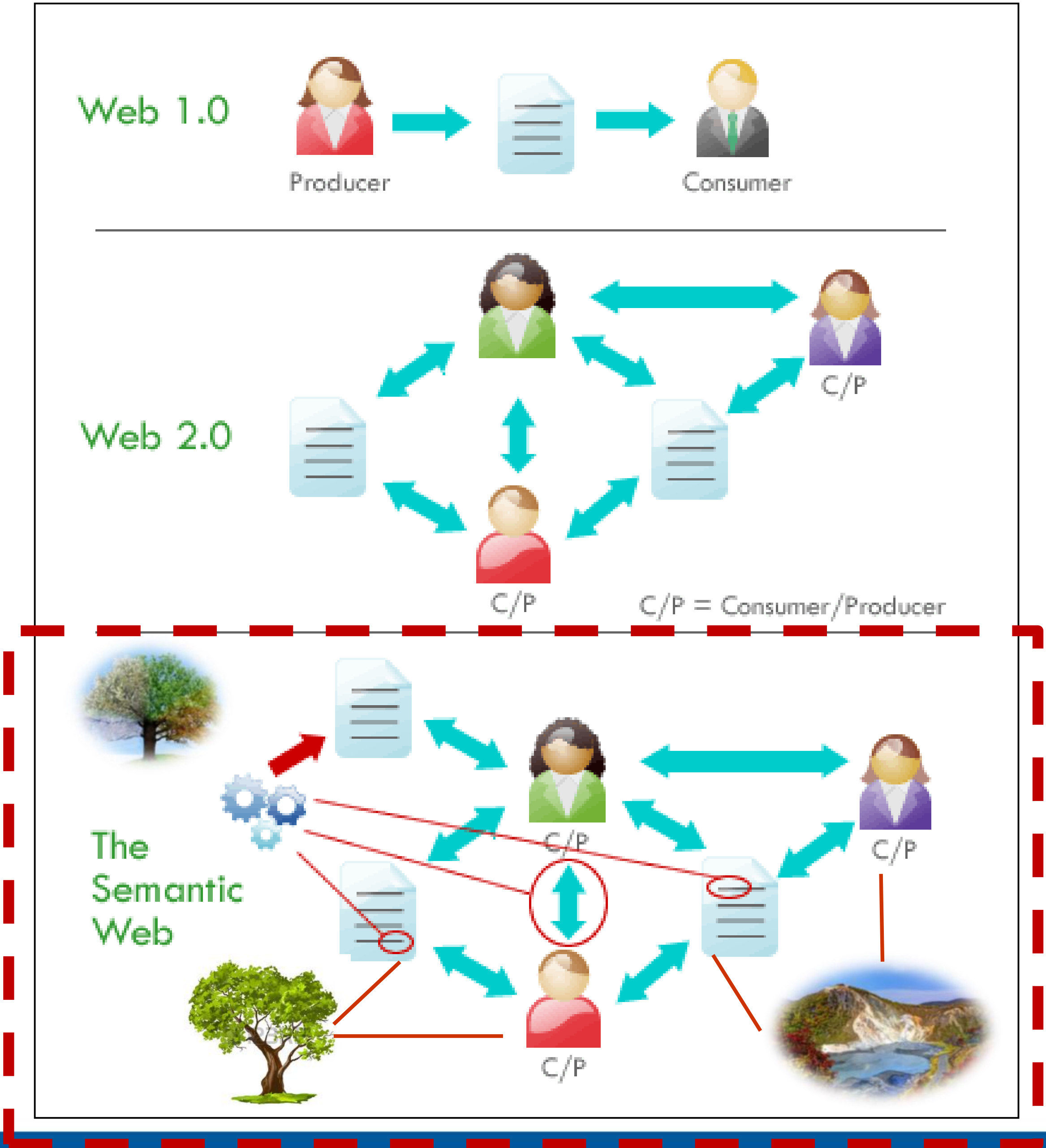
Accessible

Interoperable

Reusable

Wilkinson, M.D., Dumontier, M., Aalversberg, I.J., Appleton, G., Axton, M., 2016. Comment : The FAIR Guiding Principles for scientific data management and stewardship. Nat. Commun. 3:160018, 1–9.

Data Science – Requirement - Semantification



Semantic Web / Linked Open Data

Handling:

- ➢ **Complex-Data**

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

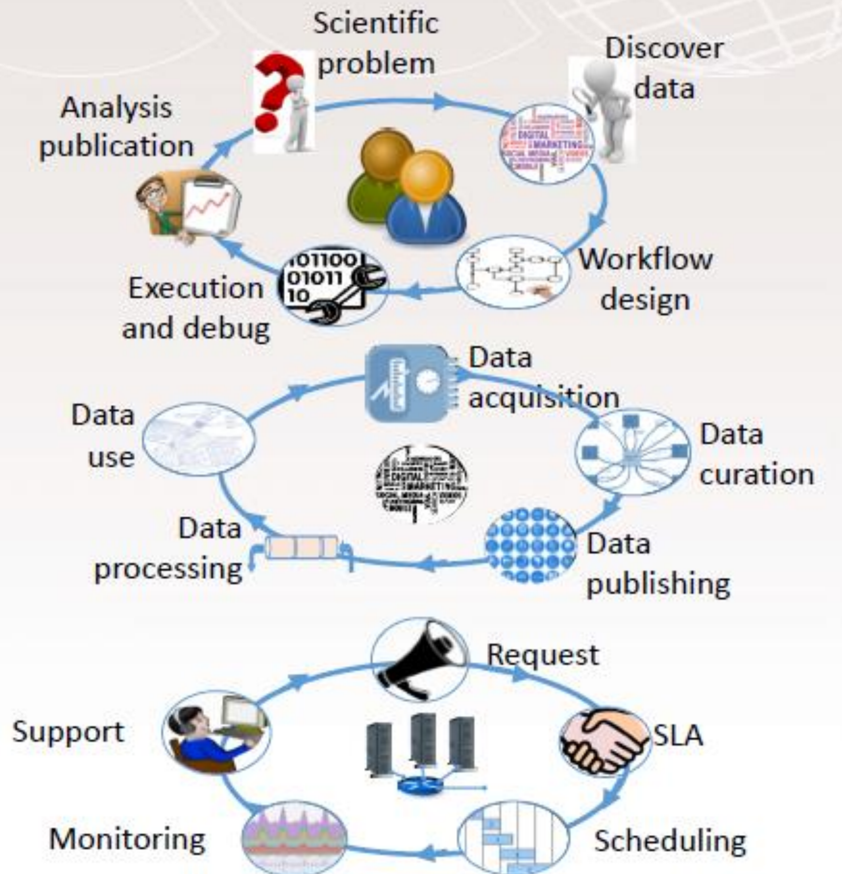
Data Science – Requirements
– Information Management

ENVRI plus
Environmental Research Infrastructures Providing Shared Solutions for Science and Society

- **Need to** support user centered research activities

- **Need to** manage data in its lifecycle

- **Need to** manage infrastructure resources, e.g., computing, storage and networks



Zhiming Zhao, 2018,
http://www.envriplus.eu/

Data Science – Requirements

Coupling to the Research infrastructure in enviornmental and earth sciences

http://www.envriplus.eu/

ENVRI plus
Environmental Research Infrastructures Providing Shared Solutions for Science and Society

Zhiming Zhao, 2018,

HELMHOLTZ
ZENTRUM FÜR UMWELTFORSCHUNG
UFZ

Data Science – Requirements – for ESS

- **Good Indicators** for ESS, environmental changes, stress & disturbances
- **Coupling in-situ and RS approaches**
- **Digitalization**

  (Big Data (Volume, Velocity, Variety, Veracity), Open Access, Freely available data, Open Science Clouds, Distributed repositories, TEP – Thematic Exploitation Platform – ESA)

- **Comparable Data and Data bases**

  (Google Engine, GBIF—the Global Biodiversity Info Copernicus RS Data, DEM …..)

- **Standardization**

  (Metadata, GoFAIR, Concept of Essential Variables

- **Semantification**

  (Semantic Web/Web 4.0, Ontology; Linked Open Da

- **Data Science Analysis**

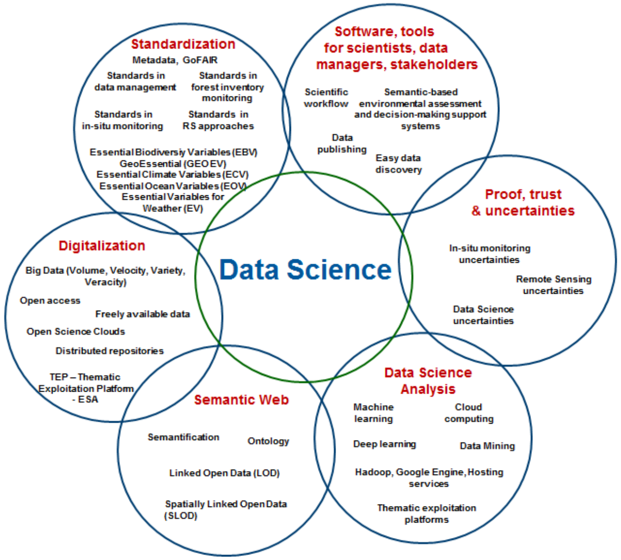
  (Machine Learning, Deep learning, Cloud Computing,

  Data Mining, Hadoop, Google Engine, Hosting services)

- **Proof, trust & uncertainties**

  (In-situ monitoring, Remote Sensing & Data Science uncertainties)

- **Easy software, tools for data manager, stakolders & for politics**



Lausch, A. et al., 2018..
Remote Sensing

Bio- Geodiversity, Ecosystem health, RS, Data Science - Paper

Lausch, A., Schmidt, A., Tischendorf, L., **2015**. Data mining and linked open data – New perspectives for data analysis in environmental research. Ecol. Modell. 295, 5–17. https://doi.org/10.1016/j.ecolmodel.2014.09.018

Lausch, A. et al., **2016**. Linking Earth Observation and taxonomic, structural and functional biodiversity: Local to ecosystem perspectives. Ecol. Indic. doi:10.1016/j.ecolind.2016.06.022

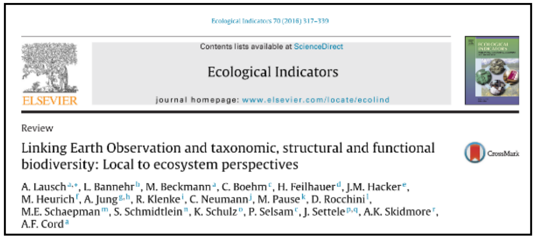
Lausch, A., et al., **2016**. Understanding Forest Health with Remote Sensing -Part I—A Review of Spectral Traits, Processes and Remote-Sensing Characteristics. Remote Sens. 2016, Vol. 8, Page 1029 8, 1029. doi:10.3390/RS8121029

Lausch, A., et al., **2017**. Understanding Forest Health with Remote Sensing-Part II—A Review of Approaches and Data Models. Remote Sens. 9, 129. doi:10.3390/rs9020129

Lausch, A. et al., **2018**. Understanding Forest Health with Remote Sensing, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches. Remote Sensing, 10, 1120; doi:10.3390/rs10071120.

Lausch, A. et al., **2018**. Understanding and assessing vegetation health by in-situ species and remote sensing approaches. Methods in Ecology and Evolution, 00: 1–11. doi.org/10.1111/2041-210X.13025.

Lausch, A. et al., **2019**. Linking Remote Sensing and Geodiversity and Their Traits Relevant to Biodiversity—Part I: Soil Characteristics. Remote Sens. 11, 2356. https://doi.org/10.3390/rs11202356



Ecological Indicators 70 (2016) 317–339

Contents lists available at ScienceDirect

Ecological Indicators

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

Review

Linking Earth Observation and taxonomic, structural and functional biodiversity: Local to ecosystem perspectives

A. Lausch[a,*], L. Bannehr[b], M. Beckmann[a], C. Boehm[c], H. Feilhauer[d], J.M. Hacker[e], M. Heurich[f], A. Jung[g,h], R. Klenke[i], C. Neumann[j], M. Pause[k], D. Rocchini[l], M.E. Schaepman[m], S. Schmidtlein[n], K. Schulz[o], P. Selsam[c], J. Settele[p,q], A.K. Skidmore[r], A.F. Cord[a]

Monitoring Bio- Geodiversity and Ecosystem health by Traits, Remote Sensing (RS) and Data Science approaches

Thank you for your attention !

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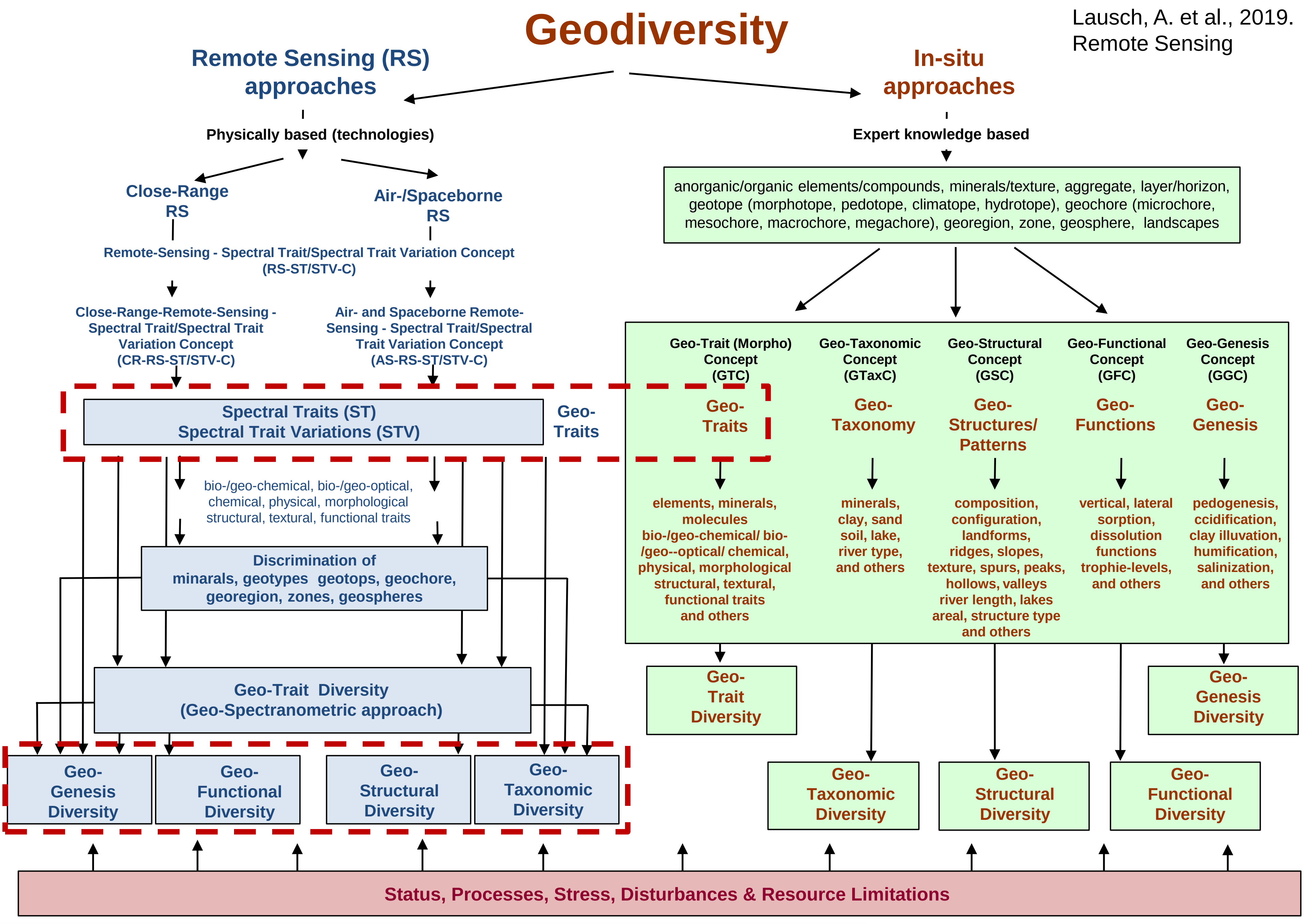
Geodiversity
Lausch, A. et al., 2019.
Remote Sensing
Remote Sensing (RS) approaches
In-situ approaches
Physically based (technologies)
Expert knowledge based
Close-Range RS
Air-/Spaceborne RS
Remote-Sensing - Spectral Trait/Spectral Trait Variation Concept (RS-ST/STV-C)
Close-Range-Remote-Sensing - Spectral Trait/Spectral Trait Variation Concept (CR-RS-ST/STV-C)
Air- and Spaceborne Remote-Sensing - Spectral Trait/Spectral Trait Variation Concept (AS-RS-ST/STV-C)
anorganic/organic elements/compounds, minerals/texture, aggregate, layer/horizon, geotope (morphotope, pedotope, climatope, hydrotope), geochore (microchore, mesochore, macrochore, megachore), georegion, zone, geosphere, landscapes
Geo-Trait (Morpho) Concept (GTC)
Geo-Taxonomic Concept (GTaxC)
Geo-Structural Concept (GSC)
Geo-Functional Concept (GFC)
Geo-Genesis Concept (GGC)
Spectral Traits (ST)
Spectral Trait Variations (STV)
Geo-Traits
Geo-Traits
Geo-Taxonomy
Geo-Structures/ Patterns
Geo-Functions
Geo-Genesis
bio-/geo-chemical, bio-/geo-optical, chemical, physical, morphological structural, textural, functional traits
elements, minerals, molecules bio-/geo-chemical/ bio-/geo--optical/ chemical, physical, morphological structural, textural, functional traits and others
minerals, clay, sand soil, lake, river type, and others
composition, configuration, landforms, ridges, slopes, texture, spurs, peaks, hollows, valleys river length, lakes areal, structure type and others
vertical, lateral sorption, dissolution functions trophie-levels, and others
pedogenesis, ccidification, clay illuvation, humification, salinization, and others
Discrimination of minarals, geotypes geotops, geochore, georegion, zones, geospheres
Geo-Trait Diversity (Geo-Spectranometric approach)
Geo-Trait Diversity
Geo-Genesis Diversity
Geo-Genesis Diversity
Geo-Functional Diversity
Geo-Structural Diversity
Geo-Taxonomic Diversity
Geo-Taxonomic Diversity
Geo-Structural Diversity
Geo-Functional Diversity
Status, Processes, Stress, Disturbances & Resource Limitations