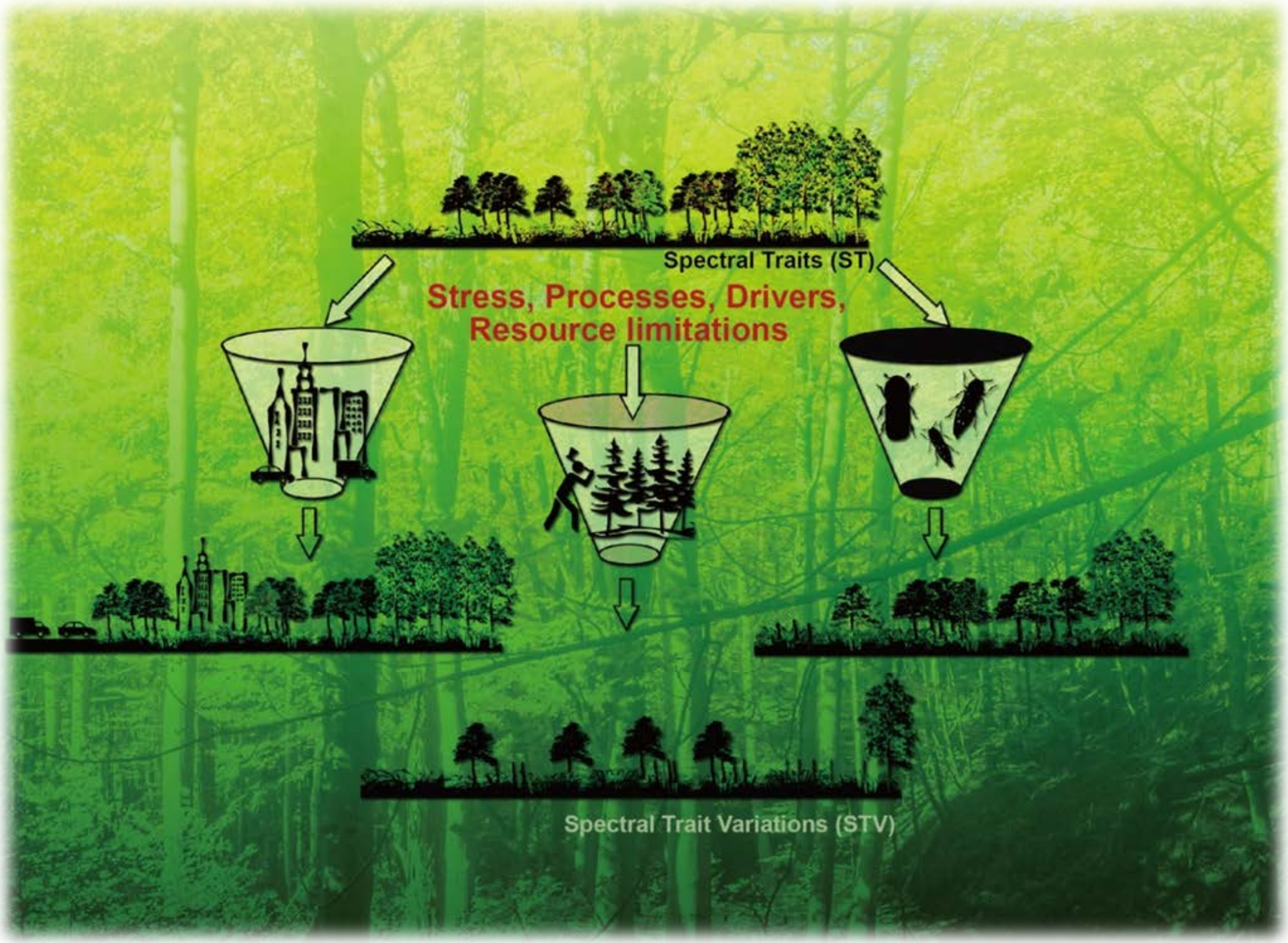
Understanding Forest health by Remote Sensing (RS)



PD Dr. Angela Lausch
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Angela.Lausch@ufz.de

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UMWELTFORSCHUNG
UFZ

Forest health by RS - Paper

remote sensing MDPI

Review

Understanding Forest Health with Remote Sensing -Part I—A Review of Spectral Traits, Processes and Remote-Sensing Characteristics

Angela Lausch [1,*], Stefan Erasmi [2], Douglas J. King [3], Paul Magdon [4] and Marco Heurich [5]

1 Department Computational Landscape Ecology, Helmholtz Centre for Environmental Research—UFZ, Permoserstr. 15, D-04318 Leipzig, Germany
2 Institute of Geography, Cartography GIS & Remote Sensing Sect, Georg-August-University Göttingen, Goldschmidtstr. 5, D-37077 Göttingen, Germany; serasmi@gwdg.de
3 Depterment of Geography and Environmental Studies, Geomatics and Landscape Ecology Lab, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada; doug.king@carleton.ca
4 Chair of Forest Inventory and Remote Sensing, Georg-August-University Göttingen, Büsgenweg 5, D-37077 Göttingen, Germany; pmagdon@gwdg.de
5 Bavarian Forest National Park, Department of Conservation and Research, Freyunger Straße 2, D-94481 Grafenau, Germany; marco.heurich@npv-bw.bayern.de
* Correspondence: angela.lausch@ufz.de; Tel.: +49-341-235-1961; Fax: +49-341-235-1939

Lausch, A., Erasmi, S., King, D.J.D., Magdon, P., Heurich, M., 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

remote sensing MDPI

Review

Understanding Forest Health with Remote Sensing-Part II—A Review of Approaches and Data Models

Angela Lausch [1,2,*], Stefan Erasmi [3], Douglas J. King [4], Paul Magdon [5] and Marco Heurich [6]

1 Department Computational Landscape Ecology, Helmholtz Centre for Environmental Research—UFZ, Permoserstr. 15, Leipzig D-04318, Germany
2 Department of Geography, Lab for Landscape Ecology, Humboldt Universität zu Berlin, Rudower Chaussee 16, 12489 Berlin, Germany
3 Cartography GIS & Remote Sensing Section, Institute of Geography, Georg–August–University Göttingen, Goldschmidtstr. 5, Göttingen D-37077, Germany; serasmi@gwdg.de
4 Geomatics and Landscape Ecology Lab, Department of Geography and Environmental Studies, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada; doug.king@carleton.ca
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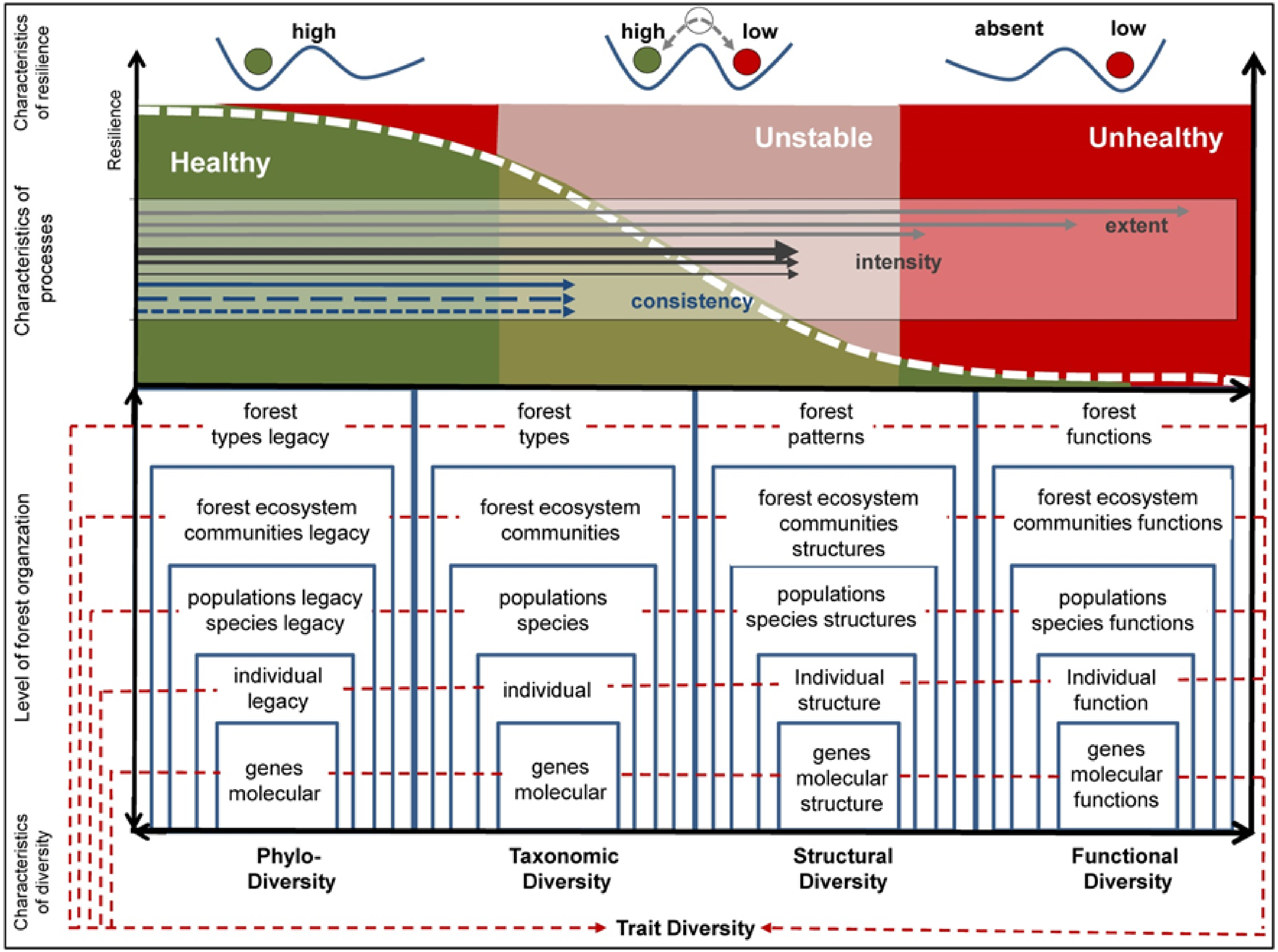
Lausch, A., Erasmi, S., King, D., Magdon, P., Heurich, M., 2017. Understanding Forest Health with Remote Sensing-Part II—A Review of Approaches and Data Models. Remote Sens. 9, 129. doi:10.3390/rs9020129

Understanding Forest health by Remote Sensing

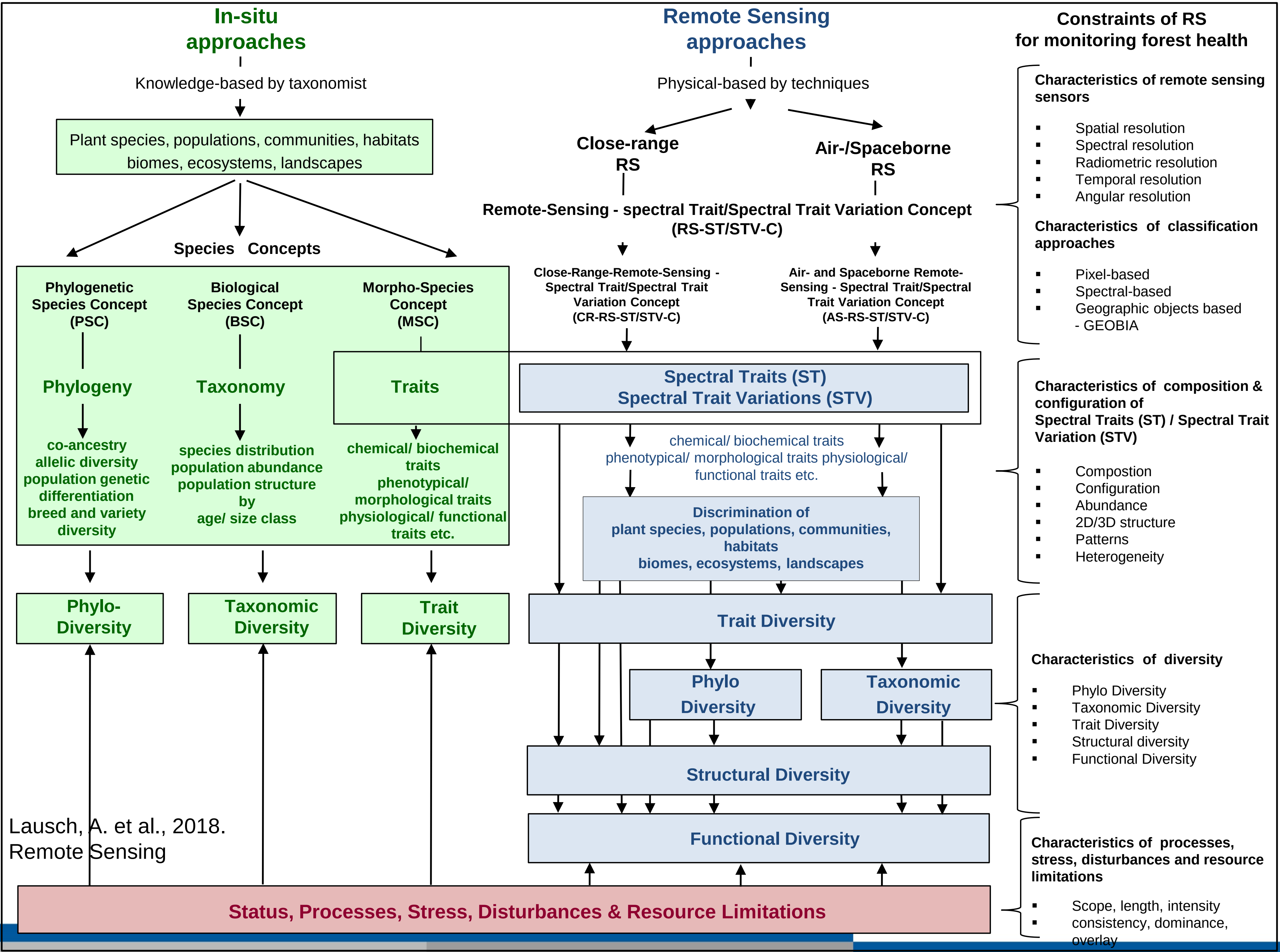
“**Healthy forest ecosystems** can be defined as **diverse systems** that are characterized by **a high resilience on different levels of biotic organization** from the **gene, molecular, individual, and community level** to that of **forest ecosystems**, with the ability to **quickly return to an initial state**…”

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.

Characteristics of Forest Health Diversity

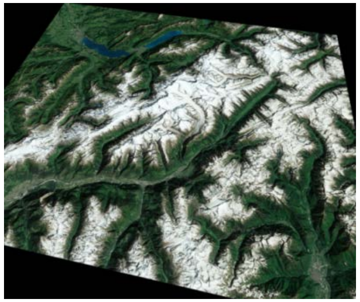


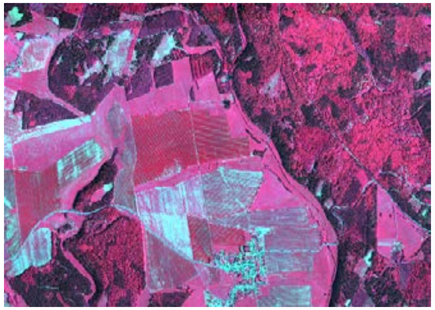
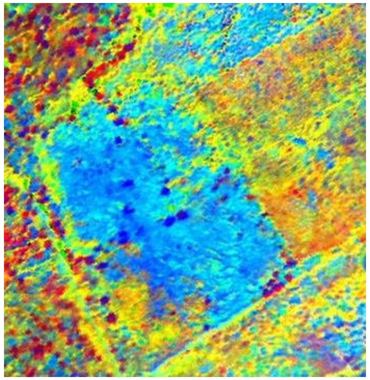
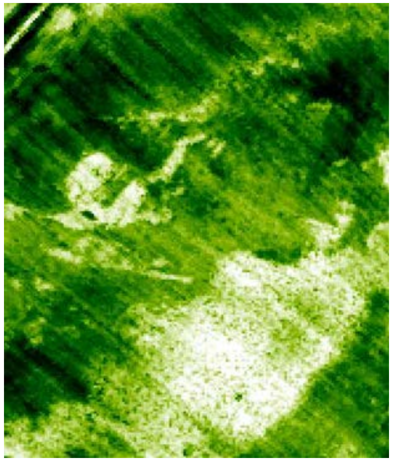
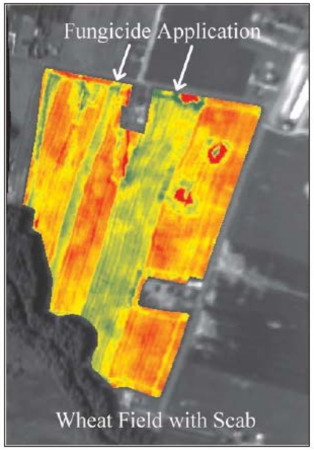
Lausch, A. et al., 2018. Understanding Forest Health with Remote Sensing, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches. Remote Sensing, 10, 1120; doi:10.3390/rs10071120.


In-situ approaches
Knowledge-based by taxonomist
Plant species, populations, communities, habitats biomes, ecosystems, landscapes
Species Concepts
Phylogenetic Species Concept (PSC)
Biological Species Concept (BSC)
Morpho-Species Concept (MSC)
Phylogeny
Taxonomy
Traits
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.
Phylo-Diversity
Taxonomic Diversity
Trait Diversity
Remote Sensing approaches
Physical-based by techniques
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)
Spectral Traits (ST) Spectral Trait Variations (STV)
chemical/ biochemical traits phenotypical/ morphological traits physiological/ functional traits etc.
Discrimination of plant species, populations, communities, habitats biomes, ecosystems, landscapes
Trait Diversity
Phylo Diversity
Taxonomic Diversity
Structural Diversity
Functional Diversity
Status, Processes, Stress, Disturbances & Resource Limitations
Constraints of RS for monitoring forest health
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
Lausch, A. et al., 2018. Remote Sensing

Approach: Remote Sensing

How can RS measure status, stress, disturbances and resource limitations of ecosystems?



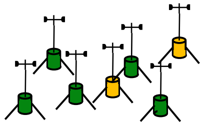
Spaceborne

Airborne


UAV - Drone

Camera trap

Wireless-Sensor-Network (WSN)



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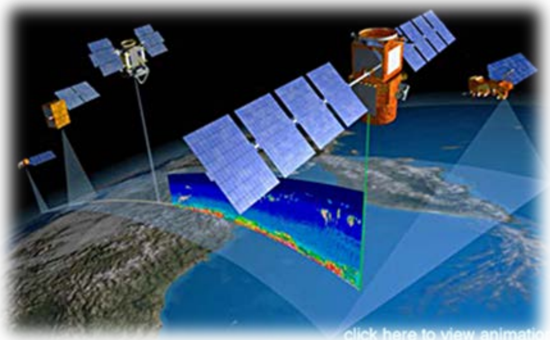
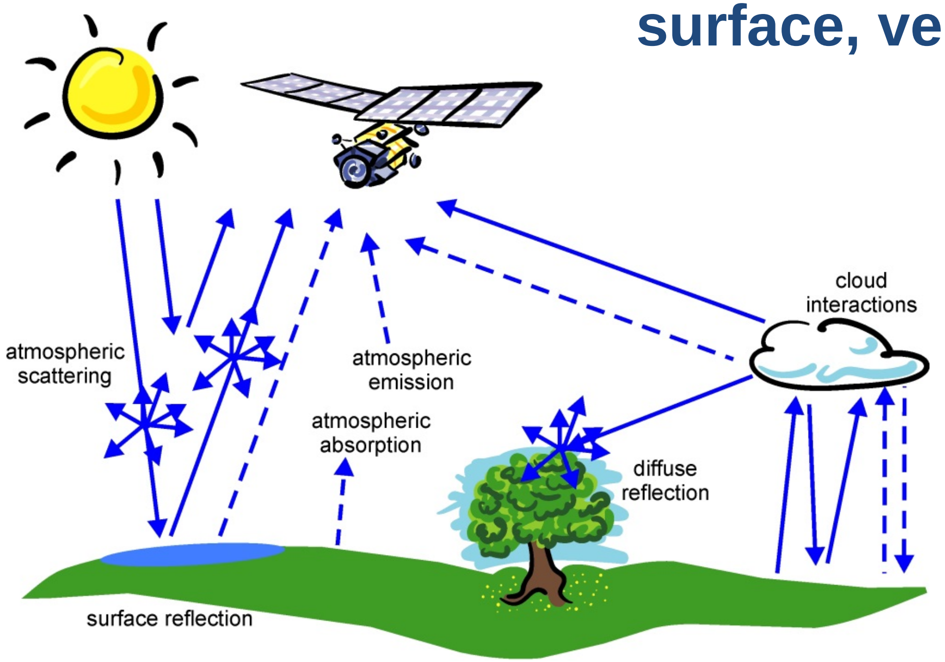
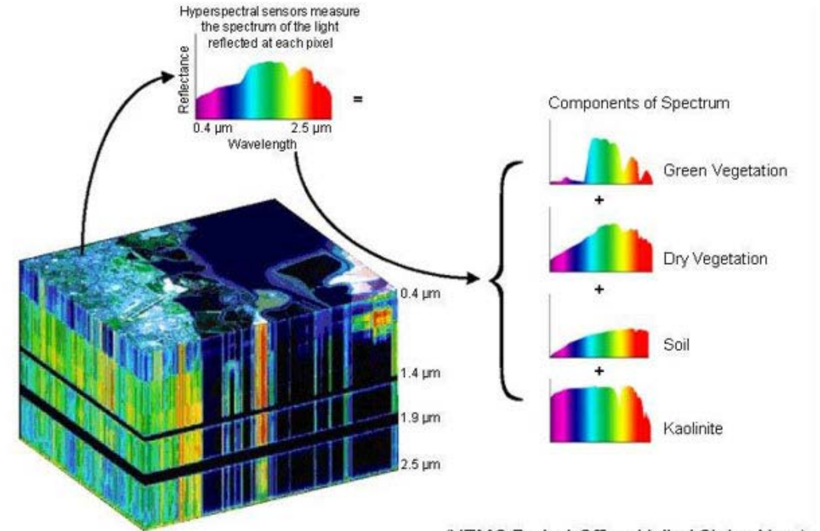
Approach: Remote Sensing



- Remote Sensing (RS)
- Physical based system
- Recording of electromagnetic spectrum
- Reflection, absorption, surface scattering

- RS record „Traits and Trait variations“ of surface, vegetation, soil, water ..





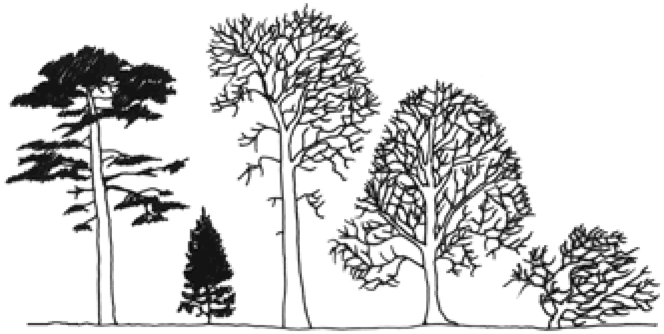
(NEMO Project Office, United States Navy)

Approach: Trait concept of species

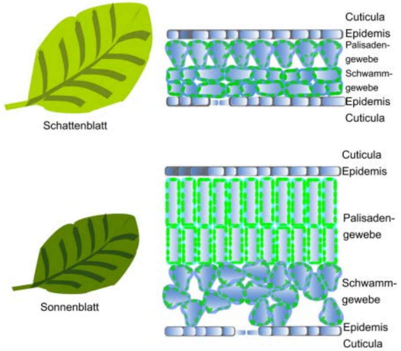
➢ **Plant traits = „Anatomical, morphological, biochemical, physiological, structural or phenological characteristics of individuals, plants, populations, communities“**

(modified after Kattge et al., 2011)

Growth-characteristics

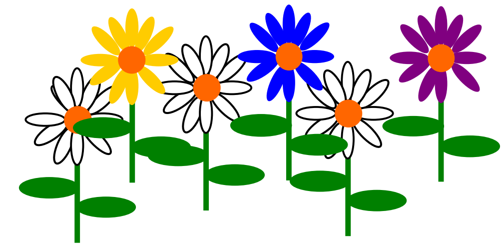


Leaf-morphology



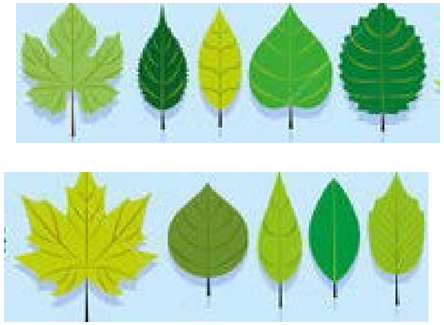
Kattge, J., et al.2011. TRY - a global database of plant traits. Glob. Chang. Biol. 17, 2905–2935. doi:10.1111/j.1365-2486.2011.02451.x

Flower-colour



Flower-shape

Leaf-shape



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"**

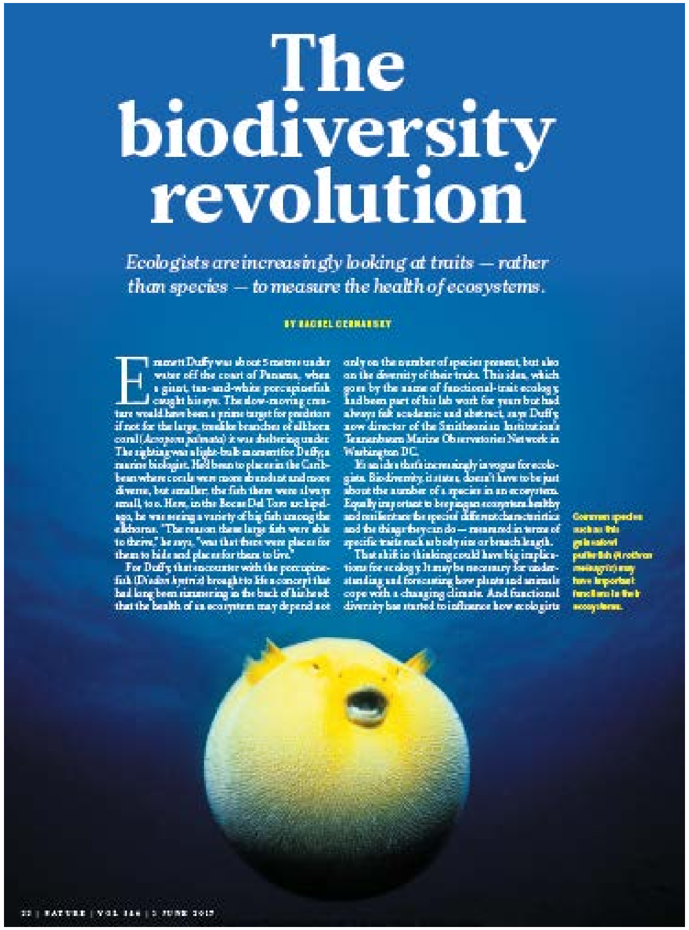
  (Green et al., 2008)

- **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

Trait concept of species – Indicators / Filters of stress

"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

Emmett Duffy was about 5 metres under water off the coast of Panama, when a giant, tan-and-white porcupinefish caught his eye. The slow-moving creature would have been a prime target for predators if not for the large, treelike branches of elkhorn coral (*Acropora palmata*) it was sheltering under. The sighting was a light-bulb moment for Duffy, a marine biologist. He'd been to places in the Caribbean where corals were more abundant and more diverse, but smaller; the fish there were always small, too. Here, in the Bocas Del Toro archipelago, he was seeing a variety of big fish among the elkhorns. "The reason these large fish were able to thrive," he says, "was that there were places for them to hide and places for them to live."

For Duffy, that encounter with the porcupinefish (*Diodon hystrix*) brought to life a concept that had long been simmering in the back of his head: that the health of an ecosystem may depend not only on the number of species present, but also on the diversity of their traits. This idea, which goes by the name of functional-trait ecology, had been part of his lab work for years but had always felt academic and abstract, says Duffy, now director of the Smithsonian Institution's Tennenbaum Marine Observatories Network in Washington DC.

It's an idea that's increasingly in vogue for ecologists. Biodiversity, it states, doesn't have to be just about the number of a species in an ecosystem. Equally important to keeping an ecosystem healthy and resilient are the species' different characteristics and the things they can do — measured in terms of specific traits such as body size or branch length.

That shift in thinking could have big implications for ecology. It may be necessary for understanding and forecasting how plants and animals cope with a changing climate. And functional diversity has started to influence how ecologists

Common species such as this guineafowl pufferfish (*Arothron meleagris*) may have important functions in their ecosystems.

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Traits

↓

Indicators of
Stress
Disturbances
Ressource limitation

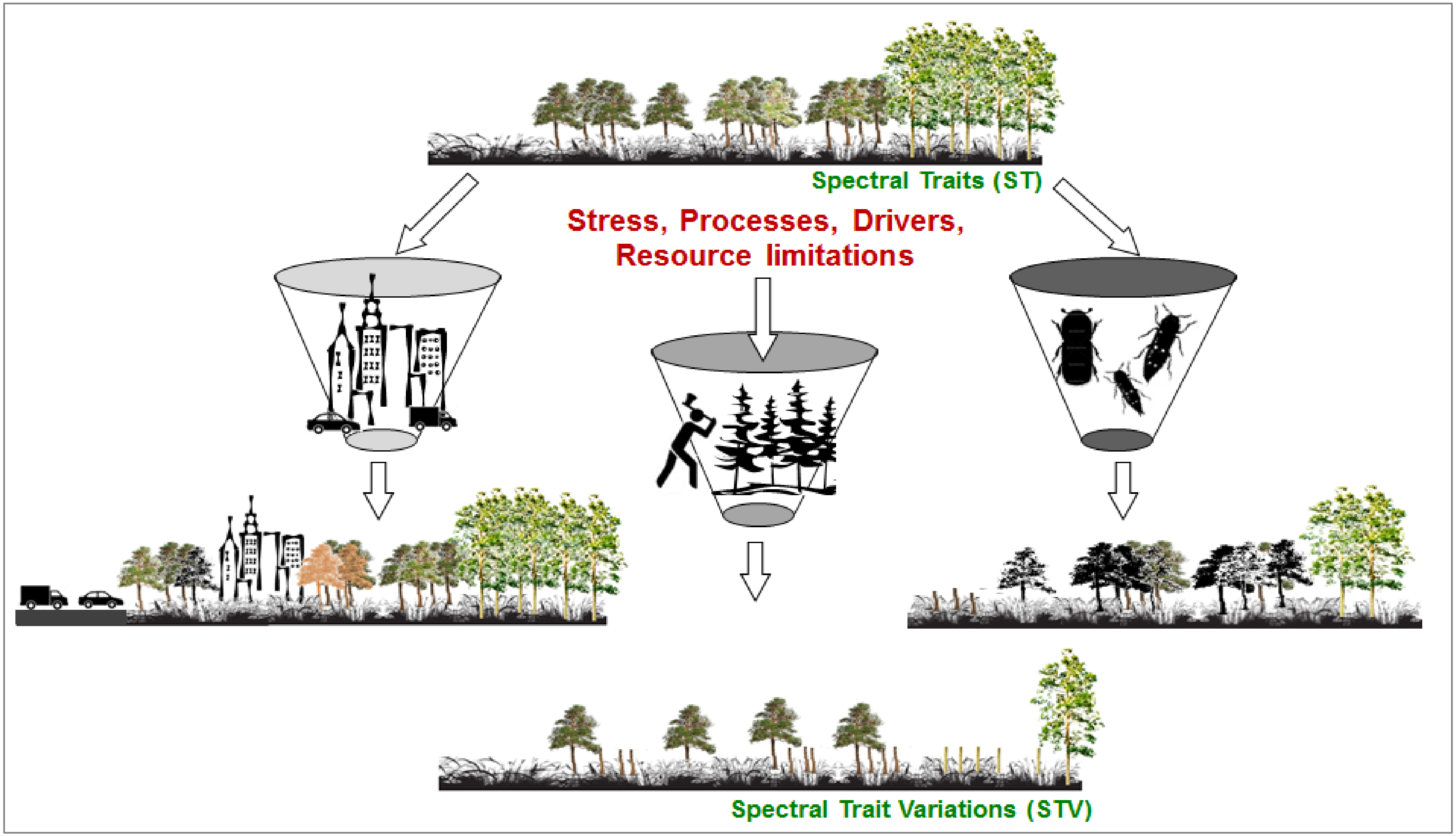
↓

Trait-Variations

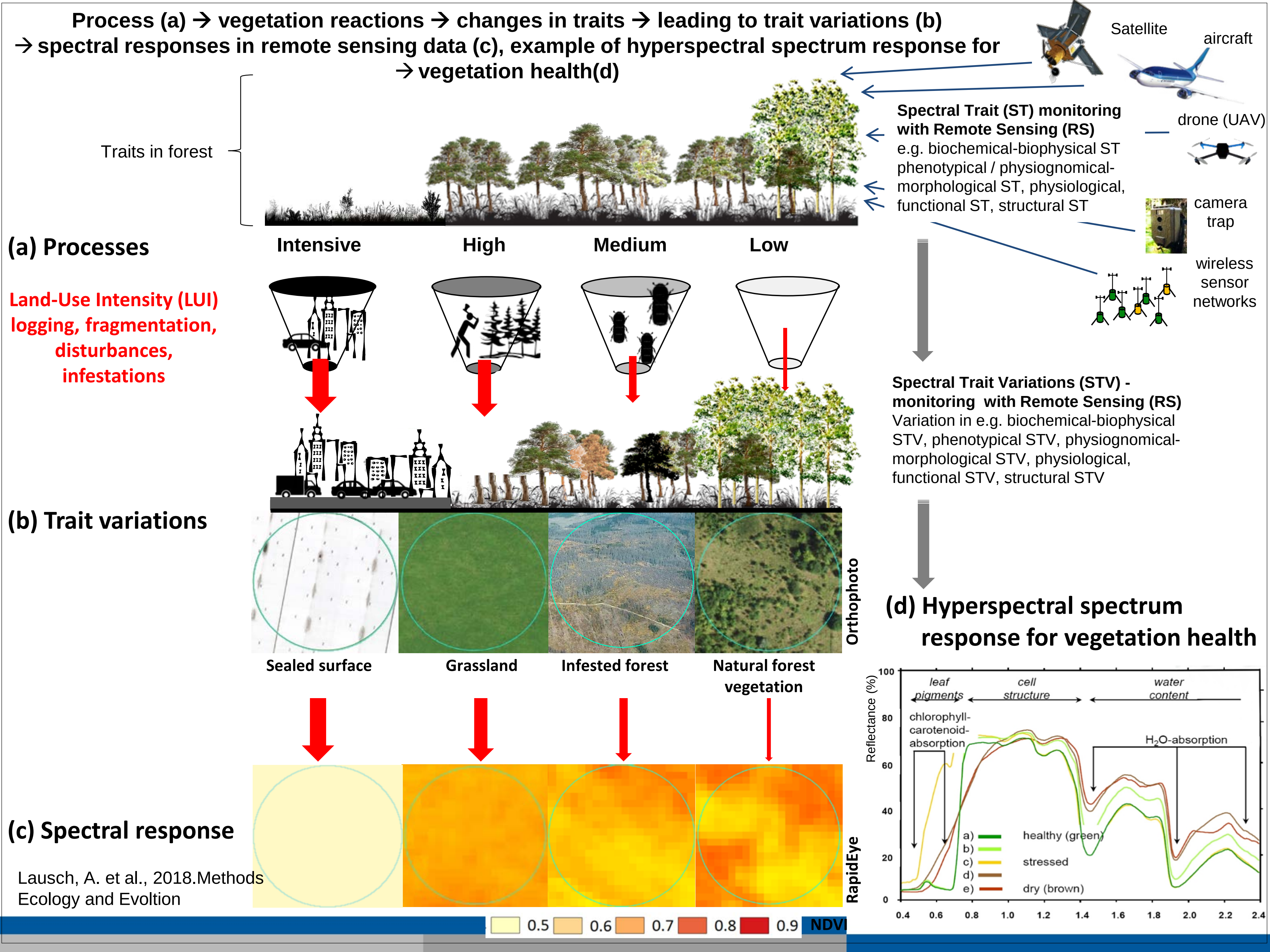
Cernansky, R. Biodiversity moves beyond counting species. *Nature* 2017, *546*, 22–24

Trait concept – Indicators / Filters of stress

Traits = Filters for stress, processes, disturbances and resource limitations

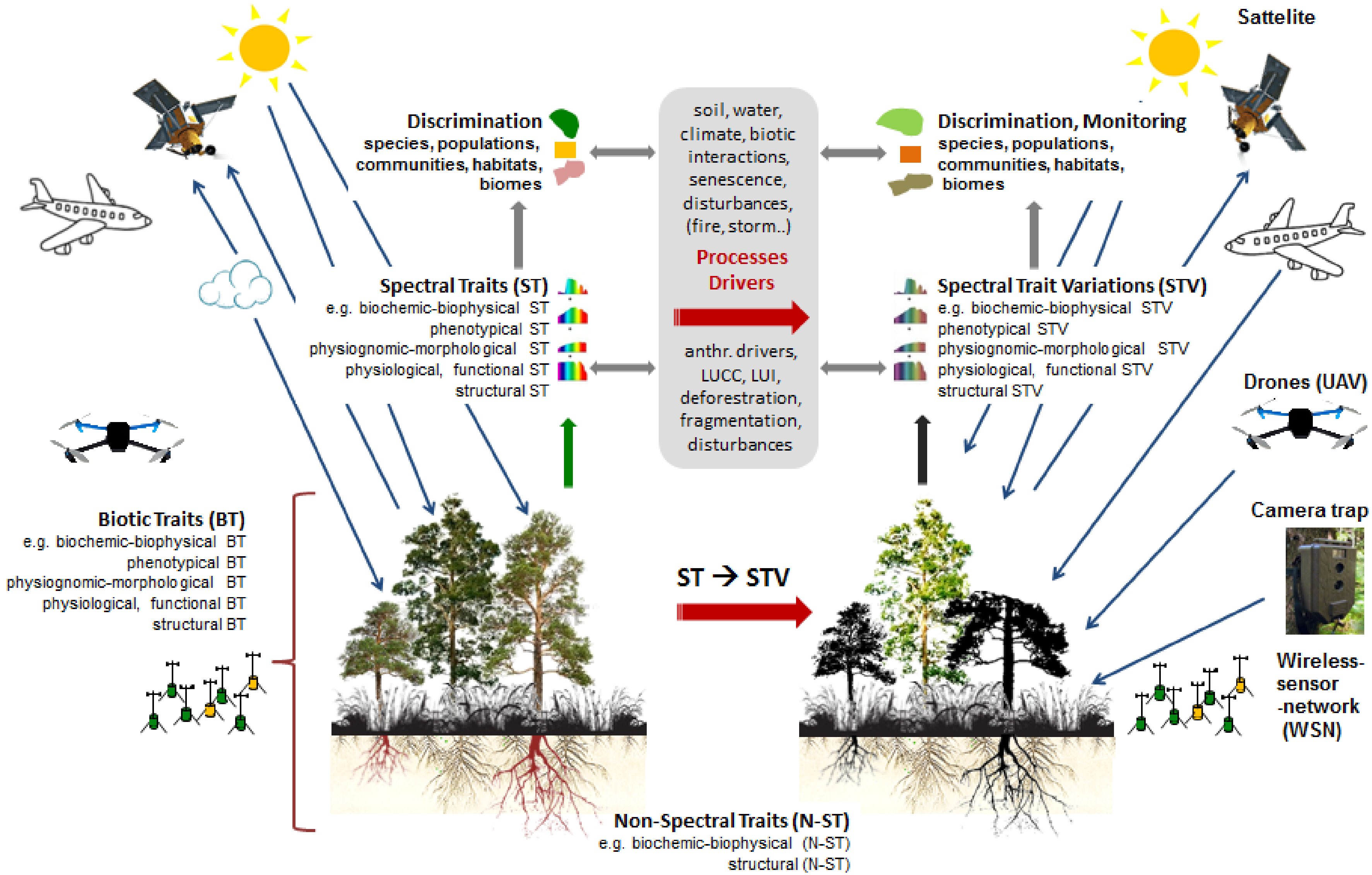


Lausch, A., et. al., 2016. Understanding Forest Health with Remote Sensing -Part I-A Review of Spectral Traits, Processes and Remote-Sensing Characteristics. Remote Sens. 2016, Vol. 8, Page 1029 8, 1029. doi:10.3390/RS8121029



Process (a) → vegetation reactions → changes in traits → leading to trait variations (b) → spectral responses in remote sensing data (c), example of hyperspectral spectrum response for → vegetation health(d)
Satellite
aircraft
drone (UAV)
camera trap
wireless sensor networks
Traits in forest
Spectral Trait (ST) monitoring with Remote Sensing (RS)
e.g. biochemical-biophysical ST phenotypical / physiognomical-morphological ST, physiological, functional ST, structural ST
(a) Processes
Intensive
High
Medium
Low
Land-Use Intensity (LUI) logging, fragmentation, disturbances, infestations
Spectral Trait Variations (STV) - monitoring with Remote Sensing (RS)
Variation in e.g. biochemical-biophysical STV, phenotypical STV, physiognomical-morphological STV, physiological, functional STV, structural STV
(b) Trait variations
Orthophoto
Sealed surface
Grassland
Infested forest
Natural forest vegetation
(d) Hyperspectral spectrum response for vegetation health
Reflectance (%)
leaf pigments
cell structure
water content
chlorophyll-carotenoid-absorption
H2O-absorption
a) healthy (green)
b)
c) stressed
d)
e) dry (brown)
0
20
40
60
80
100
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
(c) Spectral response
RapidEye
Lausch, A. et al., 2018.Methods Ecology and Evoltion
0.5
0.6
0.7
0.8
0.9
NDVI

Approach: „Remote Sensing can measure ST/STV“



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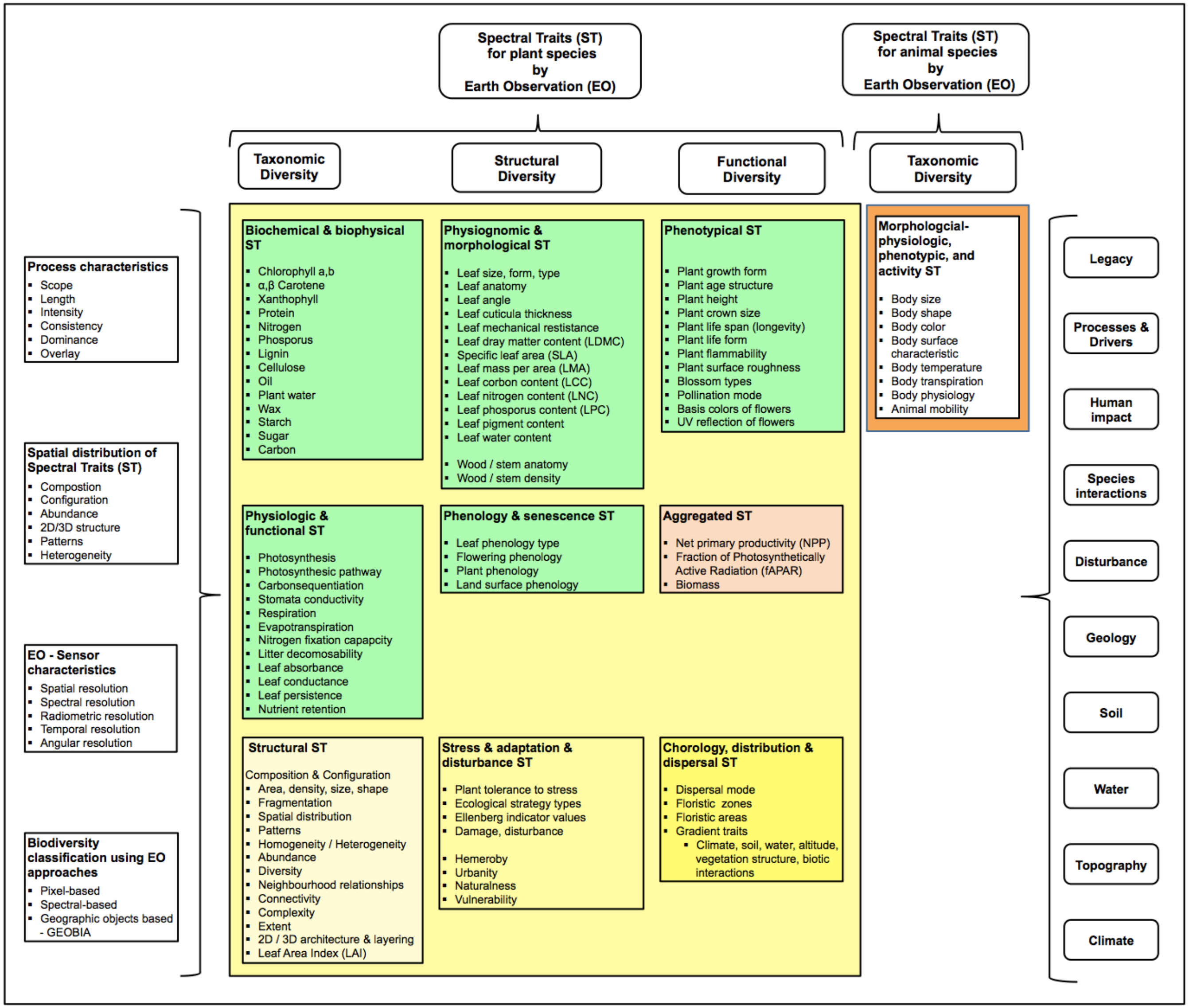
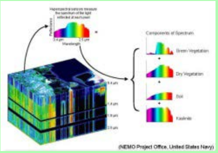
Approach: „Remote Sensing can measure ST/STV“



Examples for monitoring with hyperspectral RS

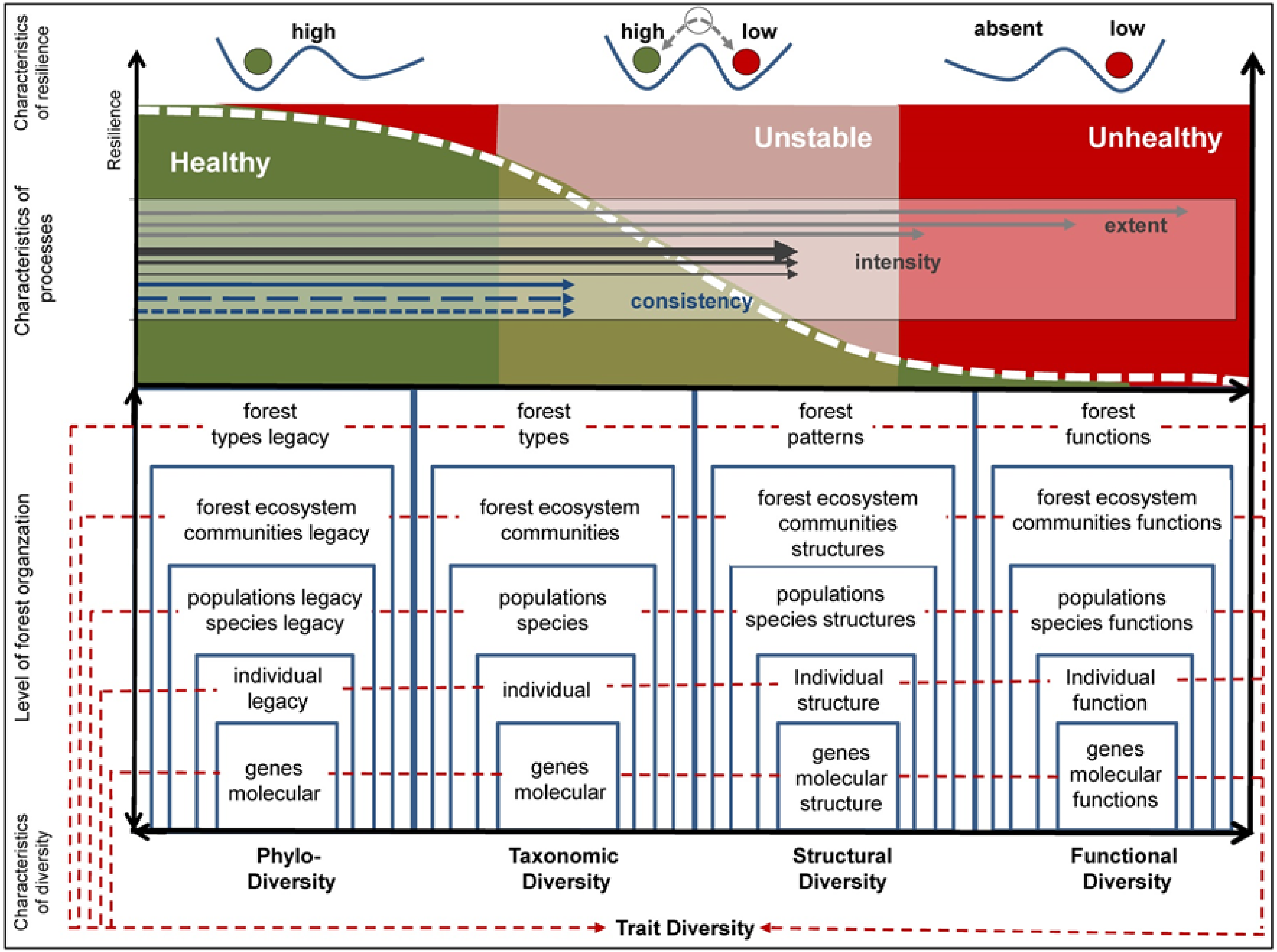
Biochemical & biophysical ST

- Chlorophyll a,b
- α,β Carotene
- Xanthophyll
- Protein
- Nitrogen
- Phosporus
- Lignin
- Cellulose
- Oil
- Plant water
- Wax
- Starch
- Sugar
- Carbon



Lausch, A., et al., 2016. Linking Earth Observation and taxonomic, structural and functional biodiversity: Local to ecosystem perspectives. Ecological Indicators 70., 317-339., doi: 10.1016/j.ecolind.2016.06.022.

Characteristics of Forest Health Diversity



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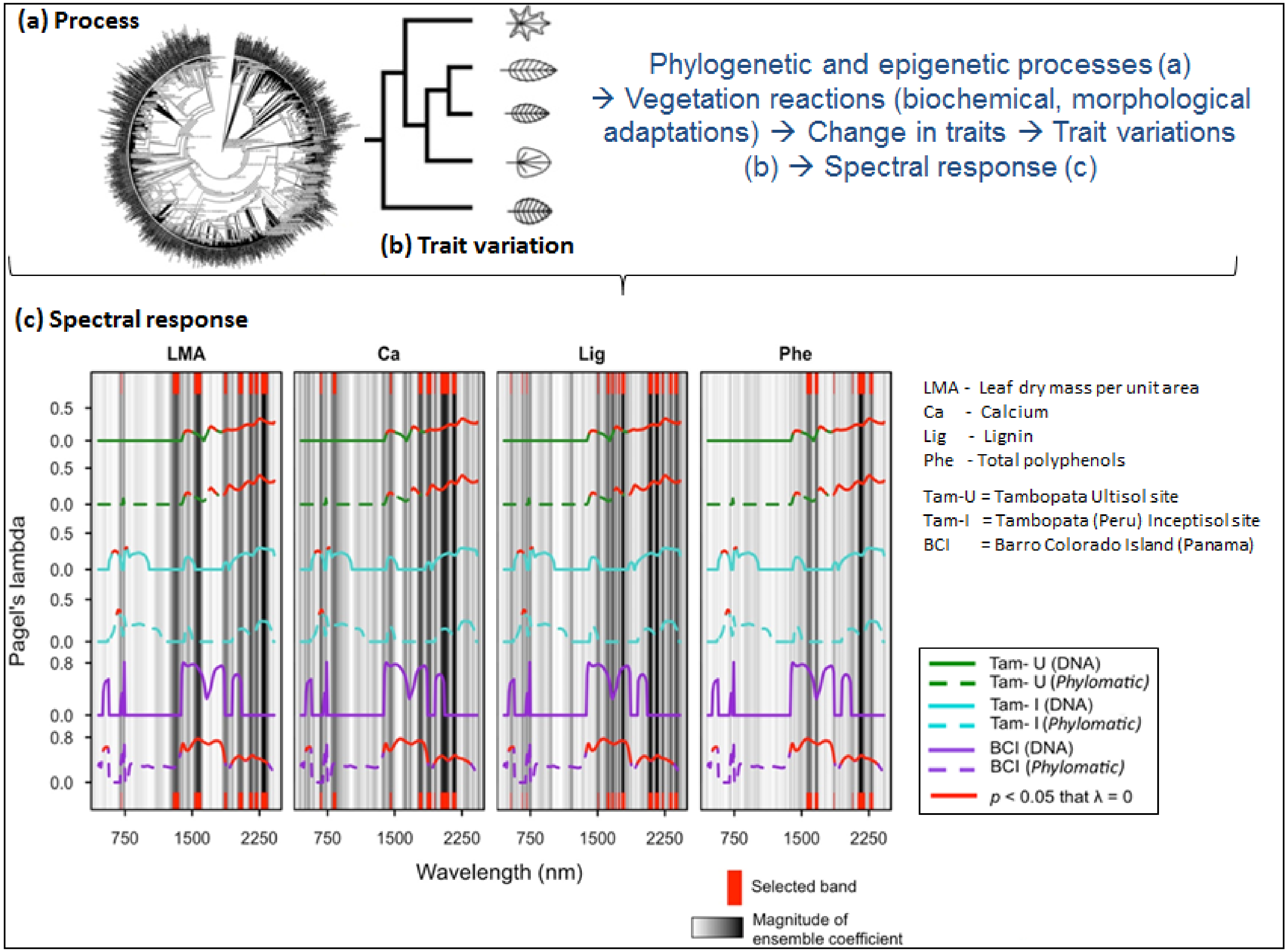
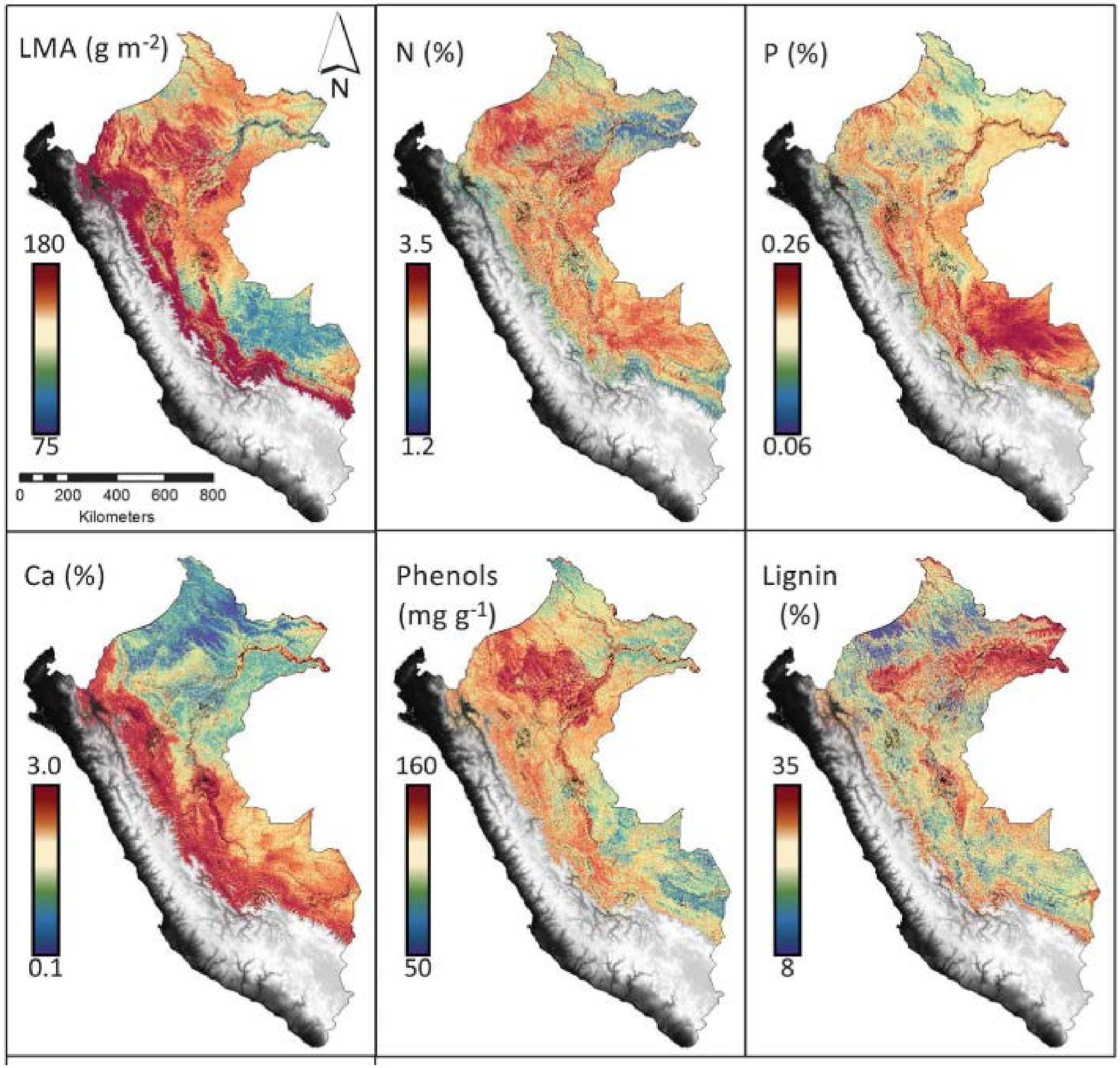
Forest health by RS – Phylogenetic – Stress & Diversity

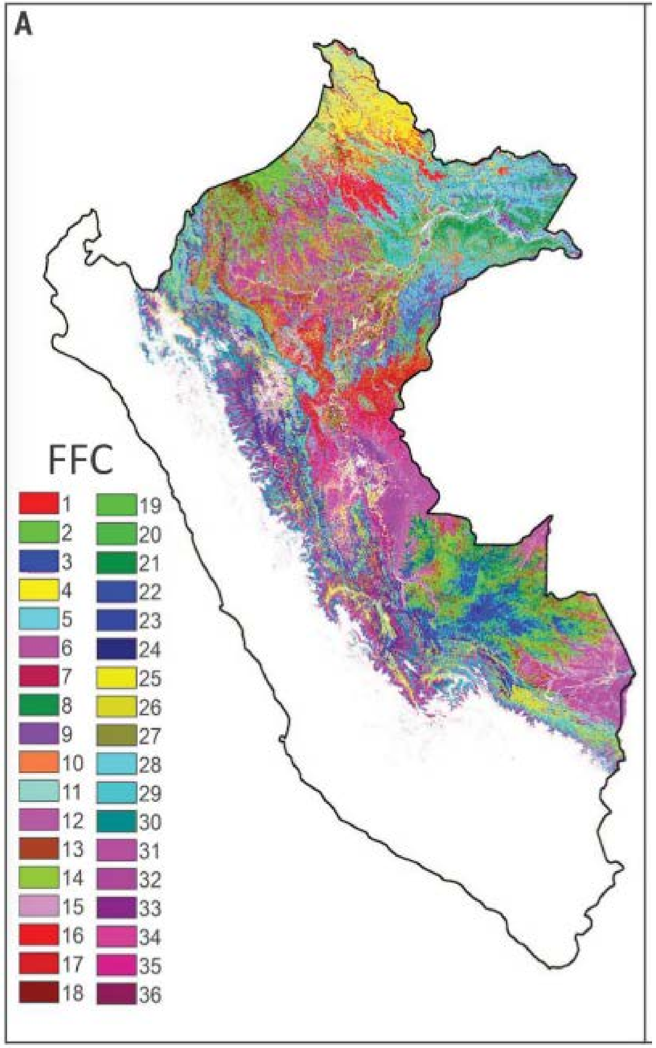


Lausch, A., Leitão,P.J., Monitoring Vegetation Diversity and Health through Spectral Traits and Trait Variations Based on Hyperspectral Remote Sensing . Hyperspectral Remote Sensing of Vegetation and Agricultural Crops. Prasad S. Thenkabail, John Lyon, Alfredo Huete (eds.) Hyperspectral Remote Sensing of Vegetation and Agricultural Crops, (second edition), 2018, in press TAYLOR & FRANCIS.

Forest health by RS – Phylo & functional Diversity

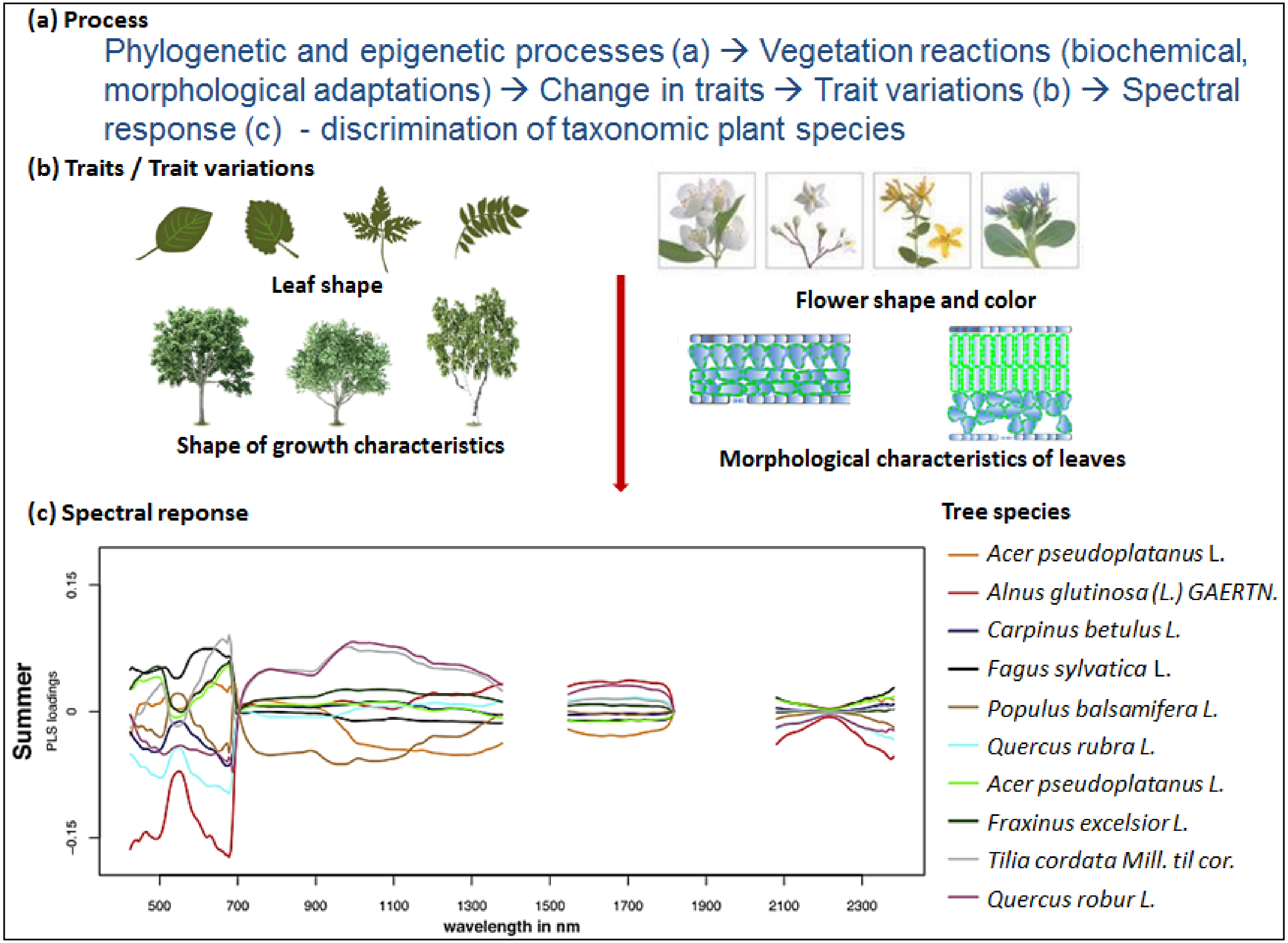


Forest functional diversity



Asner, G.P., Martin, R.E., Knapp, D.E., Tupayachi, R., Anderson, C.B., Sinca, F., Vaughn, N.R., Llactayo, W., 2017. Airborne laser-guided imaging spectroscopy to map forest trait diversity and guide conservation. Science (80-.). 355, 385–389. doi:10.1126/science.aaj1987

Forest health by RS – Taxonomic – Stress & Diversity

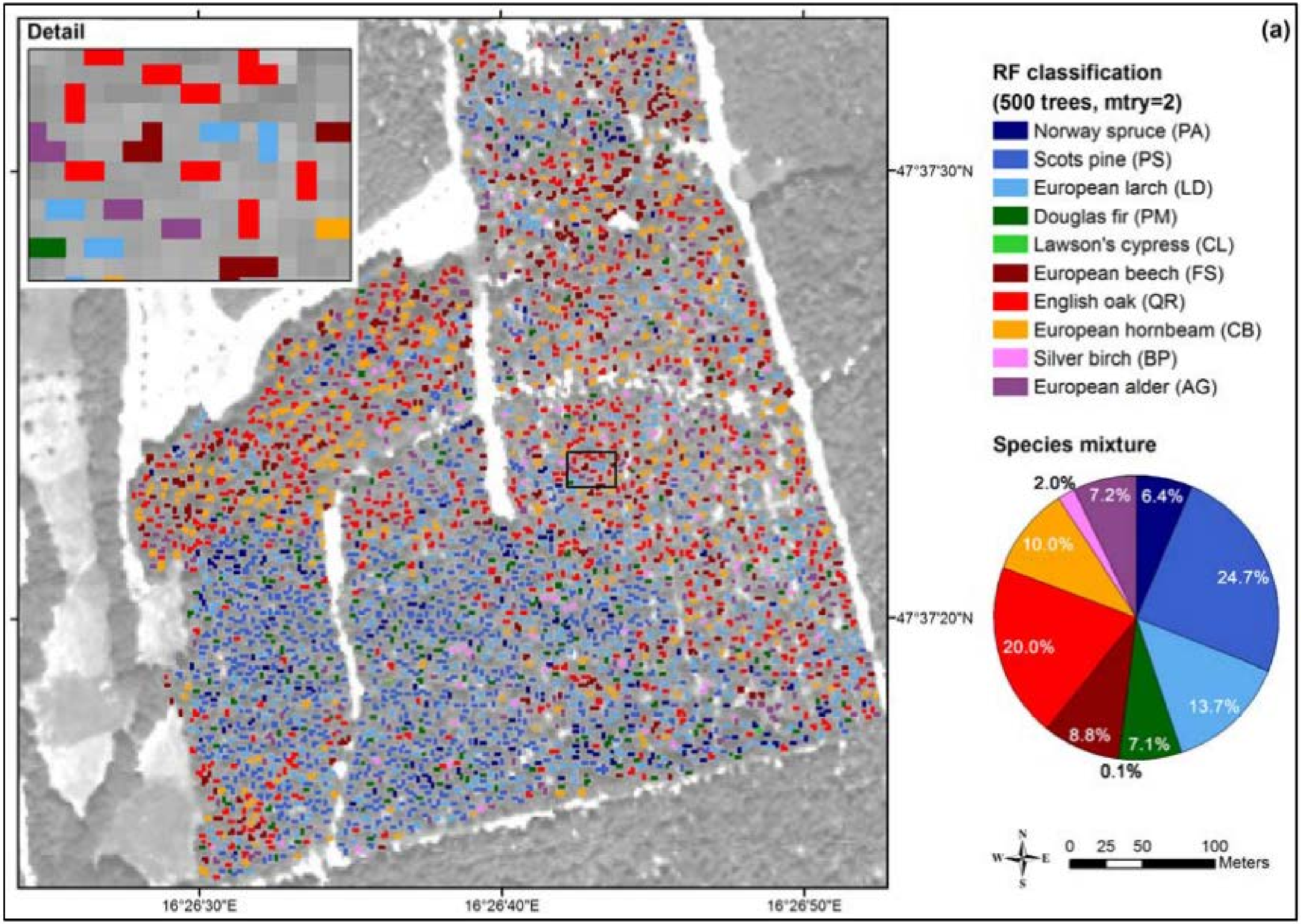


Tree Species Classification

RS:
Hyperspectral (HySpex)

Lausch, A., Leitão,P.J., Monitoring Vegetation Diversity and Health through Spectral Traits and Trait Variations Based on Hyperspectral Remote Sensing . Hyperspectral Remote Sensing of Vegetation and Agricultural Crops. Prasad S. Thenkabail, John Lyon, Alfredo Huete (eds.) Hyperspectral Remote Sensing of Vegetation and Agricultural Crops, (second edition), 2018, in press TAYLOR & FRANCIS.

Forest health by RS – Taxonomic – Stress & Diversity



Tree Species Classification

RS:
8-Band WorldView-2

East of Austria (47°38′N, 16°26′E) in

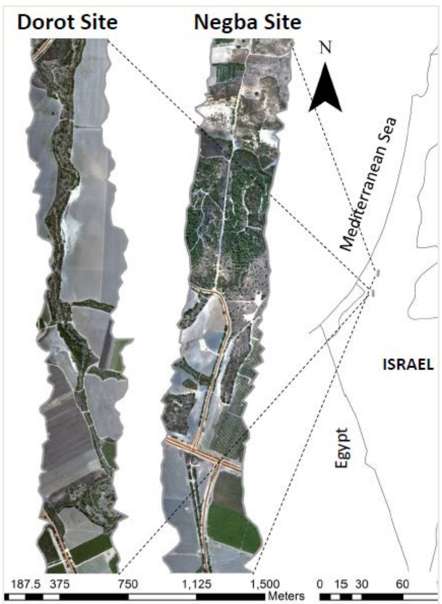
Immitzer, M., Atzberger, C., Koukal, T., 2012. Tree species classification with Random forest using very high spatial resolution 8-band worldView-2 satellite data. Remote Sens. 4, 2661–2693. doi:10.3390/rs4092661

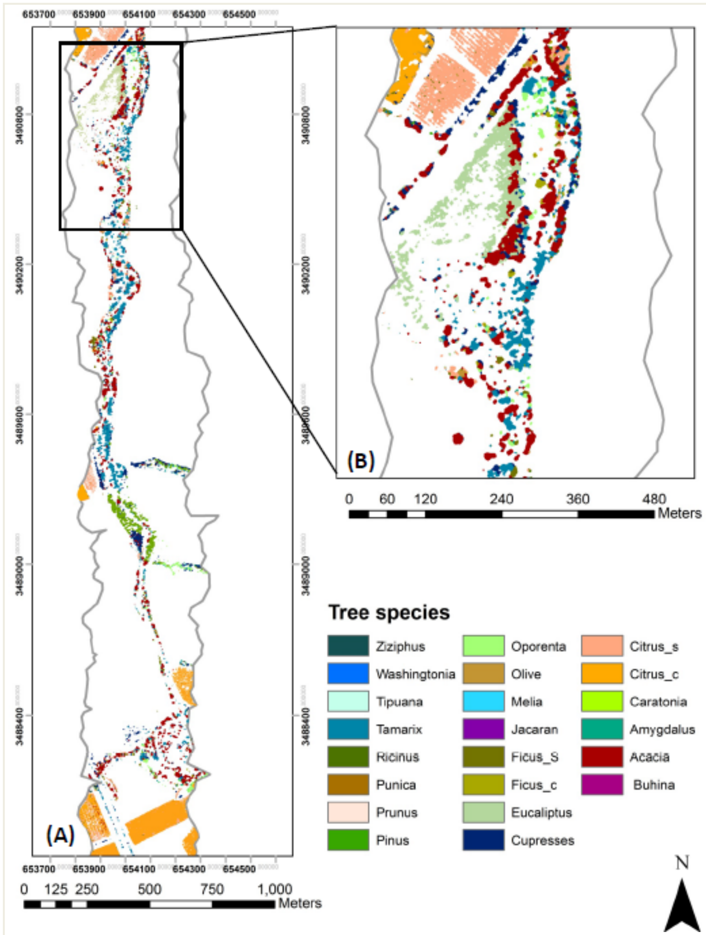
Forest health by RS – Taxonomic – Stress & Diversity

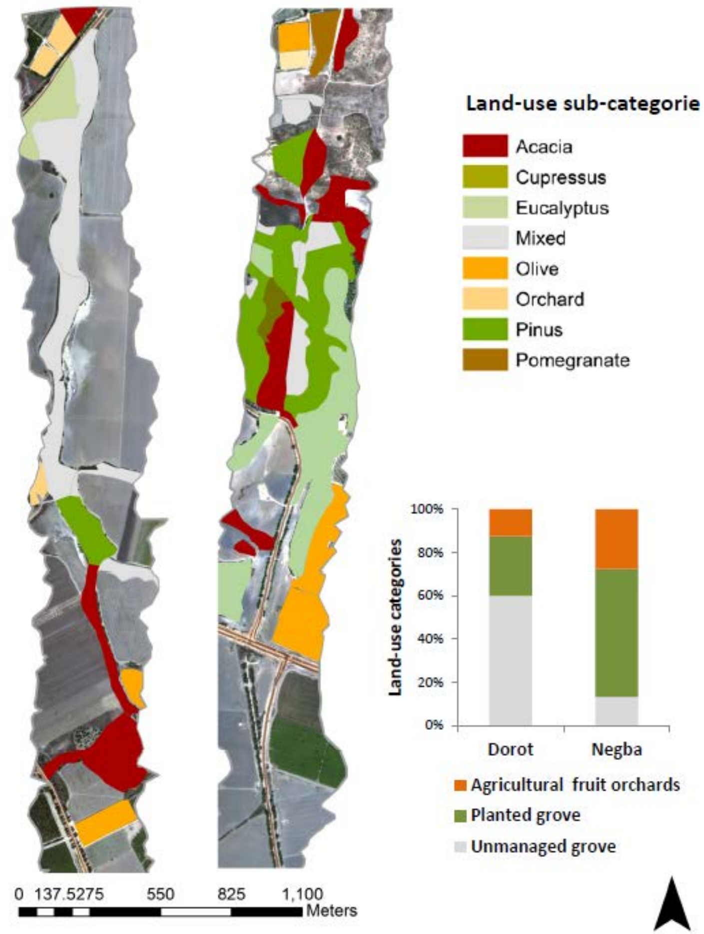
Biochemical & biophysical ST

- Chlorophyll a,b
- α,β Carotene
- Xanthophyll
- Protein
- Nitrogen
- Phosporus
- Lignin
- Cellulose
- Oil
- Plant water
- Wax
- Starch
- Sugar
- Carbon

Traits of plants - important for discrimination of plants by RS







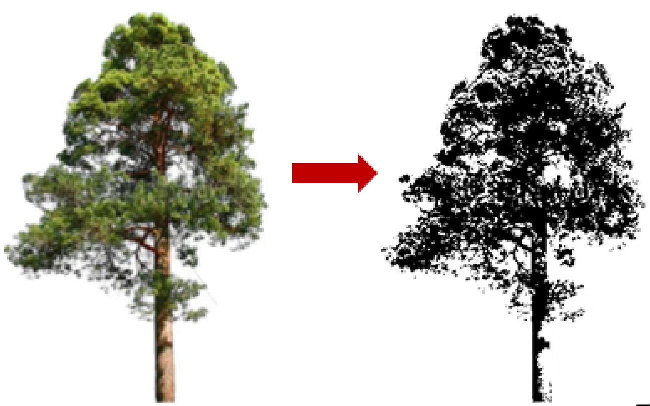
Paz-Kagan, T., Caras, T., Herrmann, I., Shachak, M., Karnieli, A., 2017. Multiscale mapping of species diversity under changed land use using imaging spectroscopy. Ecol. Appl. 27, 1466–1484. doi:10.1002/eap.1540

Forest health by RS – Structural & Functional Diversity

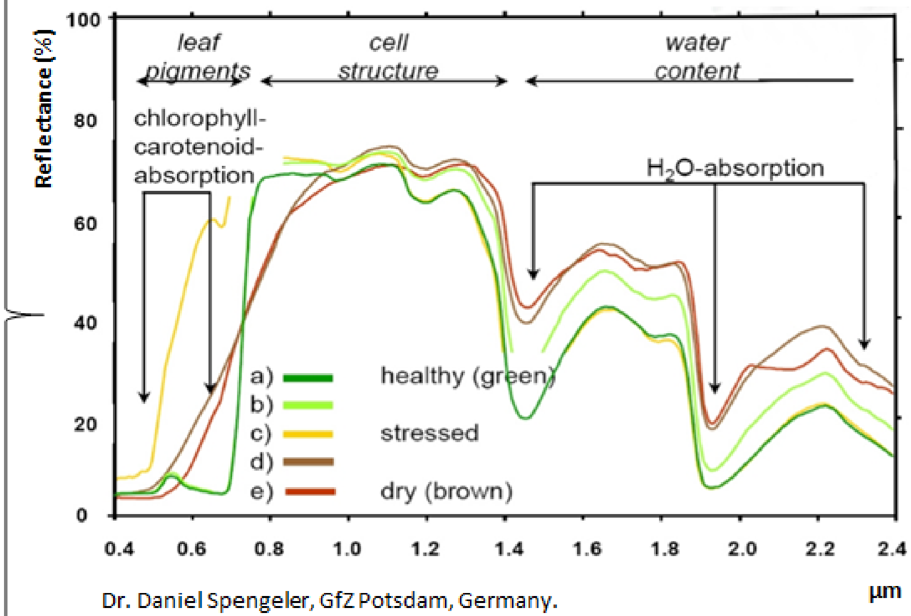
Process (a) → Vegetation reactions → Changes in traits → lead to trait variations (b) → Spectral response (c)

(a) Process

(b) Trait variation

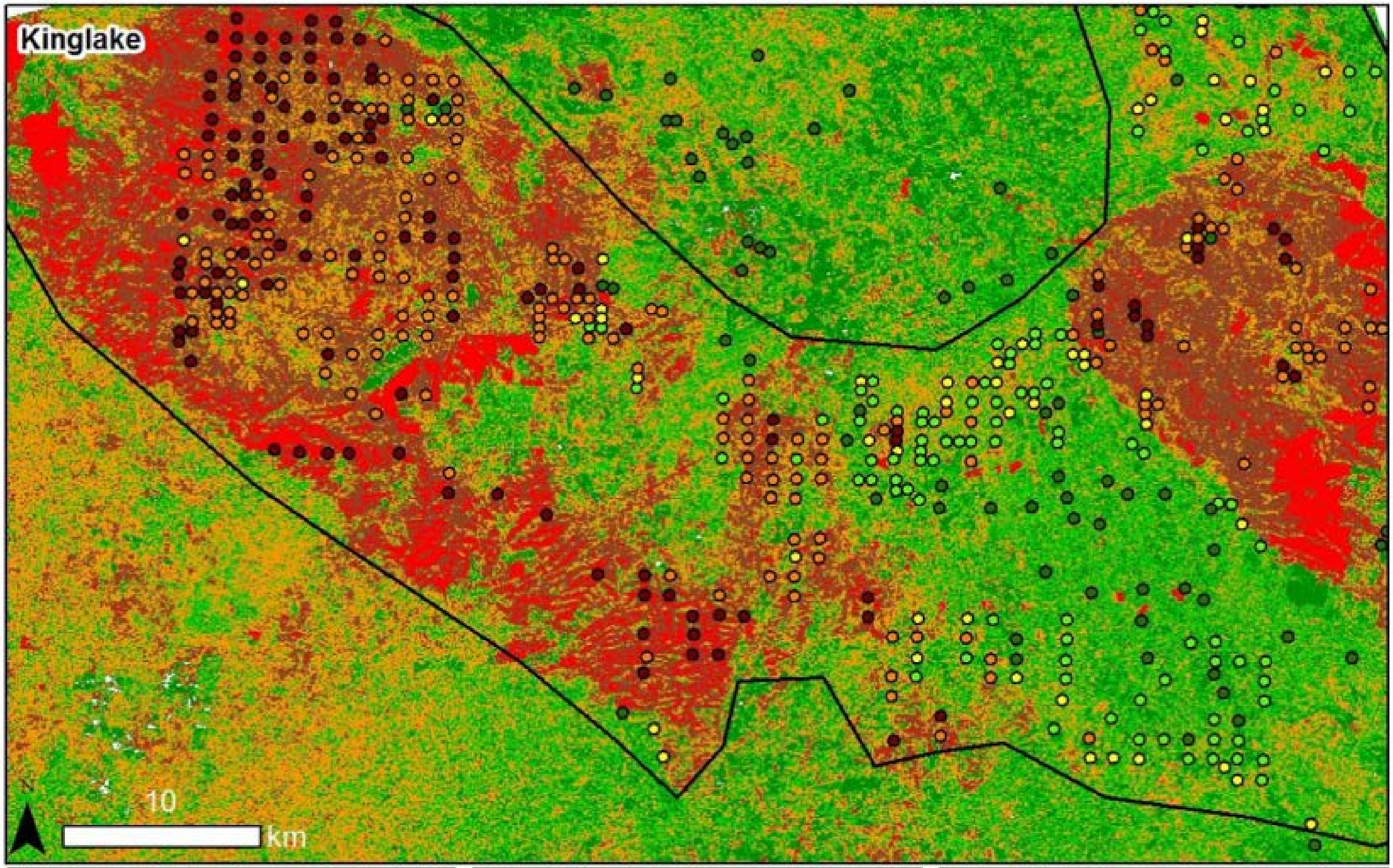


(c) Spectral response



Lausch, A., Leitão,P.J., Monitoring Vegetation Diversity and Health through Spectral Traits and Trait Variations Based on Hyperspectral Remote Sensing . Hyperspectral Remote Sensing of Vegetation and Agricultural Crops. Prasad S. Thenkabail, John Lyon, Alfredo Huete (eds.) Hyperspectral Remote Sensing of Vegetation and Agricultural Crops, (second edition), 2018, in press TAYLOR & FRANCIS.

Forest health by RS – Forest fire severity estimation



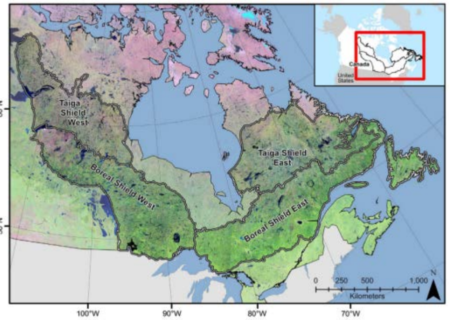
Forest fire severity: Unchanged, Low, Medium, Medium-high, High

Synthetic Aperture Radars (SAR)

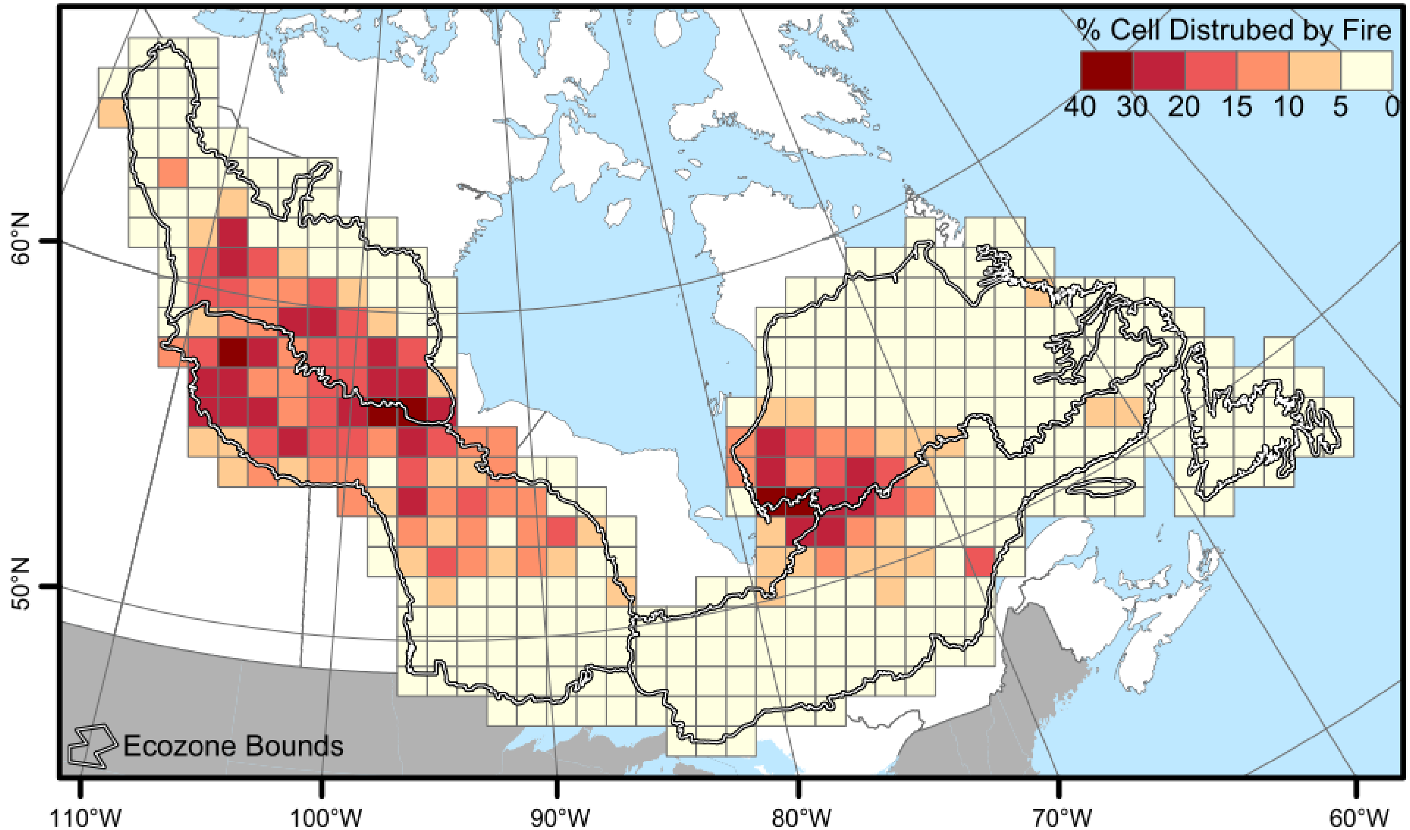
Australia, Fires during Black Saturday, (February–March 2009) – the Kinglake

Tanase, M.A., Kennedy, R., Aponte, C., 2015. Radar Burn Ratio for fire severity estimation at canopy level: An example for temperate forests. Remote Sens. Environ. 170, 14–31. doi:10.1016/j.rse.2015.08.025

Forest health by RS – Forest fire severity estimation

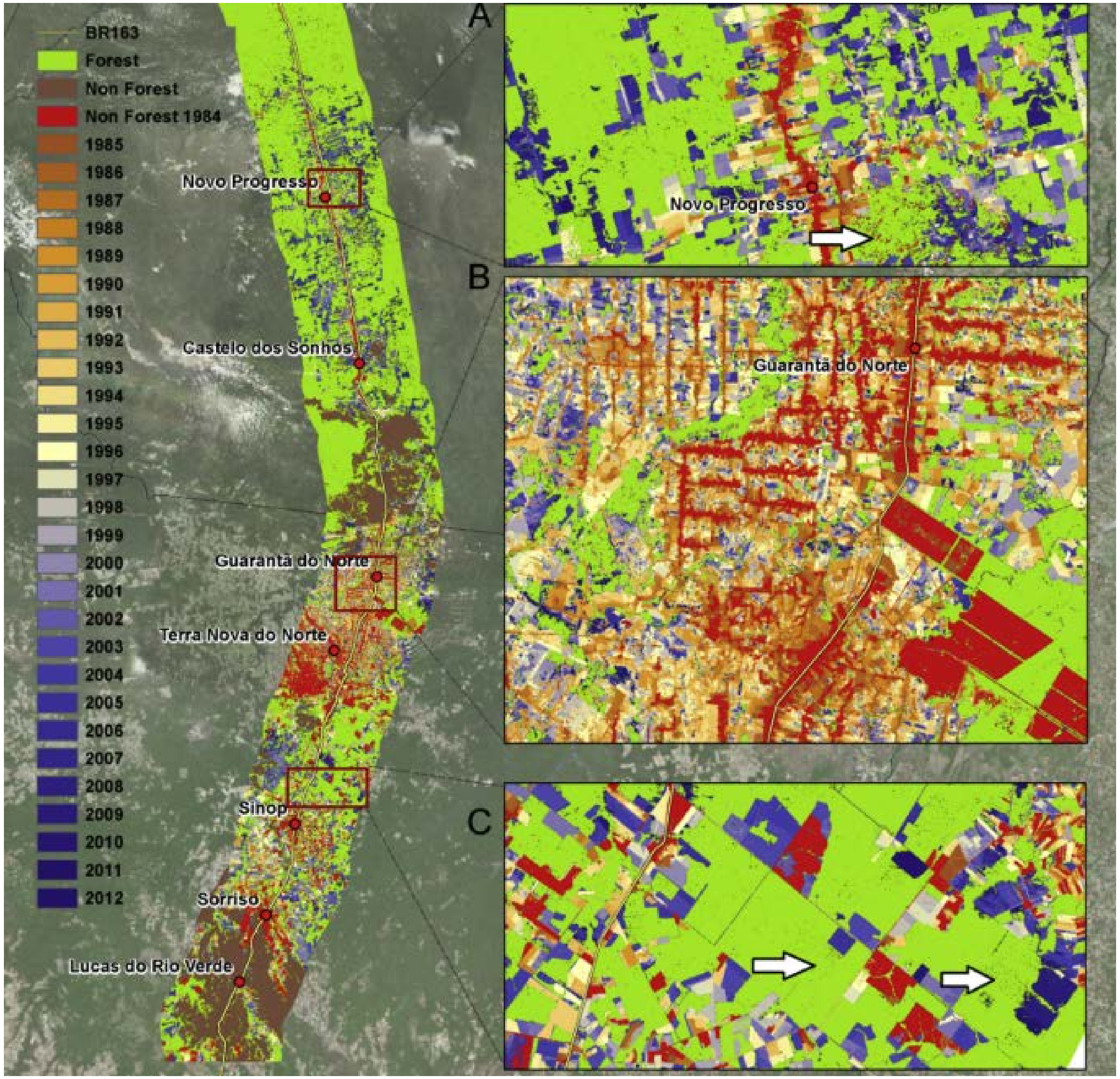


Time Series – Landsat (1986-2006)



Frazier, R.J., Coops, N.C., Wulder, M.A., Hermosilla, T., White, J.C., 2018. Analyzing spatial and temporal variability in short-term rates of post-fire vegetation return from Landsat time series. Remote Sens. Environ. 205, 32–45. doi:10.1016/j.rse.2017.11.007

Forest health by RS – Long-term deforestation, fragmentation

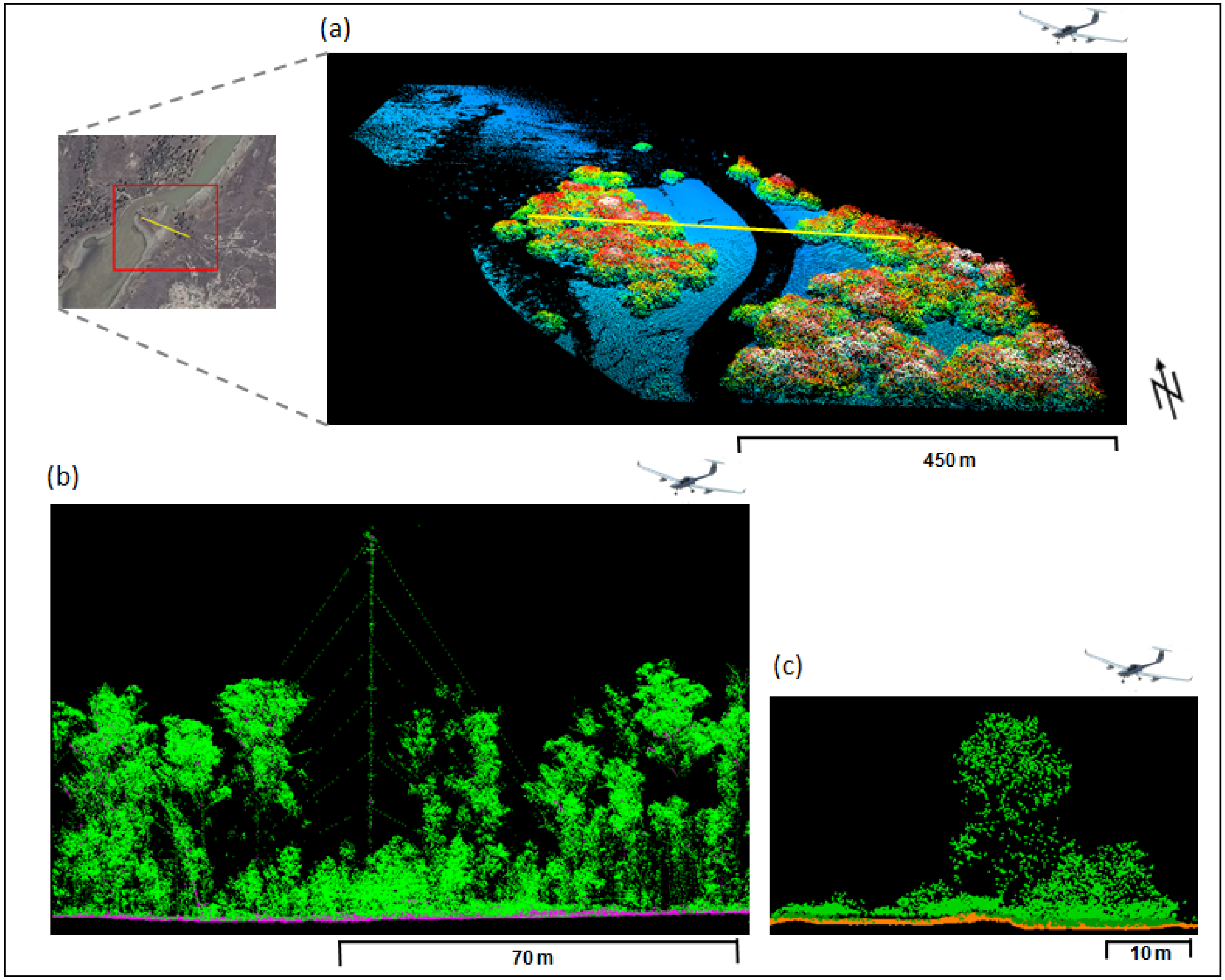


Time Series – Landsat (1984-1912), Brazilian

Müller, H., Griffiths, P., Hostert, P., 2016. Long-term deforestation dynamics in the Brazilian Amazon — Uncovering historic frontier development along the Cuiabá – Santarém highway. Int. J. Appl. Earth Obs. Geoinf. 44, 61–69. doi:10.1016/j.jag.2015.07.005

Forest health by RS – 2/3 D Structural Diversity

- Traits → **Structural traits**

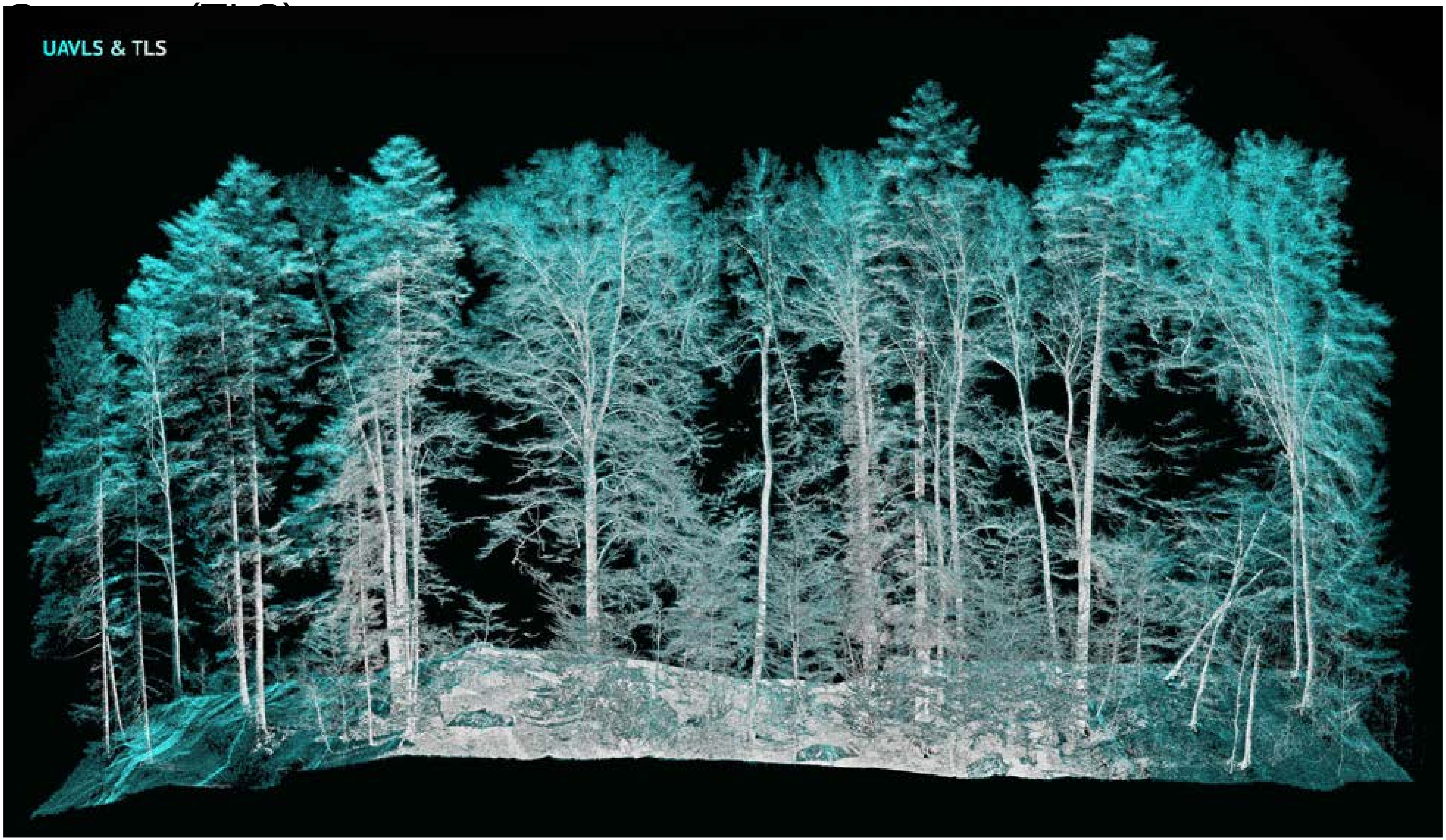


LiDAR

Lausch, A., et al., 2016. Linking Earth Observation and taxonomic, structural and functional biodiversity: Local to ecosystem perspectives. Ecological Indicators 70., 317-339., doi: 10.1016/j.ecolind.2016.06.022.

Forest health by RS – 2/3 D Structural Diversity

Coupling - Laserscanning (UAVLS) & Terrestrial Laser

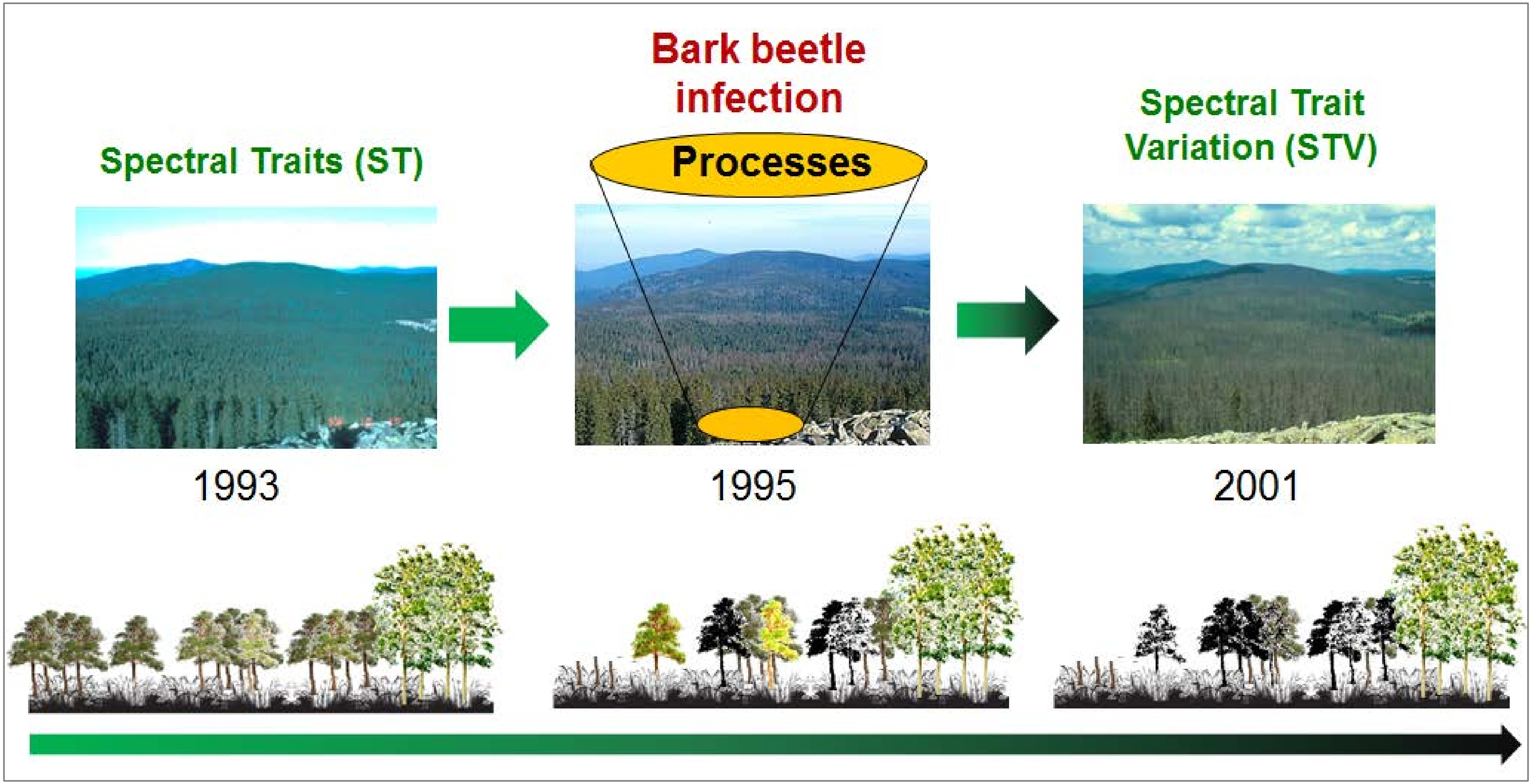


Laegeren Forest, Switzerland

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

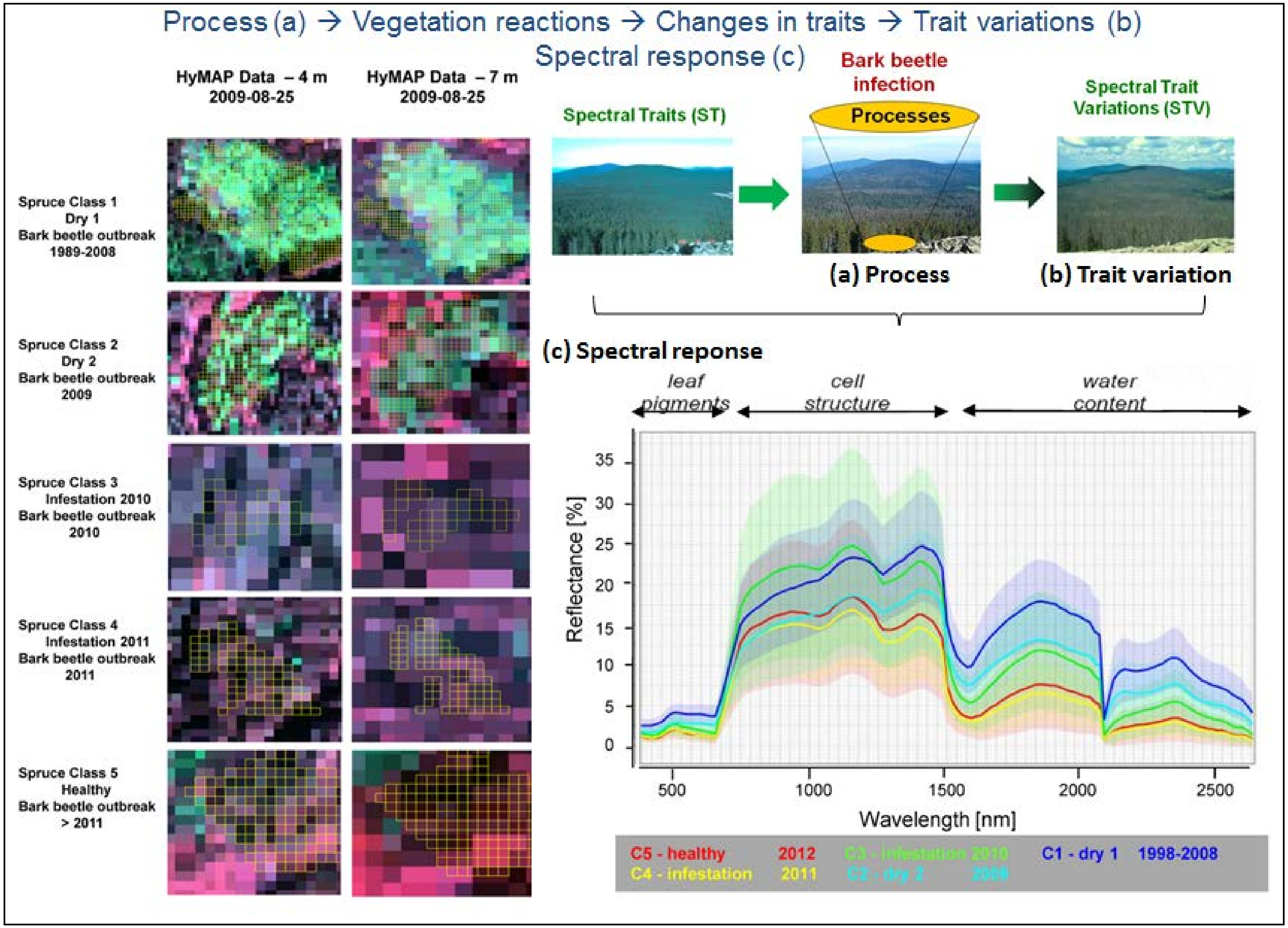
Forest health by RS – Structural & Functional Diversity

Traits/ Trait variations = Proxy / filter for status, stress, disturbances, processes & 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

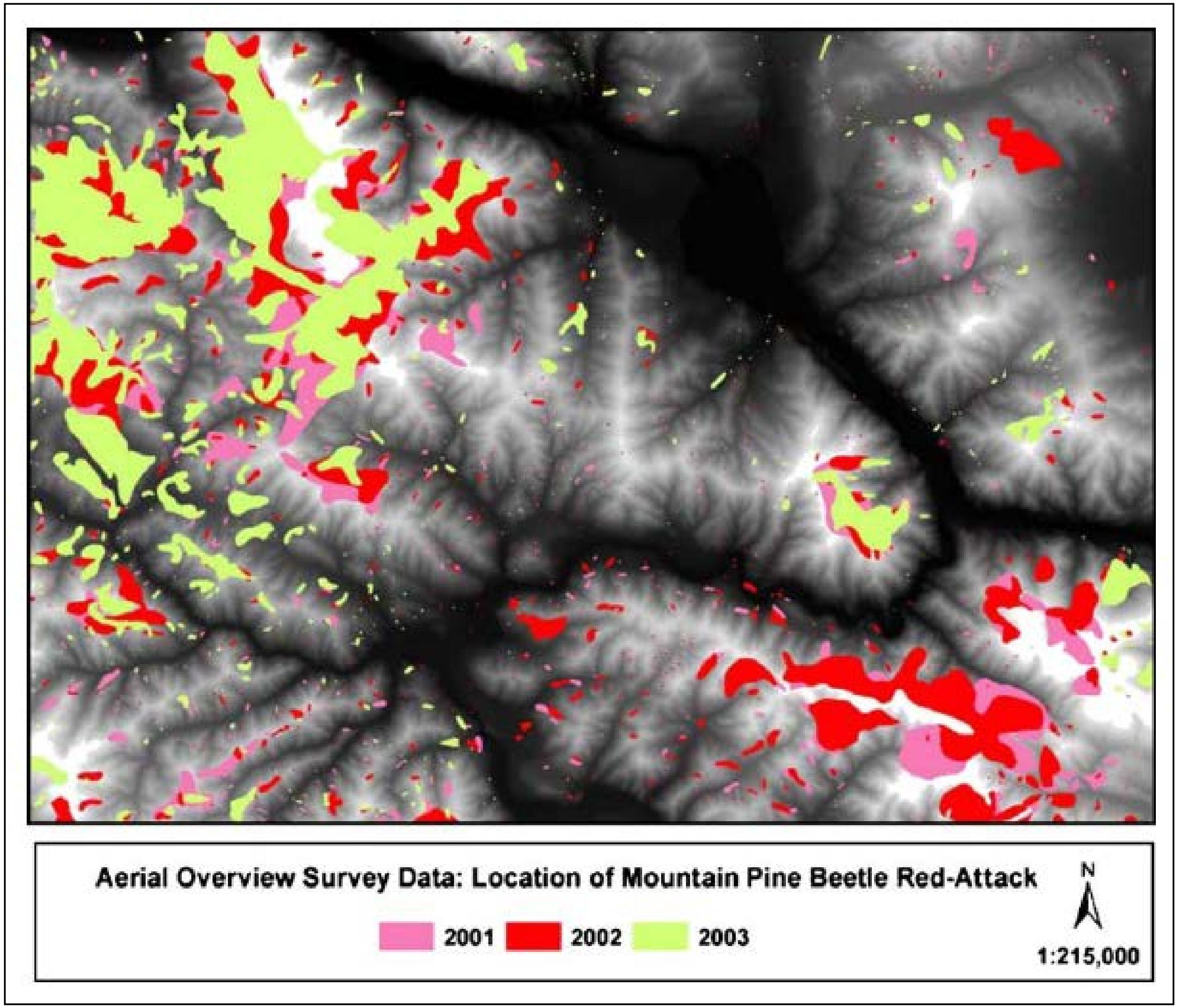
Forest health by RS – Structural & Functional Diversity



Bark beetle infection

Lausch, A., Leitão,P.J., Monitoring Vegetation Diversity and Health through Spectral Traits and Trait Variations Based on Hyperspectral Remote Sensing . Hyperspectral Remote Sensing of Vegetation and Agricultural Crops. Prasad S. Thenkabail, John Lyon, Alfredo Huete (eds.) Hyperspectral Remote Sensing of Vegetation and Agricultural Crops, (second edition), 2018, in press TAYLOR & FRANCIS.

Forest health by RS – Structural & Functional Diversity

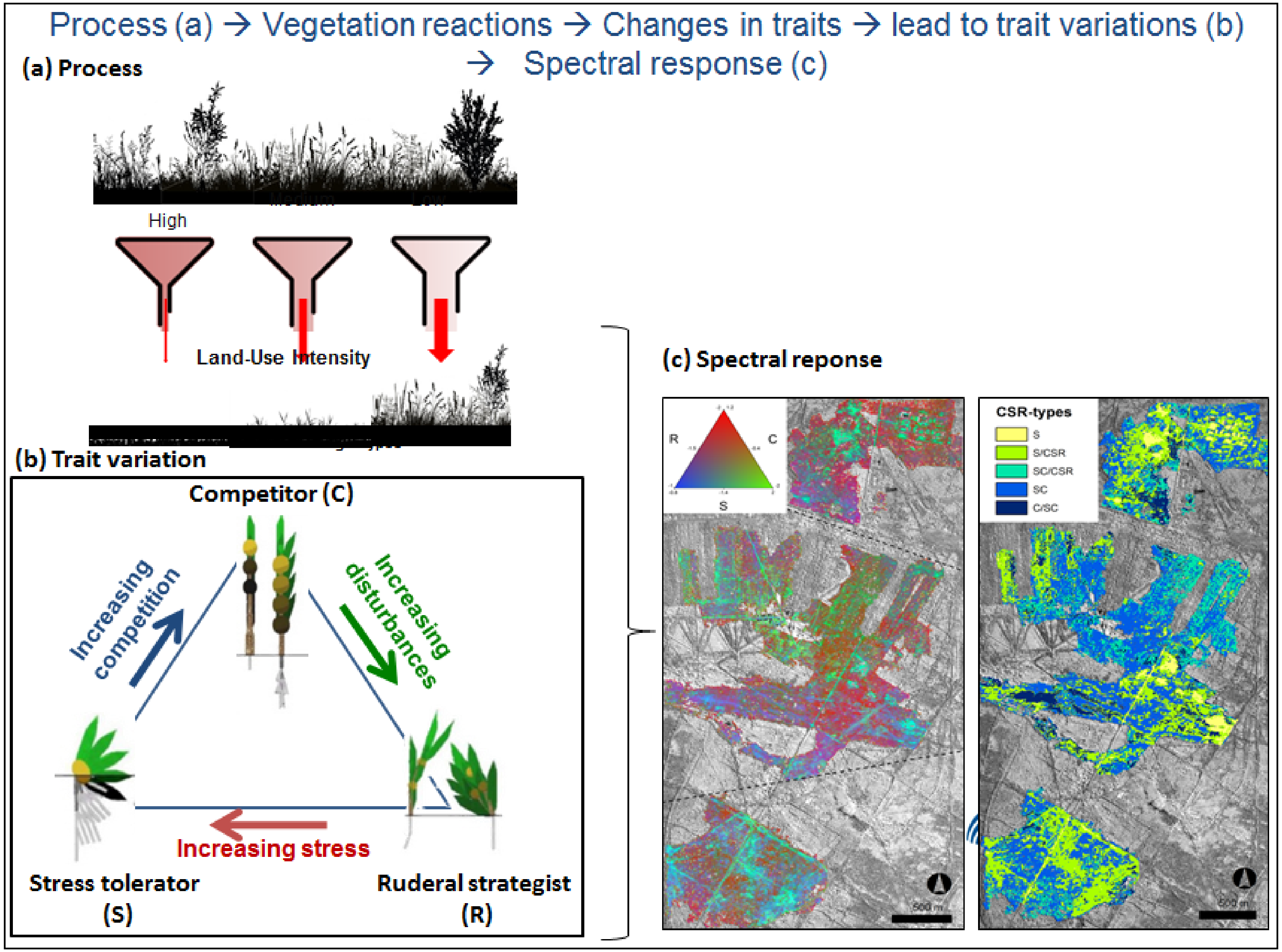


Mountain pine beetle red-attack

Landsat

Wulder, M.A., White, J.C., Bentz, B., Alvarez, M.F., Coops, N.C., 2006. Estimating the probability of mountain pine beetle red-attack damage. Remote Sens. Environ. 101, 150–166. doi:10.1016/j.rse.2005.12.010

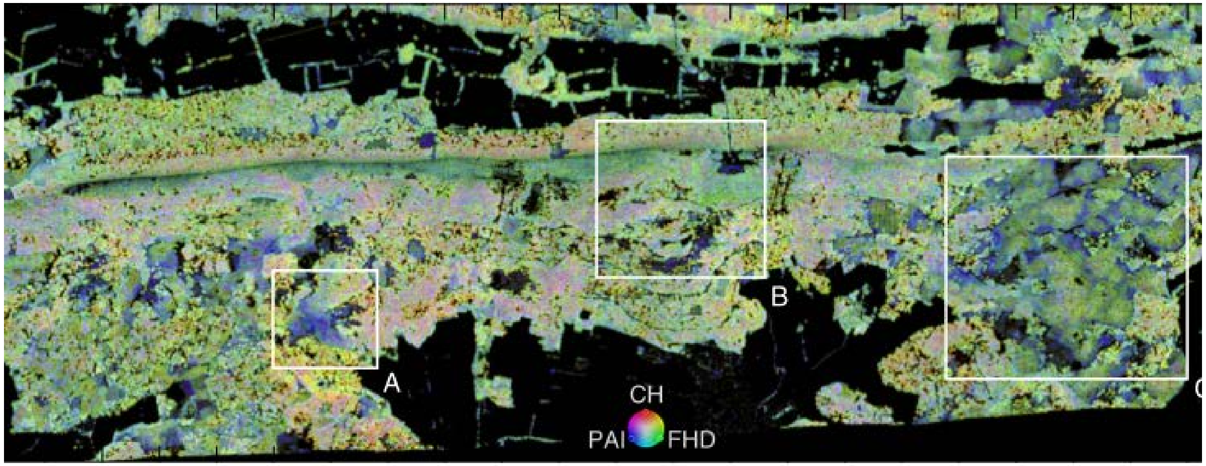
Forest health by RS – Structural & Functional Diversity



Lausch, A., Leitão,P.J., Monitoring Vegetation Diversity and Health through Spectral Traits and Trait Variations Based on Hyperspectral Remote Sensing . Hyperspectral Remote Sensing of Vegetation and Agricultural Crops. Prasad S. Thenkabail, John Lyon, Alfredo Huete (eds.) Hyperspectral Remote Sensing of Vegetation and Agricultural Crops, (second edition), 2018, in press TAYLOR & FRANCIS.

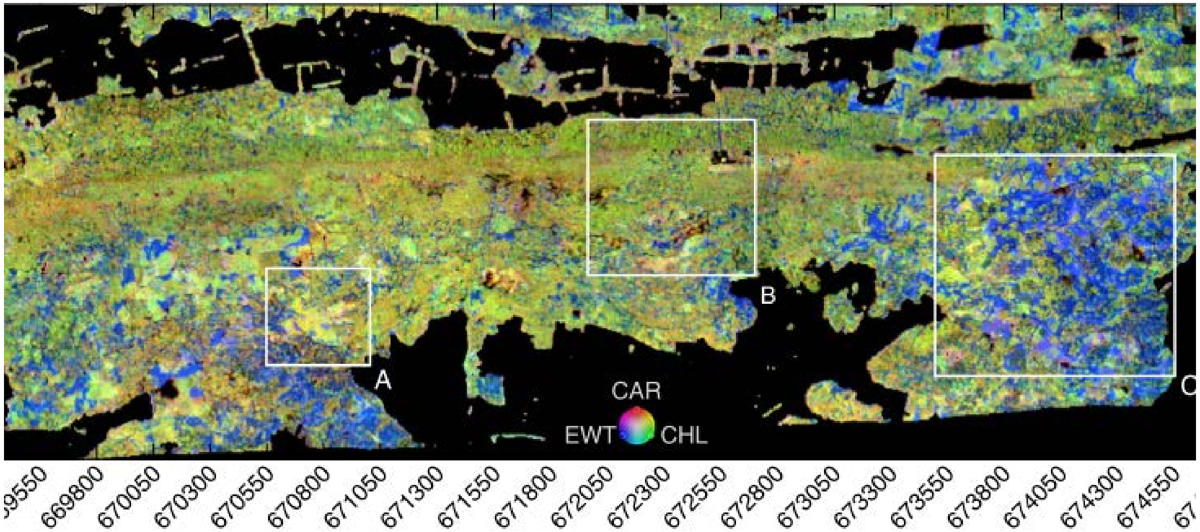
Forest health by RS – Structural & Functional Diversity

Spatial composition of morphological, physiological traits to derivate FH diversity



Morphological forest traits

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

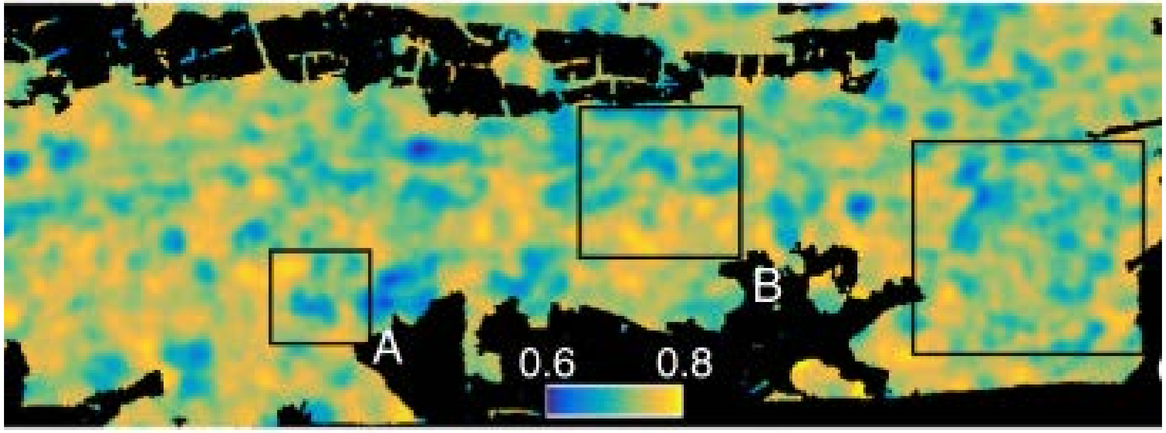


Physiological forest traits

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

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

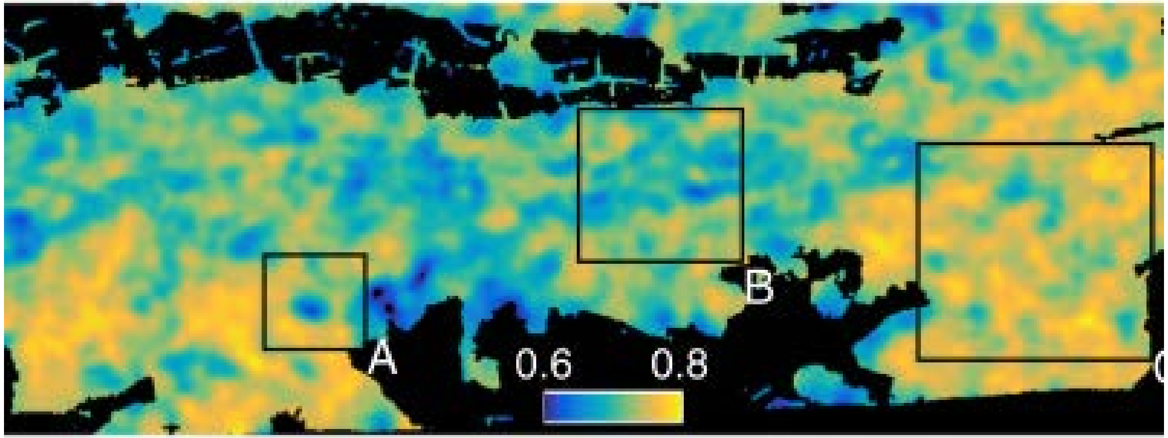
Forest health by RS – Structural & Functional Diversity



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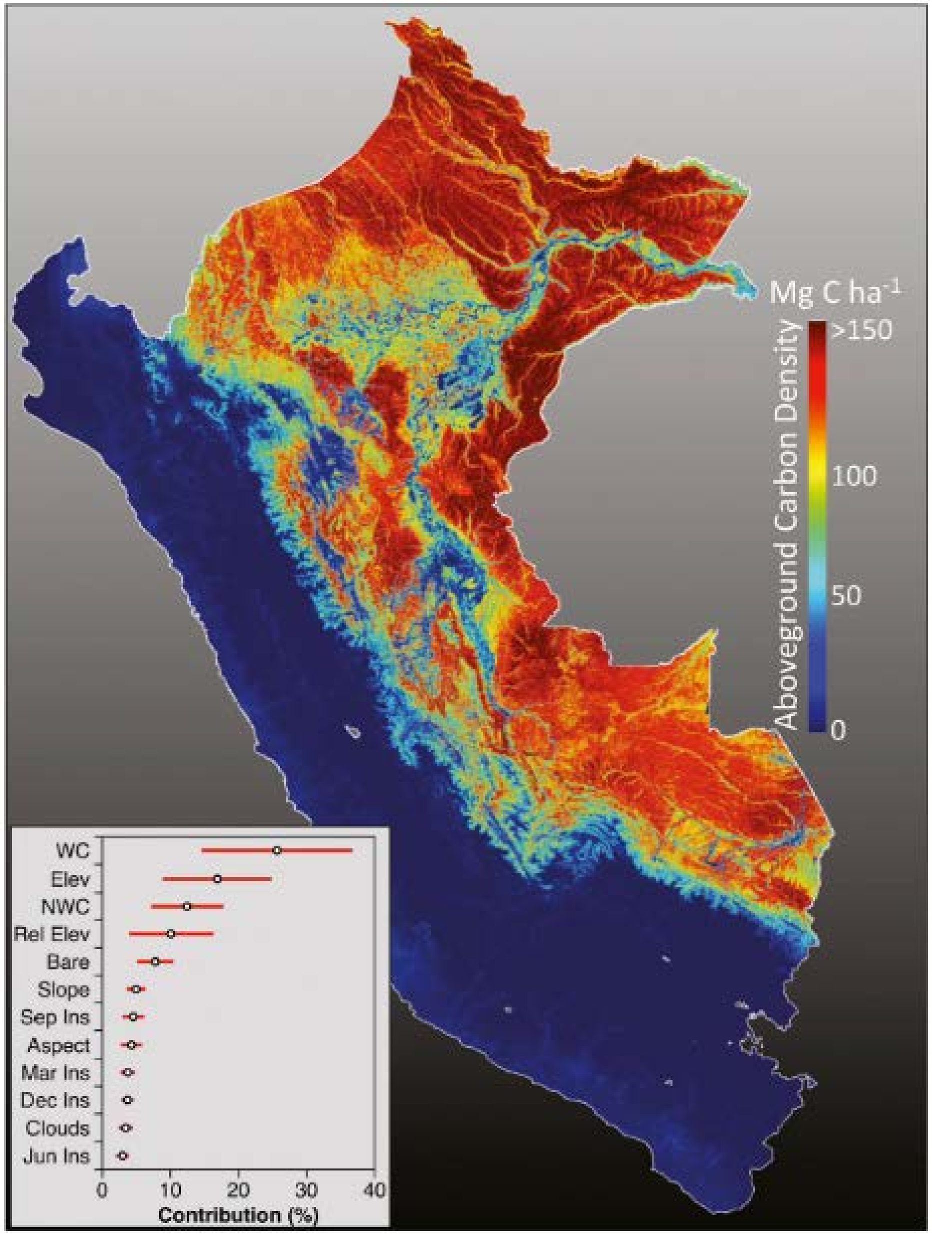
Schneider, F.D., Morsdorf, F., Schmid, B., Petchey, O.L., Hueni, A., Schimel, D.S., Schaepman, M.E., 2017. Mapping functional diversity from remotely sensed morphological and physiological forest traits. Nat. Commun. doi:10.1038/s41467-017-01530-3

Forest health by RS – Functional Diversity



Aboveground carbon density (ACD)

ACD were define by faktors:

- fractional cover of woody plants (WC),
- elevation,
- nonwoody plant cover (NWC),
- relative elevation above nearest water body (Rel Elev),
- bare substrate cover,
- topo- graphic slope and aspect,
- solar insolation at four points of the year (e.g., Jan Ins),
- cloud cover

Asner, G.P., et al., 2014. Targeted carbon conservation at national scales with high-resolution monitoring. Proc. Natl. Acad. Sci. 111, E5016-5022. doi:10.1073/pnas.1419550111

Forest health by RS – Paper – Data Science as a bridge

Multi-Source-Forest / Vegetation health - Monitoring Network (MU-SO-FH-MN)

remote sensing

MDPI

Review

Understanding Forest Health with Remote Sensing, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches

Angela Lausch [1,2,*], Erik Borg [3], Jan Bumberger [4], Peter Dietrich [4,5], Marco Heurich [6,7], Andreas Huth [8], András Jung [9,10], Reinhard Klenke [11], Sonja Knapp [12], Hannes Mollenhauer [4], Hendrik Paasche [4], Heiko Paulheim [13], Marion Pause [14], Christian Schweitzer [15], Christiane Schmulius [16], Josef Settele [11,17], Andrew K. Skidmore [18,19], Martin Wegmann [20], Steffen Zacharias [4], Toralf Kirsten [21] and Michael E. Schaepman [22]

1 Department Computational Landscape Ecology, Helmholtz Centre for Environmental Research—UFZ, Permoserstr. 15, D-04318 Leipzig, Germany

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.

Received: 20 February 2018 | Accepted: 20 April 2018

DOI: 10.1111/2041-210X.13025

Methods in Ecology and Evolution BRITISH ECOLOGICAL SOCIETY

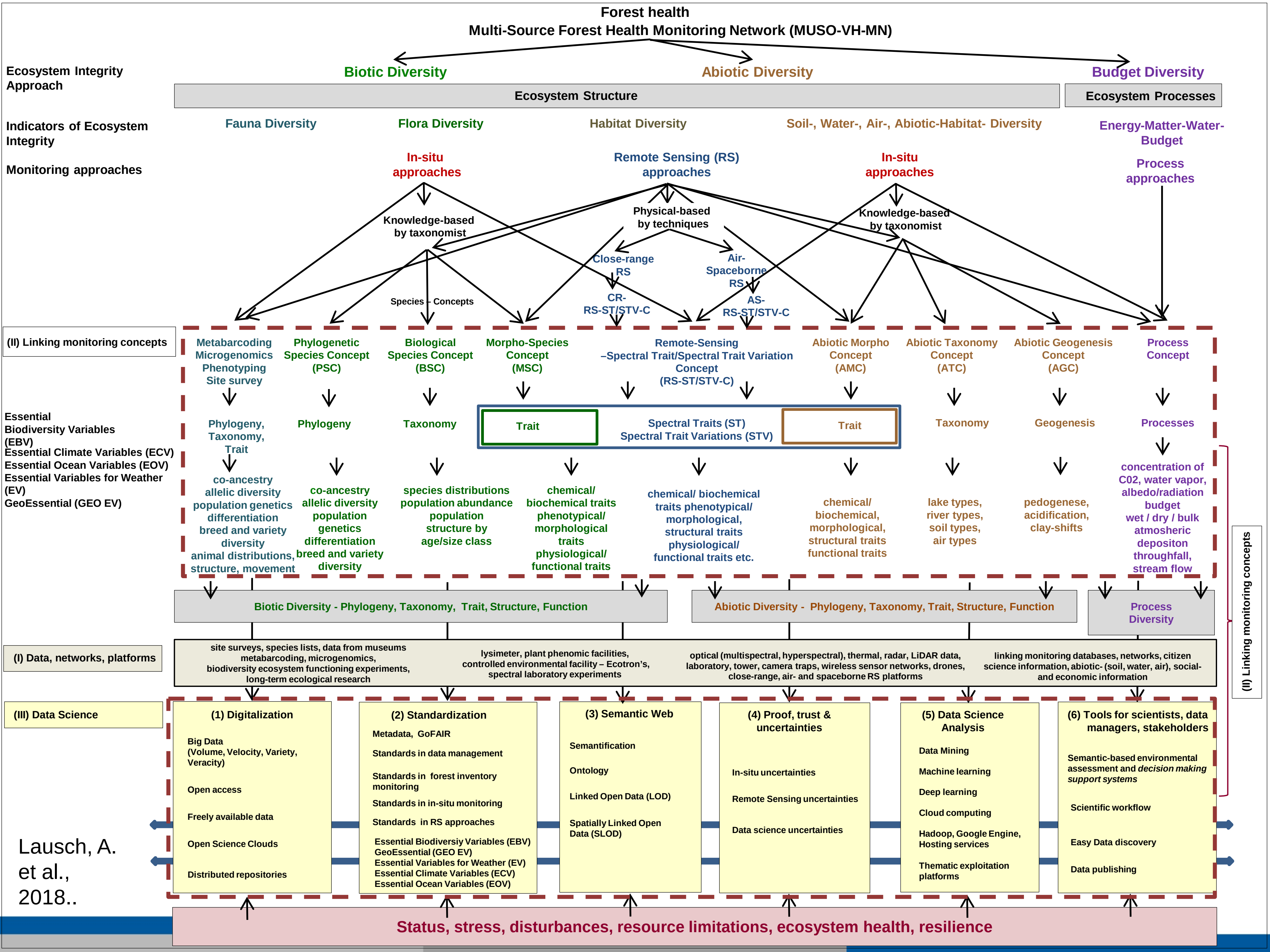
IMPROVING BIODIVERSITY MONITORING USING SATELLITE REMOTE SENSING

Understanding and assessing vegetation health by in situ species and remote-sensing approaches

Angela Lausch[1,2*] | Olaf Bastian[3] | Stefan Klotz[4] | Pedro J. Leitão[2,5] | András Jung[6,7] | Duccio Rocchini[8,9,10] | Michael E. Schaepman[11] | Andrew K. Skidmore[12,13] | Lutz Tischendorf[14] | Sonja Knapp[15]

[1]Department of Computational Landscape Ecology, Helmholtz Centre for Environmental Research—UFZ, Leipzig, Germany; [2]Geography Department, Humboldt University Berlin, Berlin, Germany; [3]OT Boxdorf, Moritzburg, Germany; [4]Department of Community Ecology, Helmholtz Centre for Environmental Research—UFZ, Halle, Germany; [5]Department Landscape Ecology and Environmental Systems Analysis, Technische Universität Braunschweig,

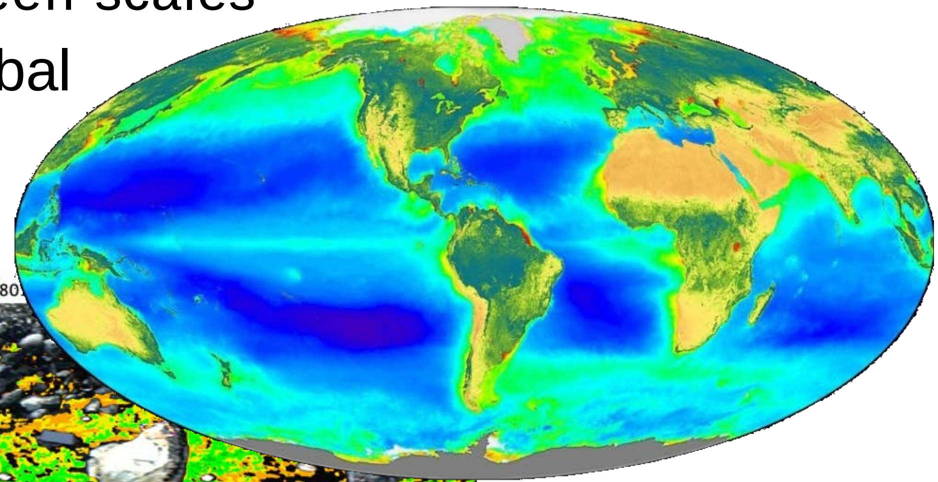
Lausch, A.; et al., 2018. Understanding and assessing vegetation health by in-situ species and remote sensing approaches. Methods in Ecology and Evolution, 00: 1–11. doi.org/10.1111/2041-210X.13025.


Forest health
Multi-Source Forest 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
CR-RS-ST/STV-C
AS-RS-ST/STV-C
Species - Concepts
(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 depositon 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
Status, stress, disturbances, resource limitations, ecosystem health, resilience
Lausch, A. et al., 2018..

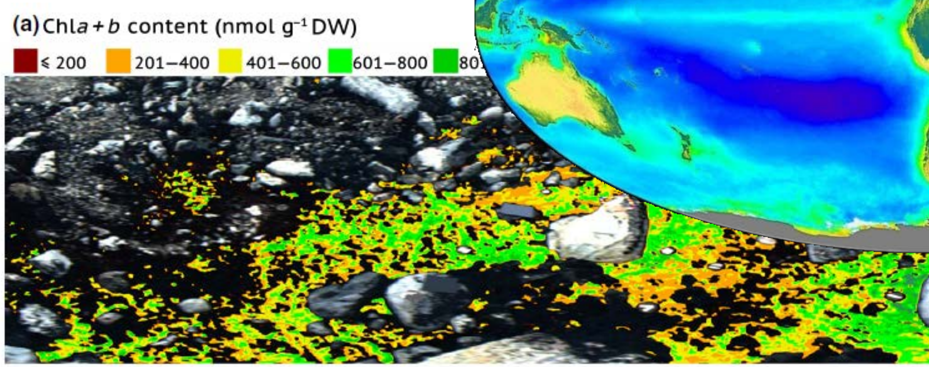
Understanding - Processes – Pattern – Interaction

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

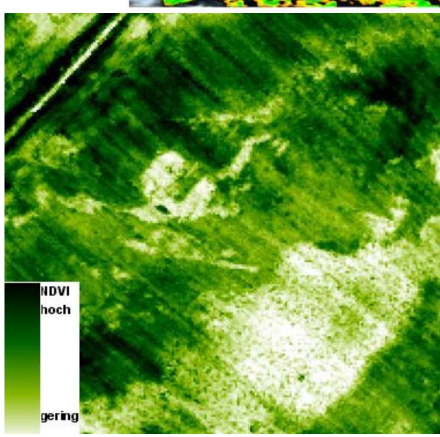
Global



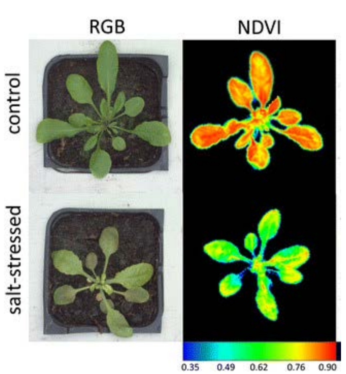
Local



Plot



Individual

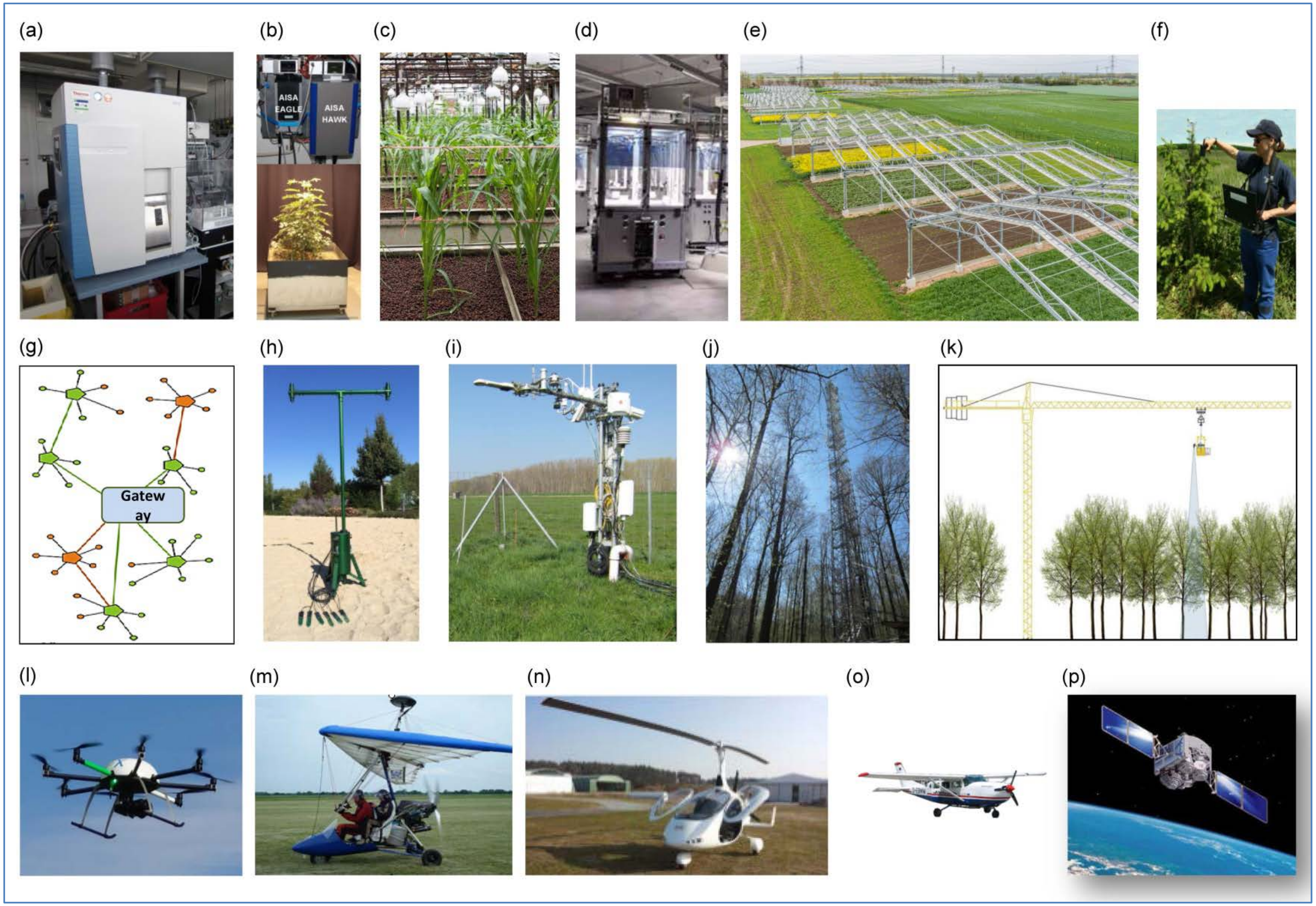


Chlorophyll-Concentration

Long-term high frequency WSN + **Long-term low frequency Air / Spaceborne RS**

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

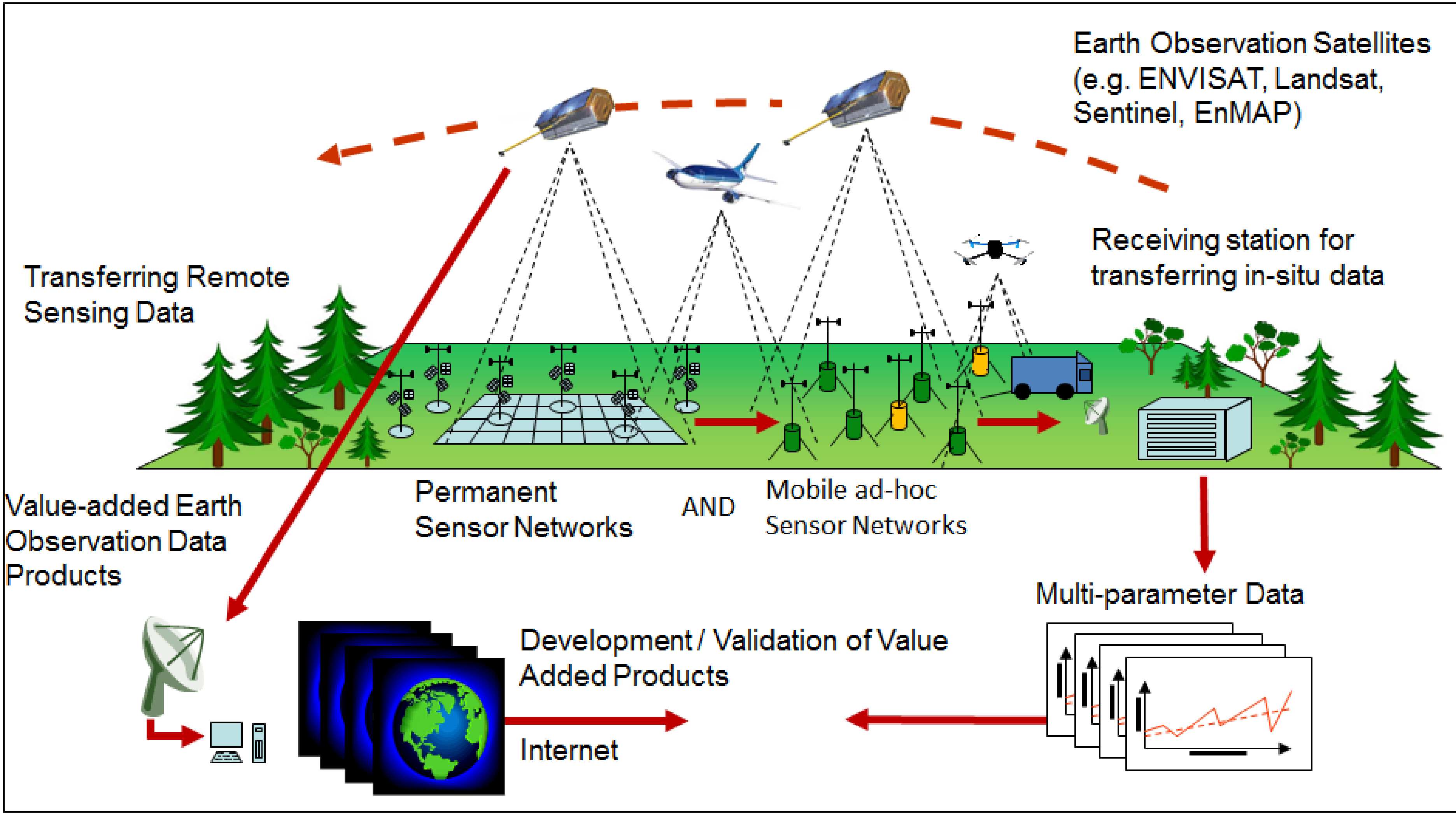
Data Science – Requirement – Remote Sensing



Different Platforms

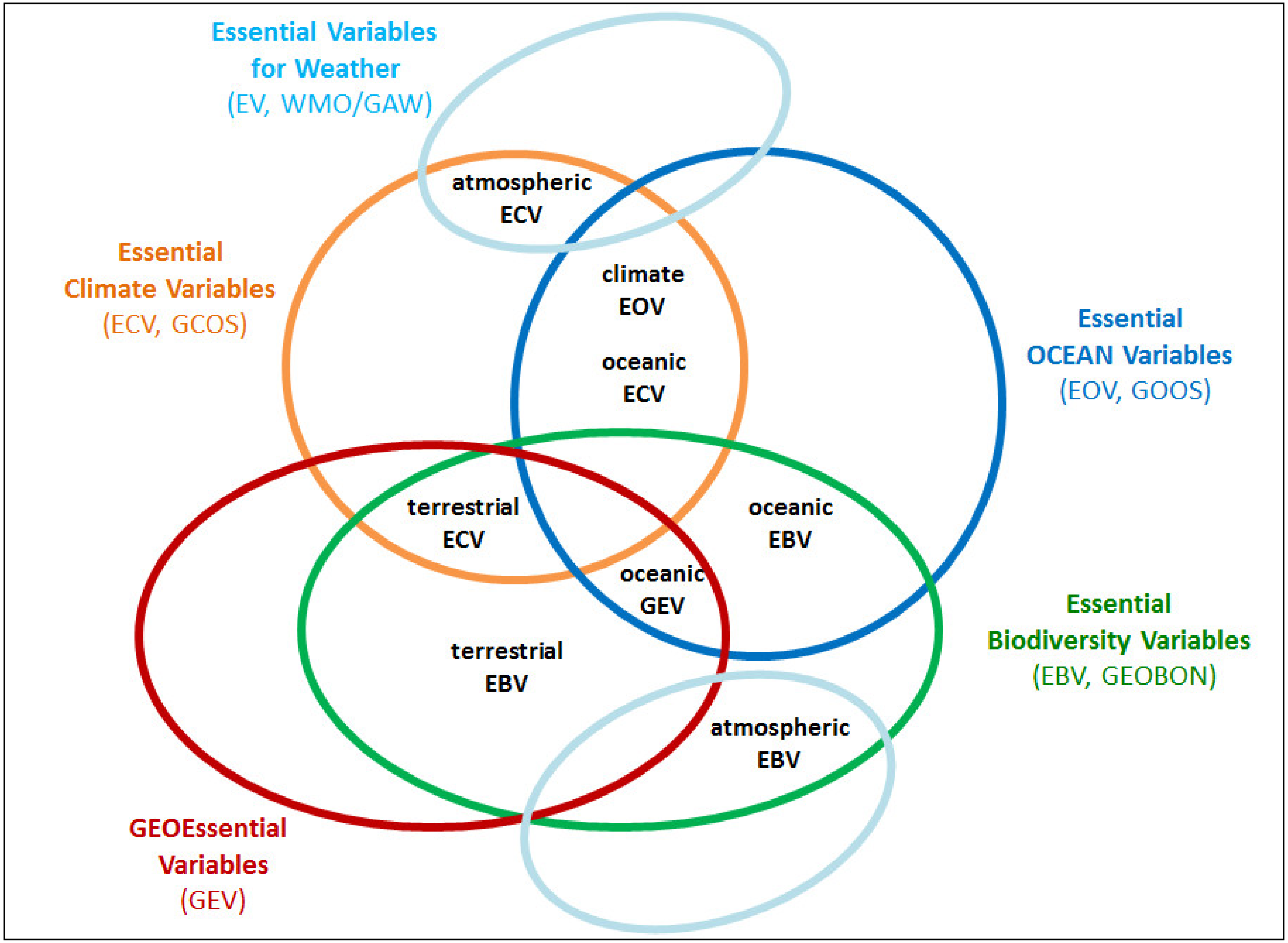
Lausch et al.,. A range of Earth Observation techniques for assessing plant diversity Jeannine Cavender-Bares, John Gamon, Philip Townsend (eds): The nature of biodiversity: prospects for remote detection of genetic, phylogenetic, functional and ecosystem components and importance in managing Planet, Jeannine Cavender-Bares, John Gamon, Philip Townsend, Springer, 2018/2019 (in press)

Data Science – Requirement – Coupling RS Platforms



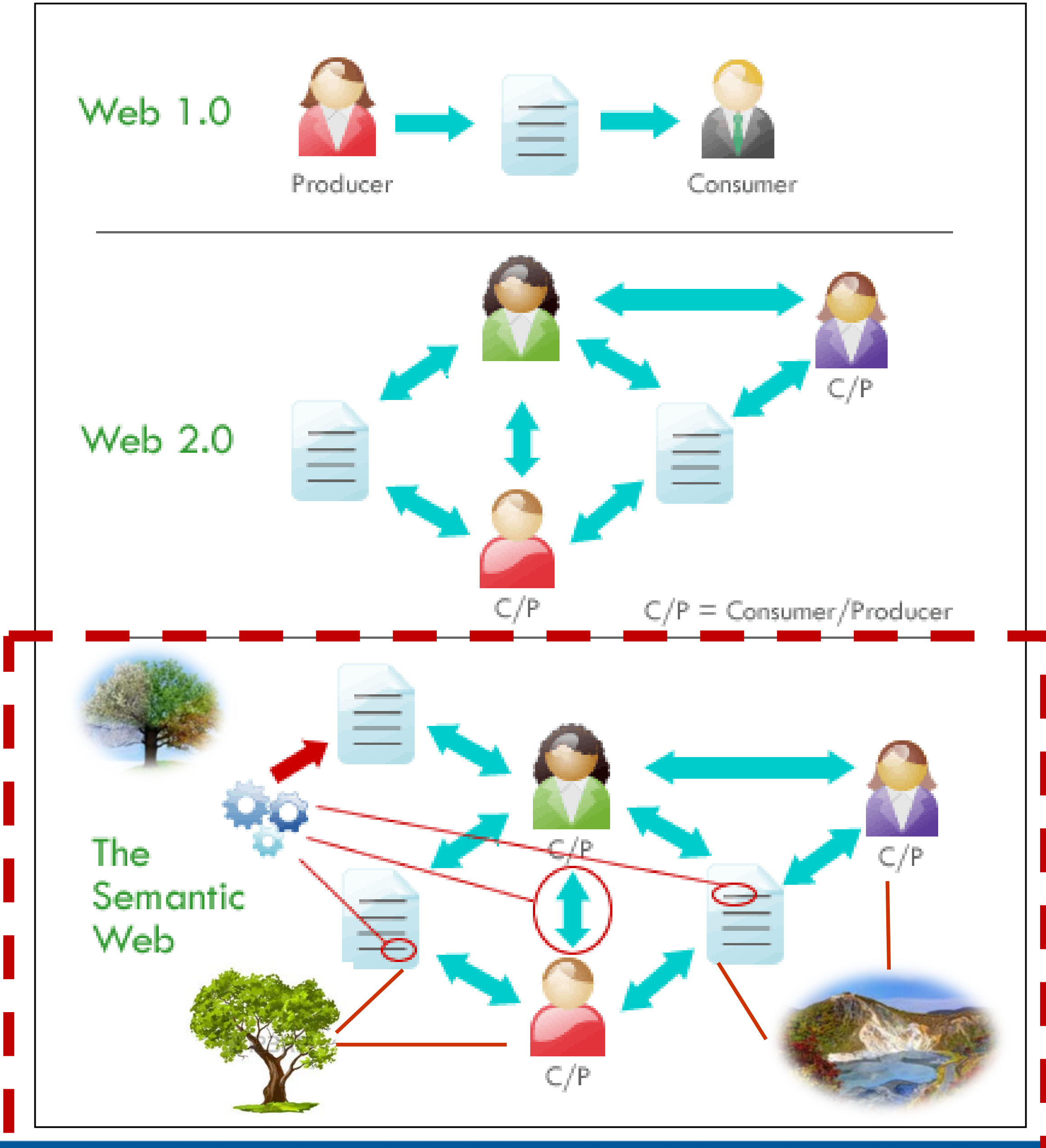
Lausch, A. et al., 2018. Understanding Forest Health with Remote Sensing, Part III: Requirements for a Scalable Multi-Source Forest Health Monitoring Network Based on Data Science Approaches. Remote Sensing, 10, 1120

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 - Semantification



Semantic Web / Linked Open Data

Handling:

- **Complex-Data**

HELMHOLTZ
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UFZ

Data Science – Requirement – Metadata/Data - FAIR

www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

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

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

Mark D. Wilkinson *et al.*[#]

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 describes
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 communications protocol
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.

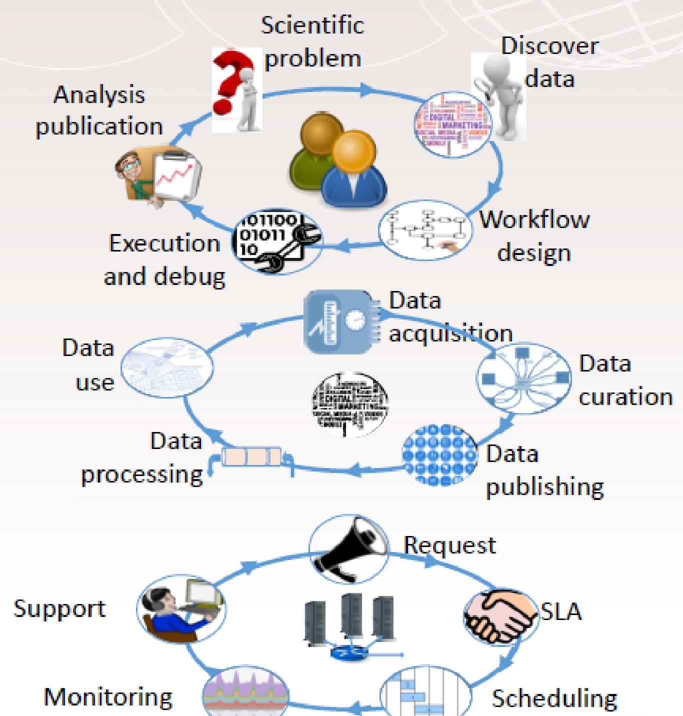
Data Science – Requirements – Data & Information Management

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

http://www.envriplus.eu/

Research support environments

- **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, International Summer School "Data Management in Environmental and Earth, Science Infrastructures: theory and practice" *Dates, 9th July – 13th July 2018,* Lecce, Italy

Forest health – Data Science as a bridge

Multi-Source-Forest / Vegetation health - Monitoring Network (MU-SO-FH-MN)

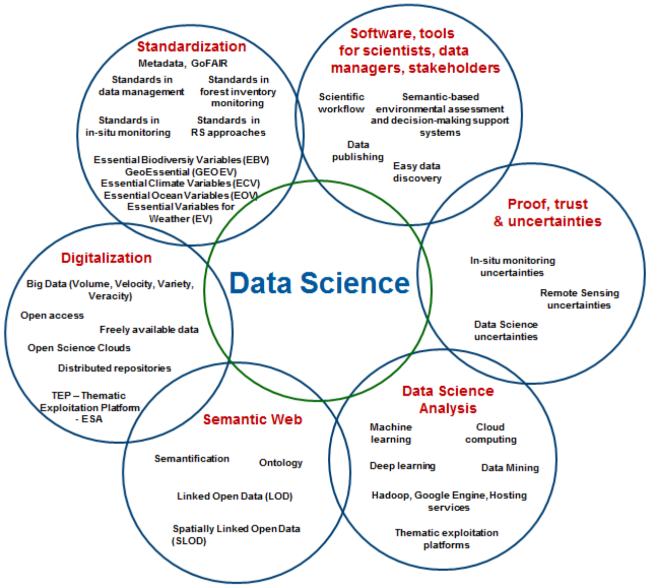
Good Indicators for environmental health, changes, stress & disturbances, SDG‘s

Digitalization

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

Standardization

(Metadata, GoFAIR, Concept of Essential Variables – EV Essential Biodiversity Variables)



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

Semantification

(Semantic Web/Web 4.0, Ontology; Linked Open Data –LOD)

Data Science Analysis

(Machine Learning, Deep learning, Cloud Computing, Data Mining, Hadoop, Google Engine, Hosting services)

Proof, trust & uncertainties

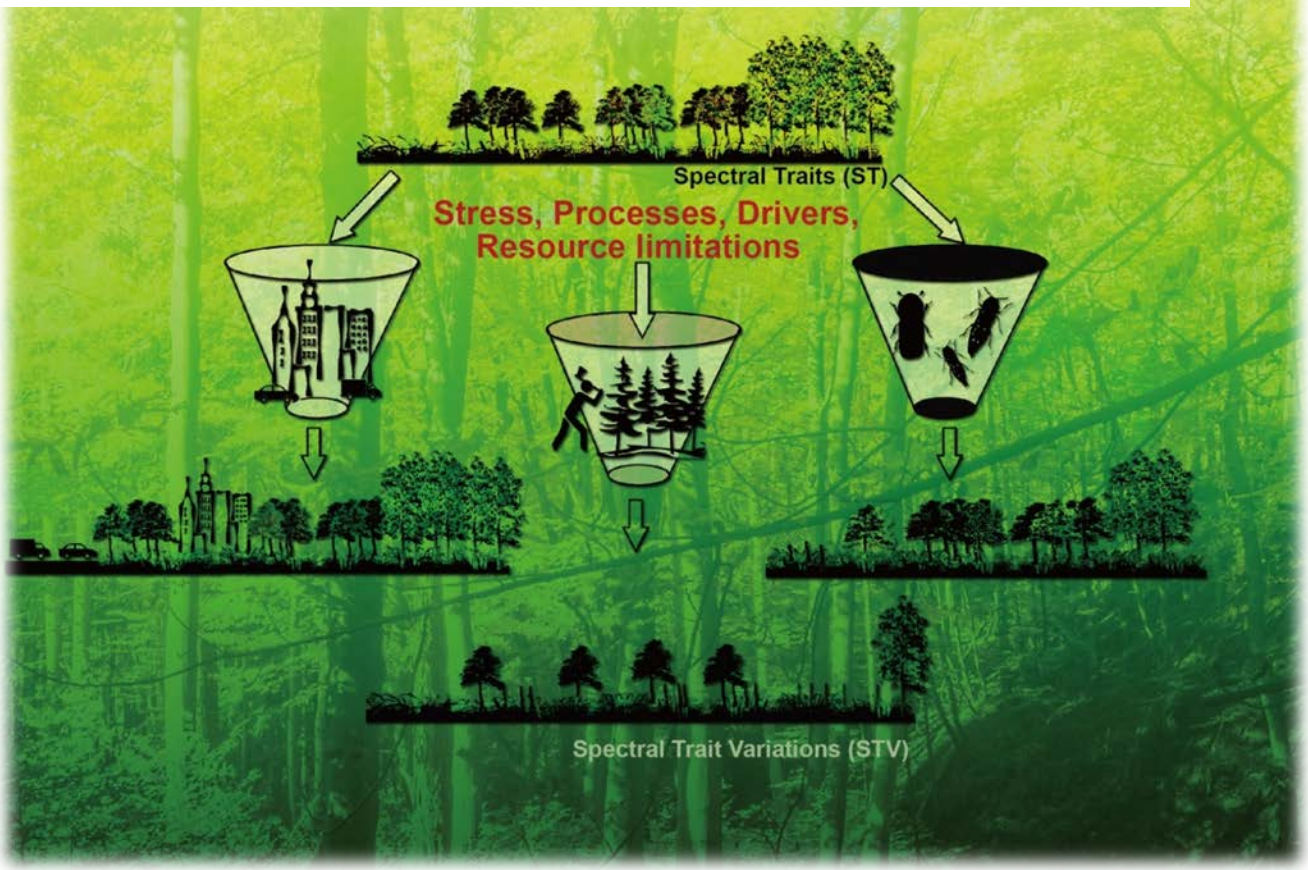
(In-situ monitoring, Remote Sensing & Data Science uncertainties)

Easy software, tools for data manager, stakolders

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

Understanding Forest health by Remote Sensing (RS)

Thank you very much for your attention !



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UMWELTFORSCHUNG
UFZ