Renseigner des variables essentielles à la biodiversité par la télédétection

Sandra Luque, Jean Baptiste Féret, Eric Chraibi, Marc Lang, Samuel Alleaume

tetis
TERRITOIRE ENVIRONNEMENT TÉLÉDÉTECTION INFORMATION SPATIALE

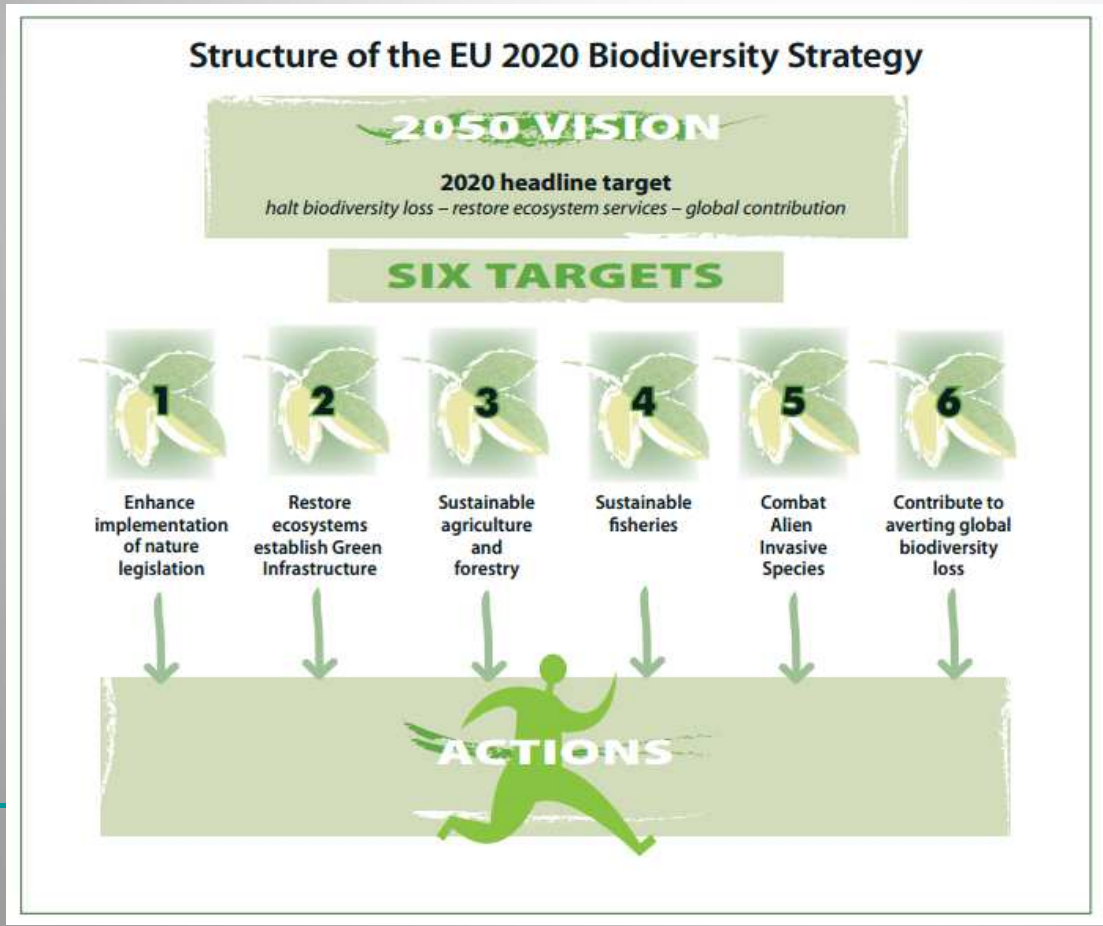
irstea

EU Biodiversity Strategy

→ Halt the loss of biodiversity and ecosystem services in the EU and globally

Target 2

→ Maintain and restore ecosystems



"All the News That's Fit to Print"

The New York Times

Late Edition
Today, clouds and sunshine, afternoon showers or thunderstorms, high 74. **Tonight,** cloudy, showers, 53. **Tomorrow,** partly sunny, cooler, high 66. Weather map, Page B16.

VOL. CLXVIII ... No. 58,320 © 2019 The New York Times Company NEW YORK, TUESDAY, MAY 7, 2019 $3.00

Wildlife Facing Extinction Risk All Over Globe

U.S. ADVISERS SAY CHINA IS RENEGING

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

Media Release

(Cliquez ici pour le texte en Français)

- Summary for Policymakers, photos, 'B-roll', other media resources: bit.ly/IPBESReport
- Media launch webcast live from #IPBES7 (Paris, France): bit.ly/IPBESWebcast starts at 1p.m. (Paris time – CEST) / 7 a.m. (US EDT) / noon (London – BST)
- For interviews: media@ipbes.net or French: +33 62520-0281 English: +1-416-878-8712 or +1- 415-290-5516 or +49- 176-2538-2223 (After 7 May: +49-152-3830-0667

Nature's Dangerous Decline 'Unprecedented'
Species Extinction Rates 'Accelerating'

Current global response insufficient;
'Transformative changes' needed to restore and protect nature;
Opposition from vested interests can be overcome for public good

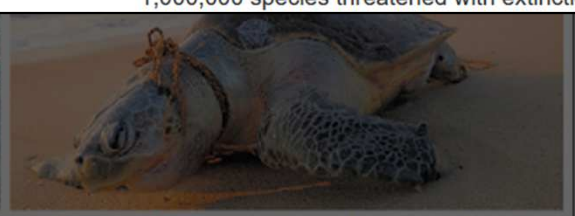
Most comprehensive assessment of its kind;
1,000,000 species threatened with extinction

in biodiversity across the globe and the dangers that creates for human civilization. A summary of its findings, which was approved by representatives from the United States and 131 other countries, was released Monday in Paris. The full report is set to be published this year.

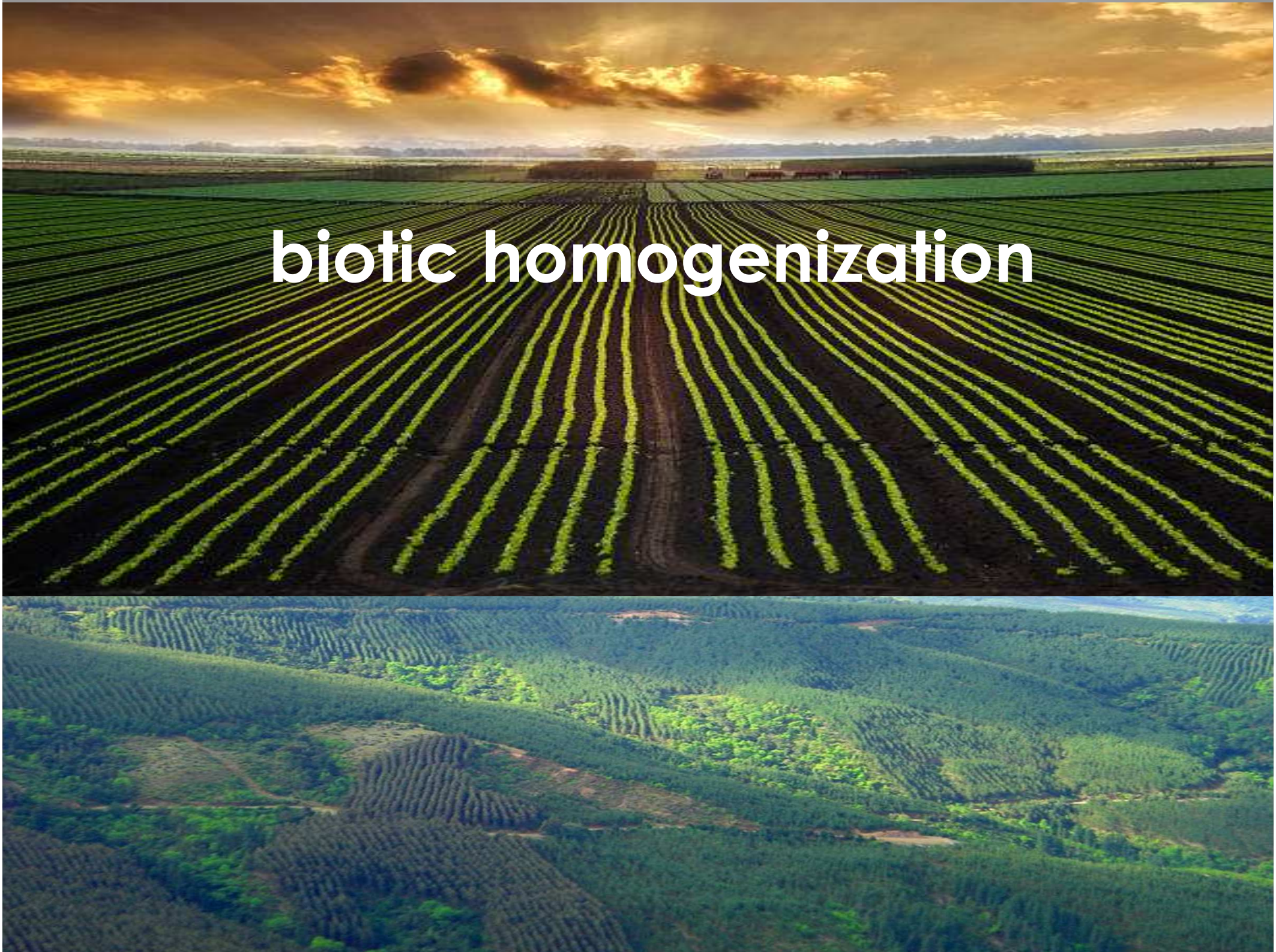
Its conclusions are stark. In most major land habitats, from

more significant concessions from Beijing.

Mr. Trump, angry that China is retreating from its commitments just as the sides appeared to be nearing a deal and confident the American economy can handle a continuation of the trade war, will increase tariffs on $200 billion worth of Chinese goods on Friday morning, his top advisers said.



CLOCKWISE FROM TOP LEFT: TONY KARUMBA/AGENCE FRANCE-PRESSE — GETTY IMAGES; BRUNO KELLY/REUTERS; JOHN ANDERSSON/A.F.P. — GETTY IMAGES; JURGEN FREUND/NPL/MINDEN PICTURES


biotic homogenization

Landscape homogenization

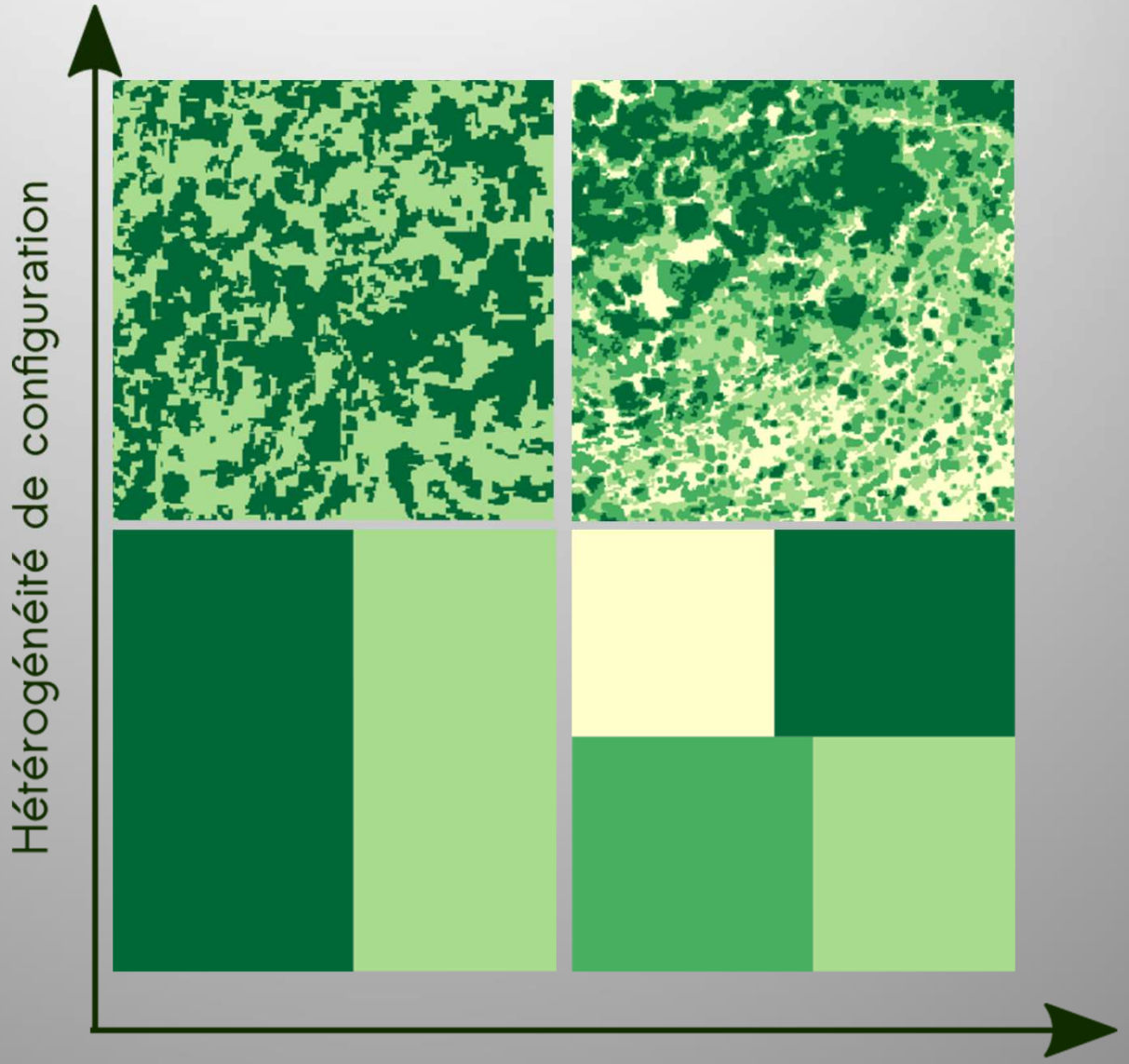
What is heterogeneity?

- **A measurable property related to a landscape**

(Kolasa and Rollo, 1991)

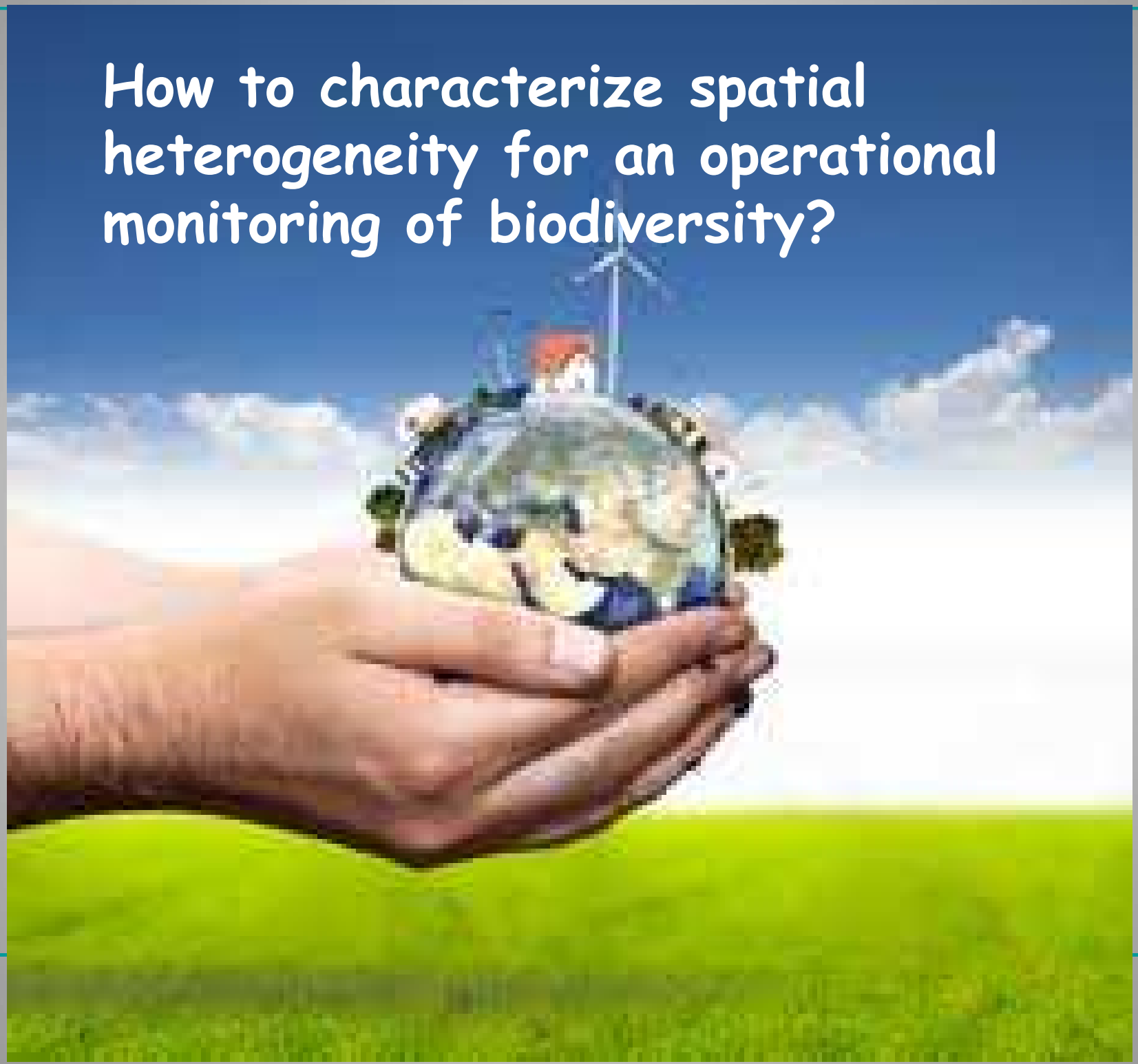
Depends on

- **the scale**
- **thematic resolution**



(Adapted from Fahrig et al, 2011)

How to characterize spatial heterogeneity for an operational monitoring of biodiversity?



Biodiversity monitoring is critical to understand how to mitigate mass extinction

- **Biodiversity is multidimensional**
- **There is no unique indicator to describe or monitor biodiversity**

→Group on Earth Observations Biodiversity Observation Network (GEO BON) aims at improving the availability of biodiversity change data to decision makers and scientists in support of policy

GEO BON

ECOLOGY

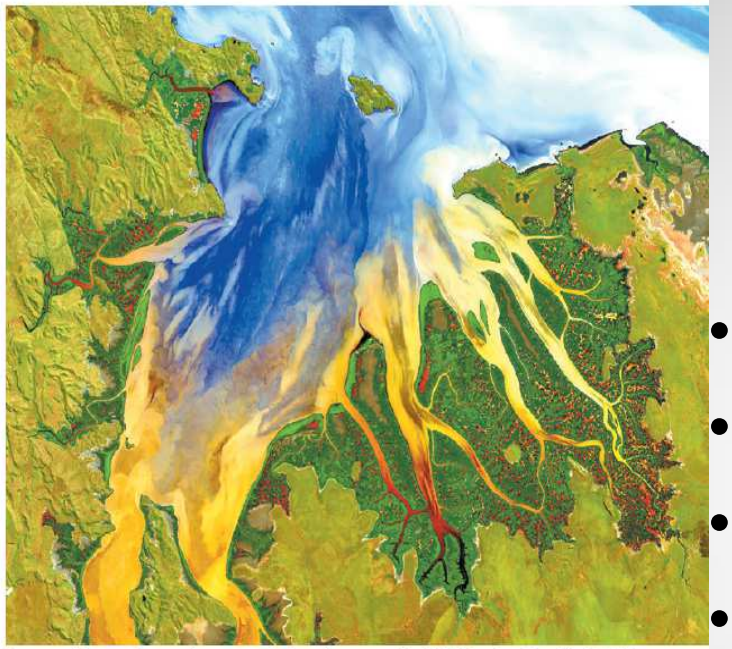
Essential Biodiversity Variables

H. M. Pereira,[1*†] S. Ferrier,[2] M. Walters,[3] G. N. Geller,[4] R. H. G. Jongman,[5] R. J. Scholes,[3] M. W. Bruford,[6] N. Brummitt,[7] S. H. M. Butchart,[8] A. C. Cardoso,[9] N. C. Coops,[10] E. Dulloo,[11] D. P. Faith,[12] J. Freyhof,[13] R. D. Gregory,[14] C. Heip,[15] R. Höft,[16] G. Hurtt,[17] W. Jetz,[18] D. S. Karp,[19] M. A. McGeoch,[20] D. Obura,[21] Y. Onoda,[22] N. Pettorelli,[23] B. Reyers,[24] R. Sayre,[25] J. P. W. Scharlemann,[26,27] S. N. Stuart,[28] E. Turak,[29] M. Walpole,[26] M. Wegmann[30]

A global system of harmonized observations is needed to inform scientists and policy-makers.

Pereira *et al.*, *Science*, 339(277-278), 2013.

Remote sensing as a key data source for biodiversity monitoring



Estuary sediment and vegetation patterns in Australia, captured by NASA's Landsat 8 satellite in 2013.

Agree on biodiversity metrics to track from space

Ecologists and space agencies must forge a global monitoring strategy, say **Andrew K. Skidmore**, **Nathalie Pettorelli** and colleagues.

Earth observation appropriate to provide information for the monitoring of biodiversity

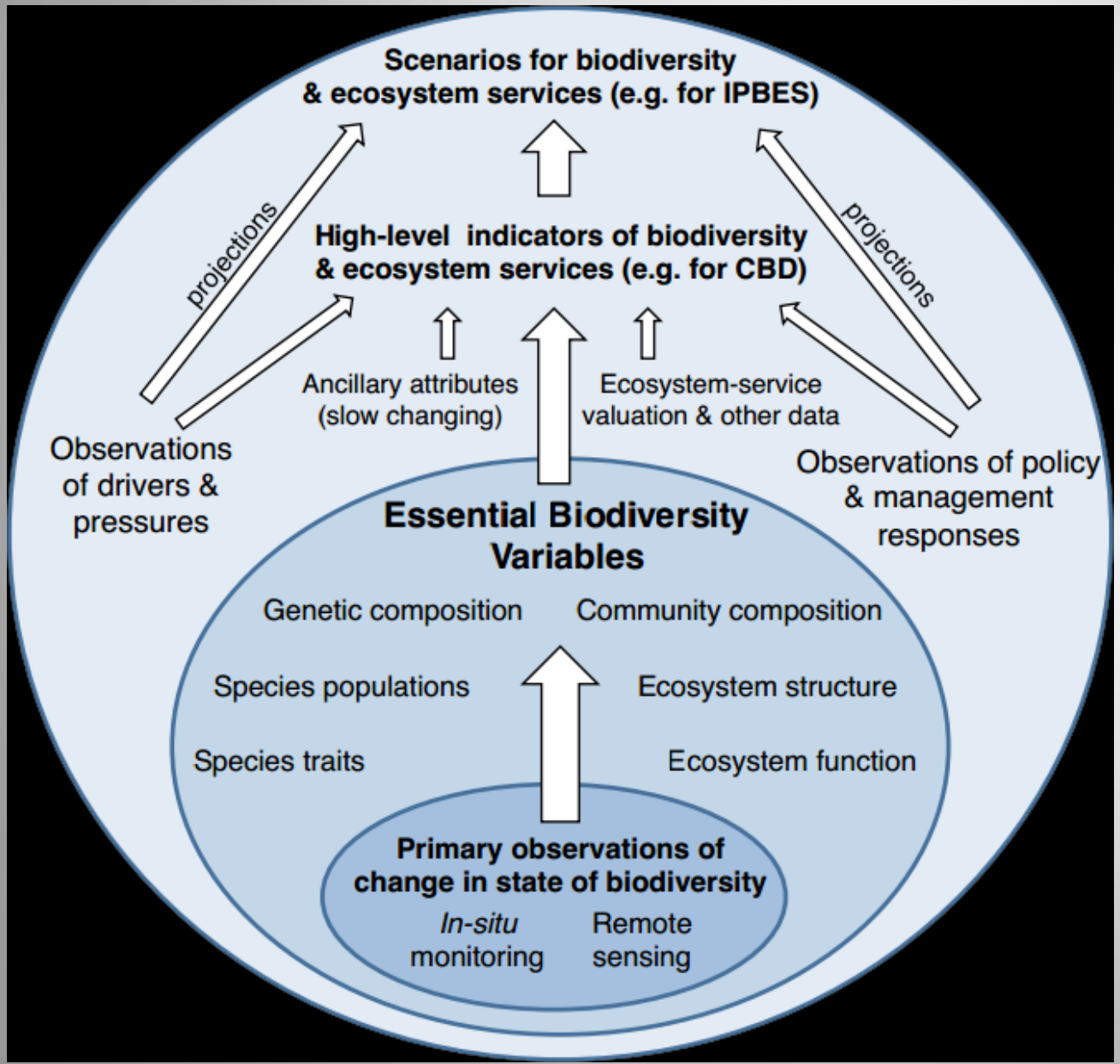
'RS enabled EBVs'

- **Regional / global monitoring**
- **Cost effective**
- **Coupling with global modeling tools**
- **Combined with *in situ* observation networks**

Very active domain of research, boosted by increased RS data availibility (including LandSat & Copernicus)

Skidmore *et al.*, *Nature*, 523(7561), 2015.

Essential Biodiversity Variables



- They provide the first level of abstraction between low-level primary observations and high-level indicators of biodiversity

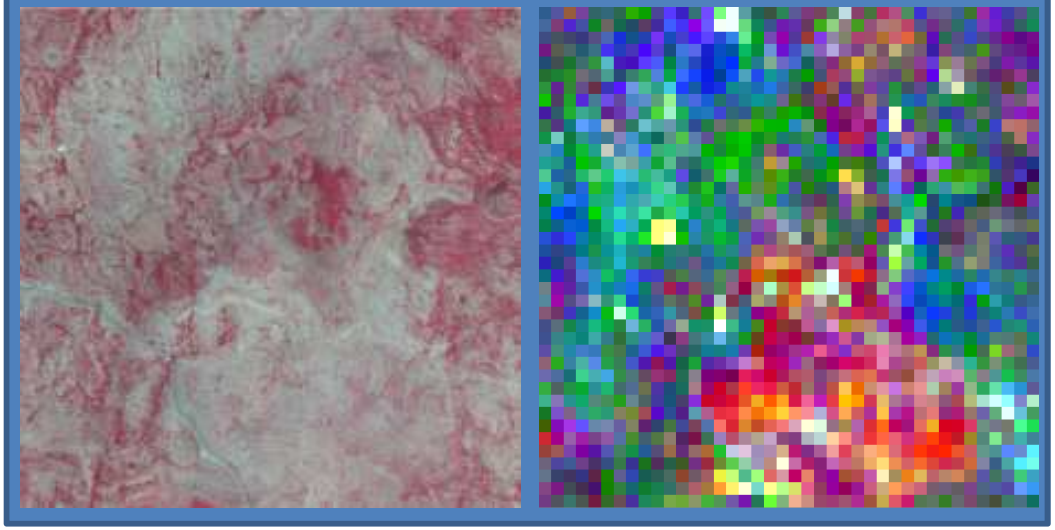
An ideal EBV should be able to

- ❑ capture critical scales and dimensions of biodiversity
- ❑ a state variable (in general) sensitive to change
- ❑ ecosystem agnostic (to the degree possible)
- ❑ technically feasible economically viable sustainable in time

Spatial patterns for various ecosystems

Mediterranean ecosystems:

Characterizing openness of vegetation



Alpine ecosystems:

Mapping habitats based on floristic inventory

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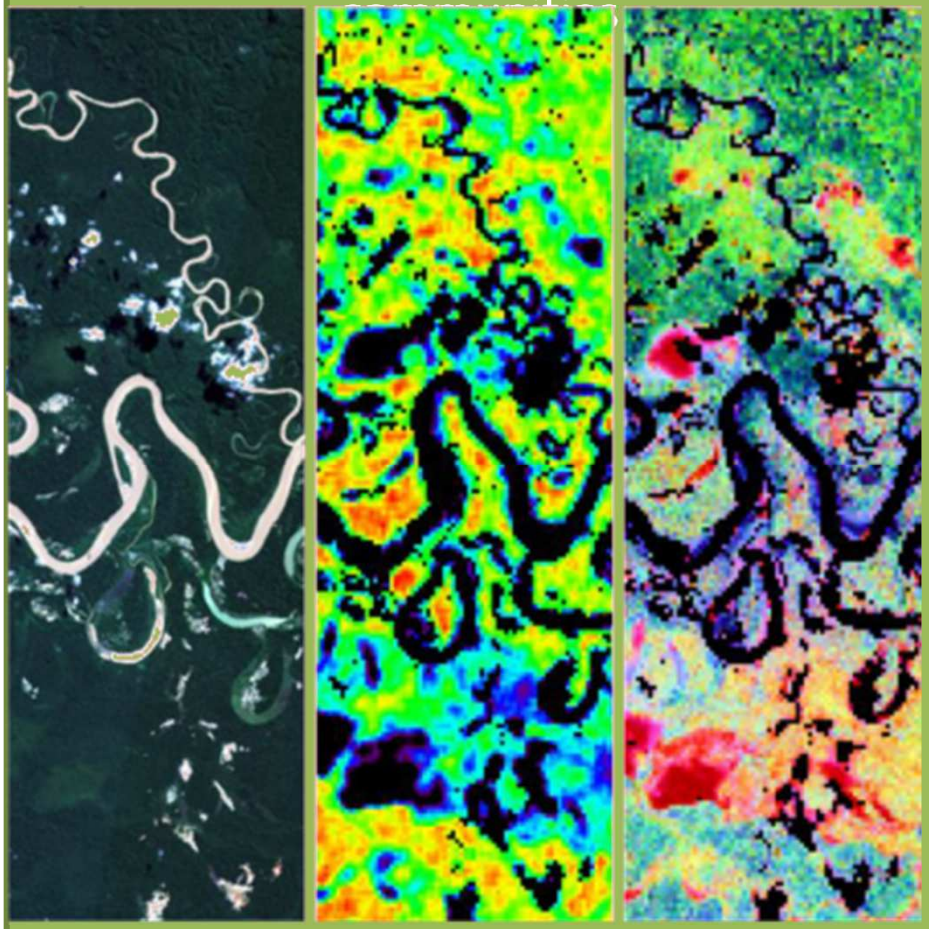
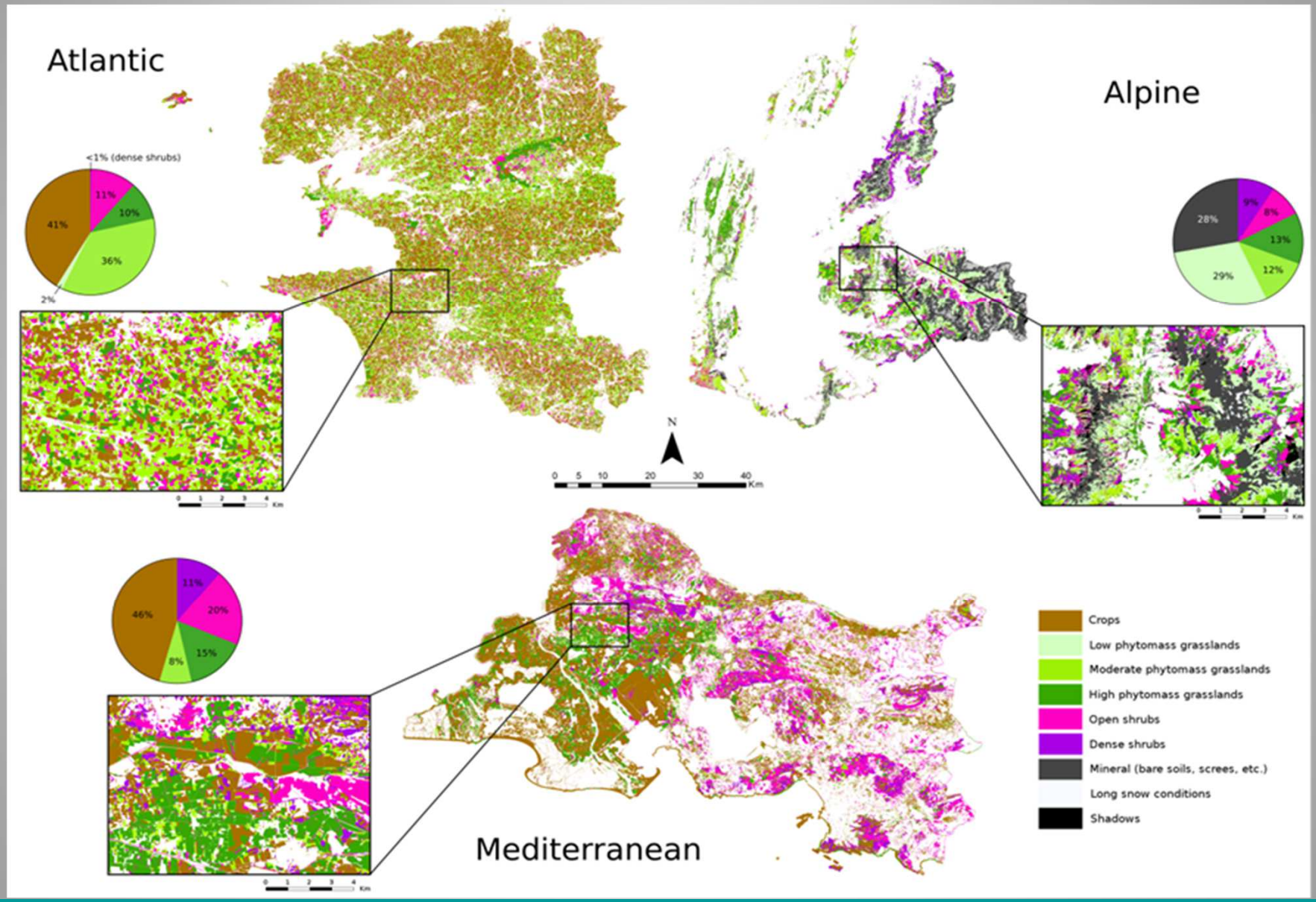
Tropical ecosystems:

Mapping taxonomic diversity & species



A generic remote sensing approach to derive operational Essential Biodiversity Variables (EBVs) for conservation planning



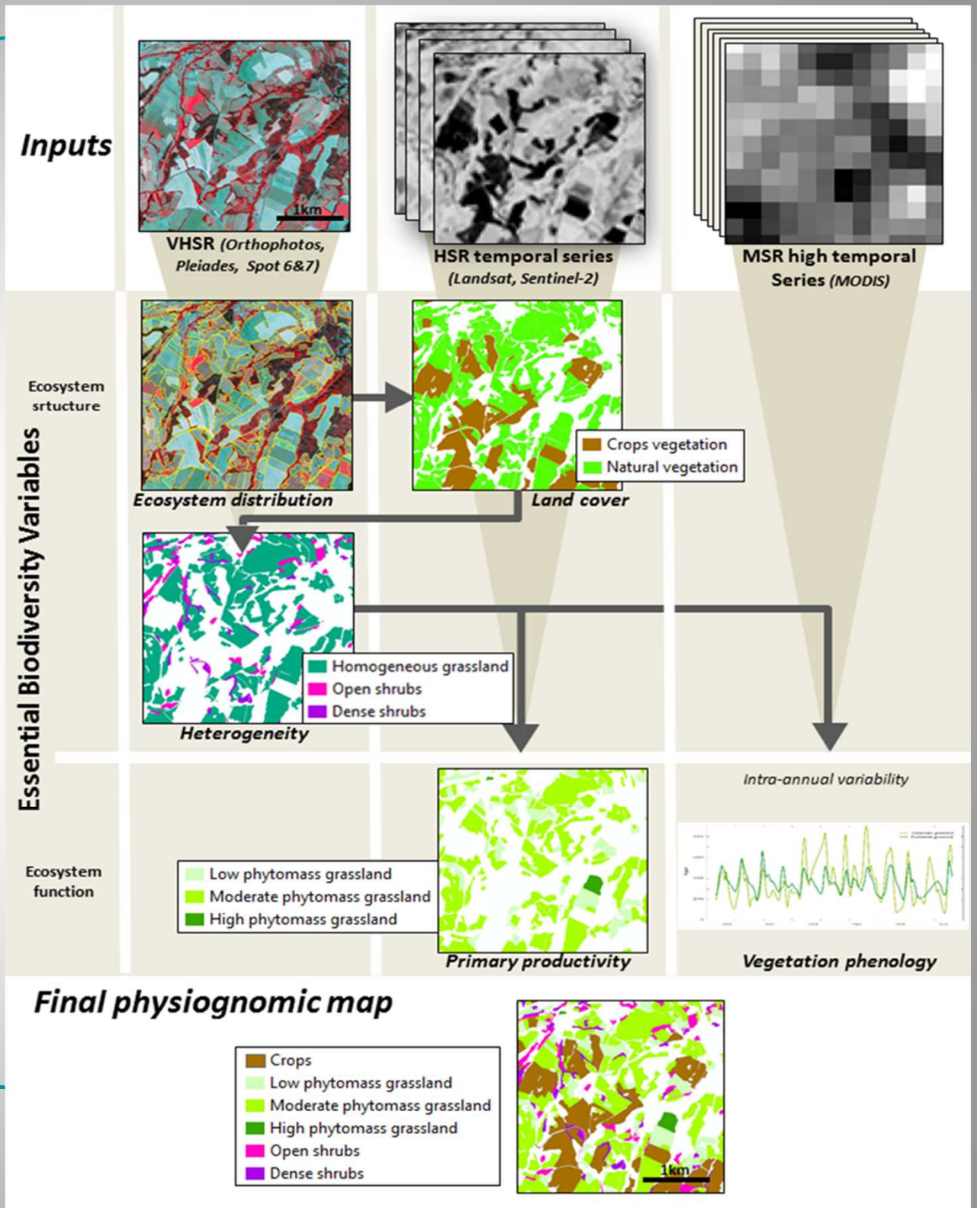
Final classification products for the Atlantic, Alpine and Mediterranean regions, France

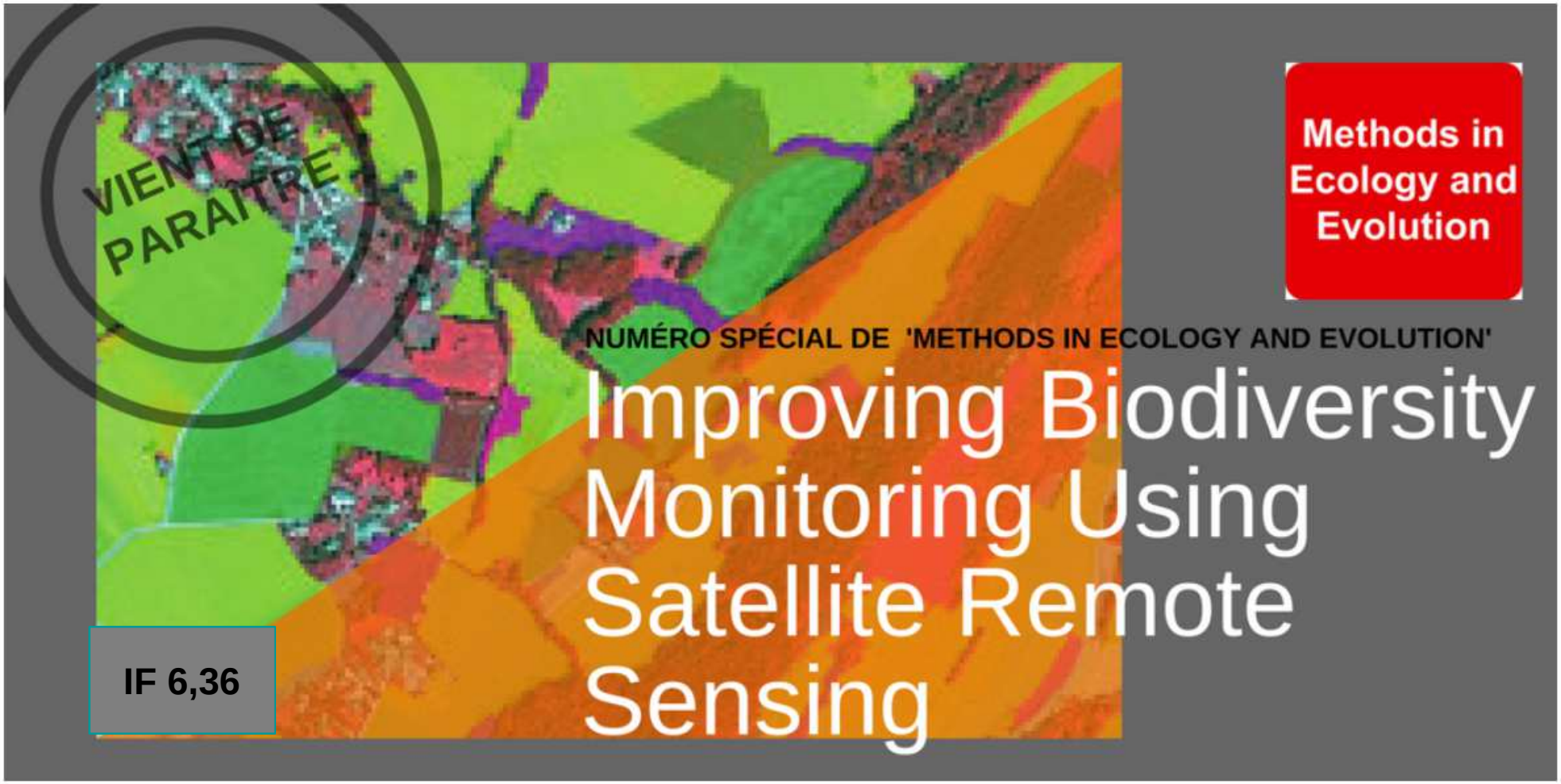
Alleaume et al MEE 2018

Global methodology to define essential biodiversity variables (based on Skidmore et al., 2015)

- We demonstrated that it is possible to derive key parameters required to develop a set of the EBV's from remote sensing data (RS).
- The joint use of remote sensing data sources with various spatial, temporal and spectral resolutions is essential for accessing the different descriptors of natural habitats.

Alleaume et al MEE 2018





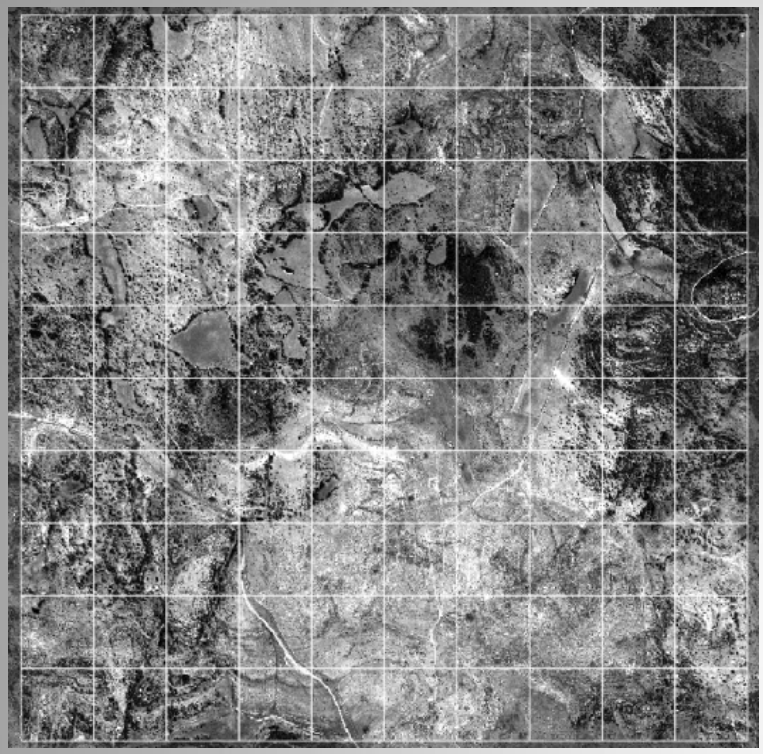
'Improving Biodiversity Monitoring using Satellite Remote Sensing', le dernier numéro spécial de la revue *Methods in Ecology and Evolution* sous la direction de Sandra Luque, Nathalie Pettorelli, Petteri Vihervaara et Martin Wegmann, documente ce que la télédétection apporte à l'écologie.

Rocchini, D, Luque, S, Pettorelli, N et al. (18 more authors) (2018) Measuring beta-diversity by remote sensing: a challenge for biodiversity monitoring. MEE ISSN 2041-210X DOI:10.1111/2041-210X.12941

THRS : Texture analysis : **FOTO** (Fourier-based Textural Ordination) **method**

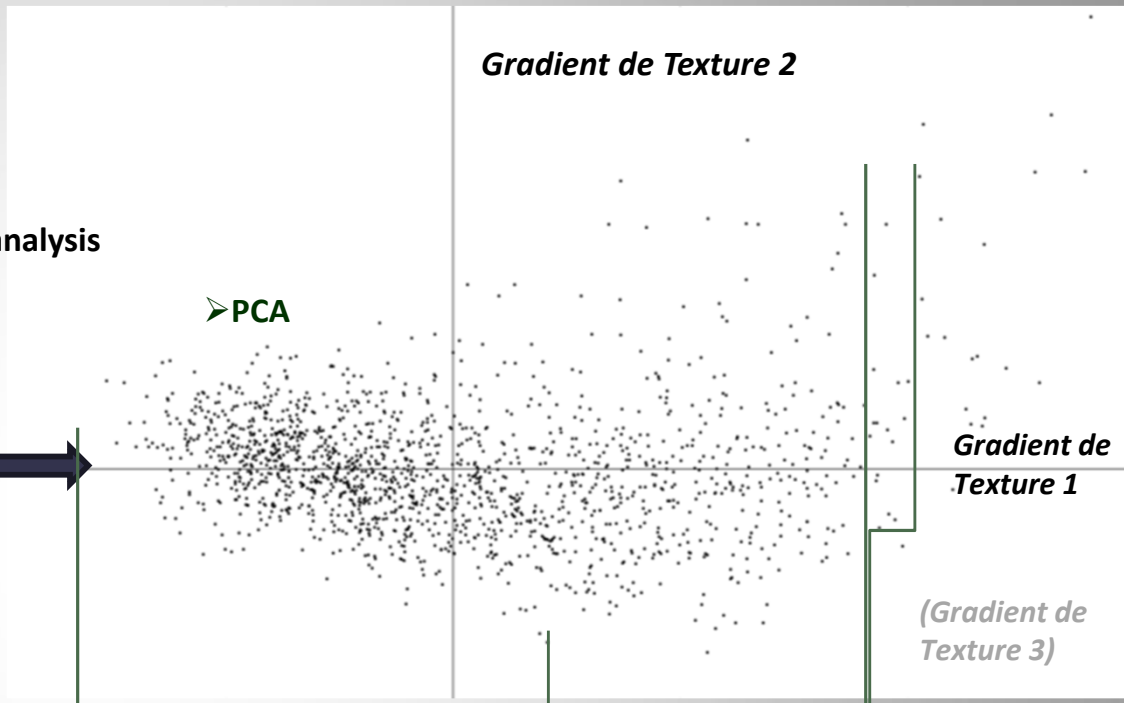
Marc Lang, PhD Thesis

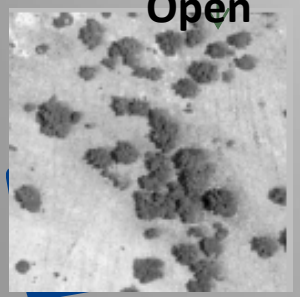
➢SPOT 6&7 windows

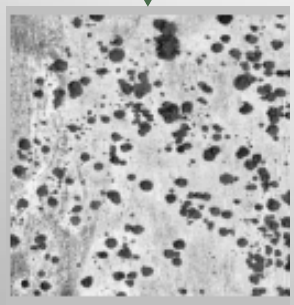


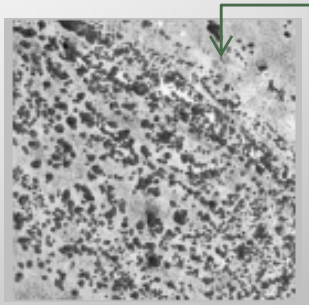
➢Fourier analysis

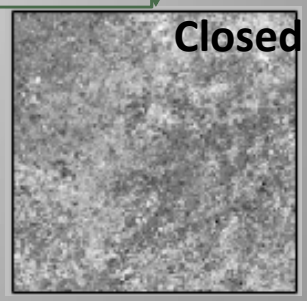
➢PCA





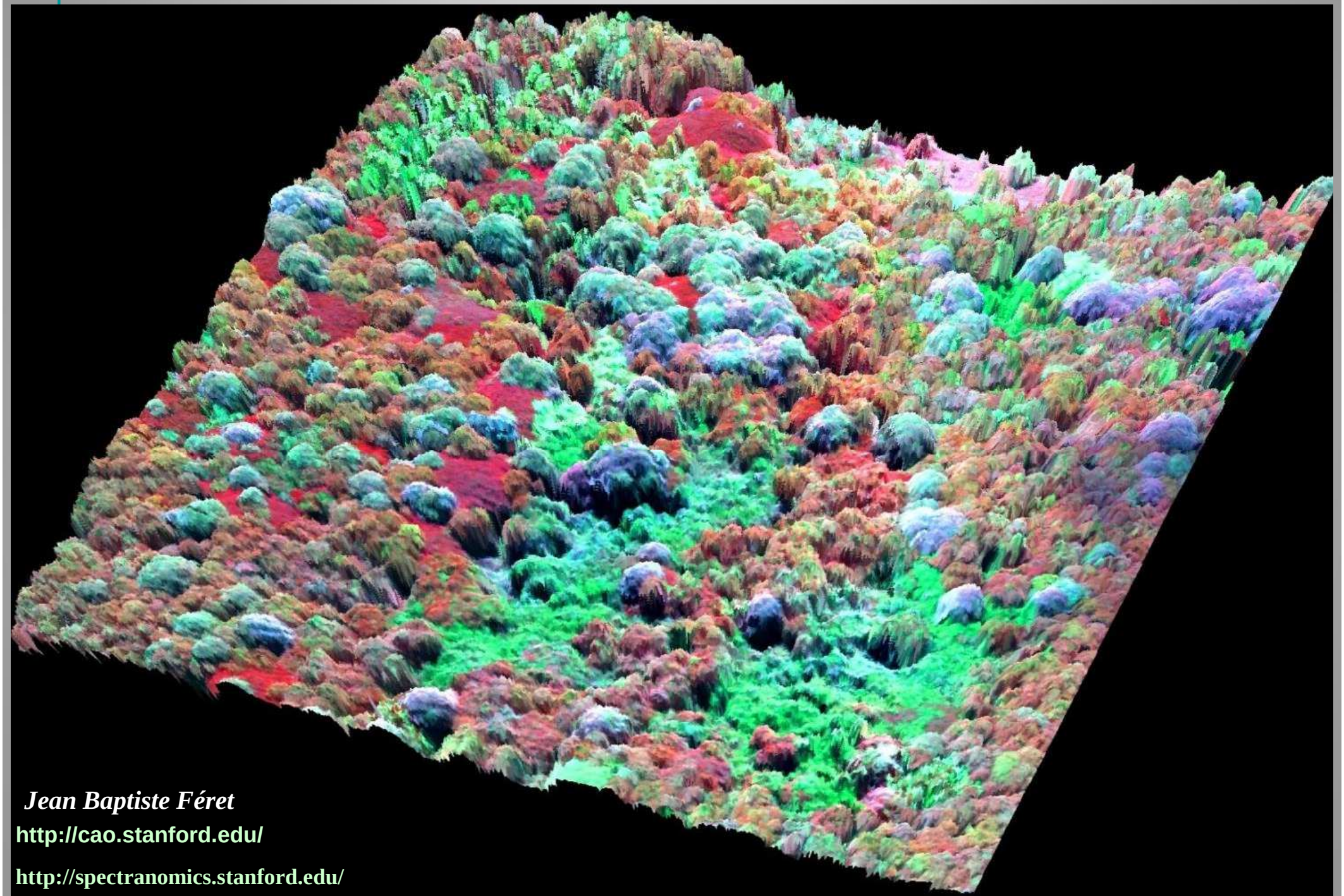






Lang, M.; Alleaume, S.; Luque, S.; Baghdadi, N.; Féret, J.-B. (2019) Complementarity between Textural and Radiometric Indices From Airborne and Spaceborne Multi VHSR Data: Disentangling the Complexity of Heterogeneous Landscape Matrix Remote Sensing 11(6) DOI 10.3390/rs11060693

Diversity of sensors: combining imaging spectroscopy with LiDAR…



Jean Baptiste Féret

http://cao.stanford.edu/

http://spectranomics.stanford.edu/

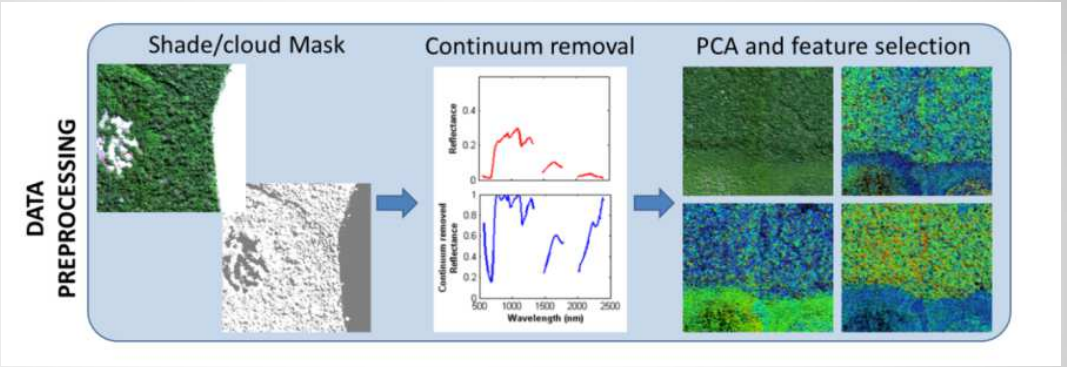
Application with high resolution imaging spectroscopy

Ecological Applications, 24(6), 2014, pp. 1289–1296

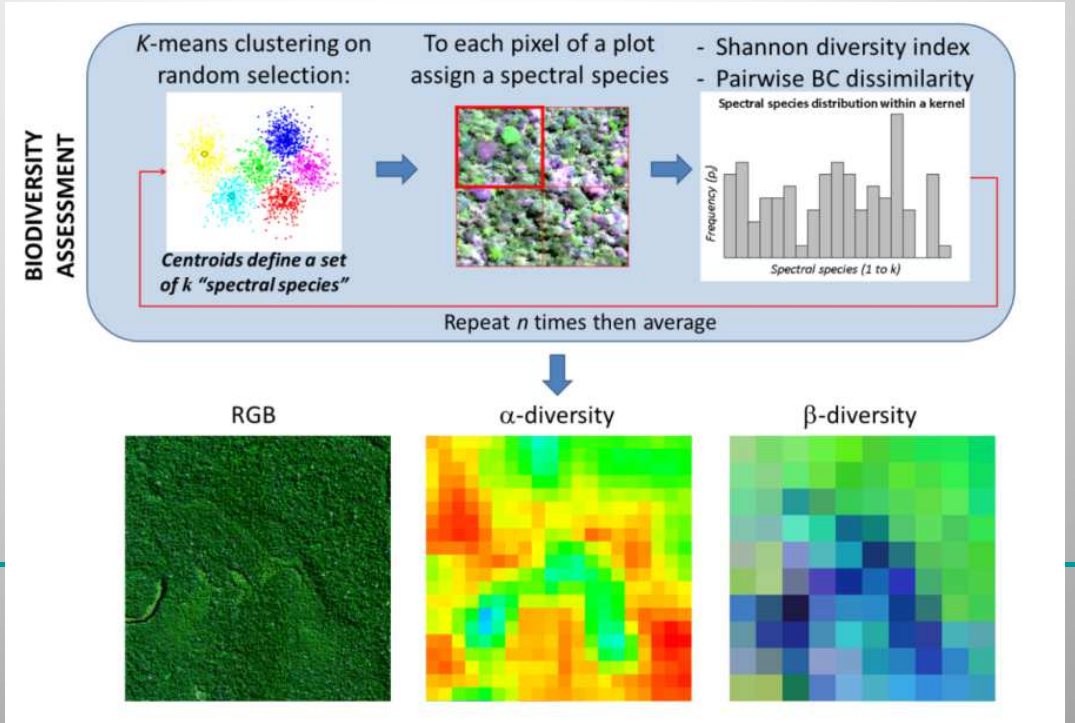
Mapping tropical forest canopy diversity using high-fidelity imaging spectroscopy

JEAN-BAPTISTE FÉRET[1] AND GREGORY P. ASNER

PRE-PROCESSING



ESTIMATION OF BIODIVERSITY INDICATORS



Operationalization of Biodiversity mapping with satellite data

- **Spectral species distribution method was successfully applied on high spatial resolution imaging spectroscopy**
- **Limitations of the method inherent to our ability to properly correct RS data from environmental effects**
  - **Topograpy**
  - **Directional effects**
  - **Atmospheric effects**
- **Other methods may be more appropriate if extensive ground data available**
- **Proper links between vegetation biophysical properties and spectral information would strongly improve robustness of the method**

Operationalization of Biodiversity mapping with satellite data

Received: 22 September 2017 | Accepted: 11 November 2017

DOI: 10.1111/2041-210X.12941

Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

IMPROVING BIODIVERSITY MONITORING USING SATELLITE REMOTE SENSING

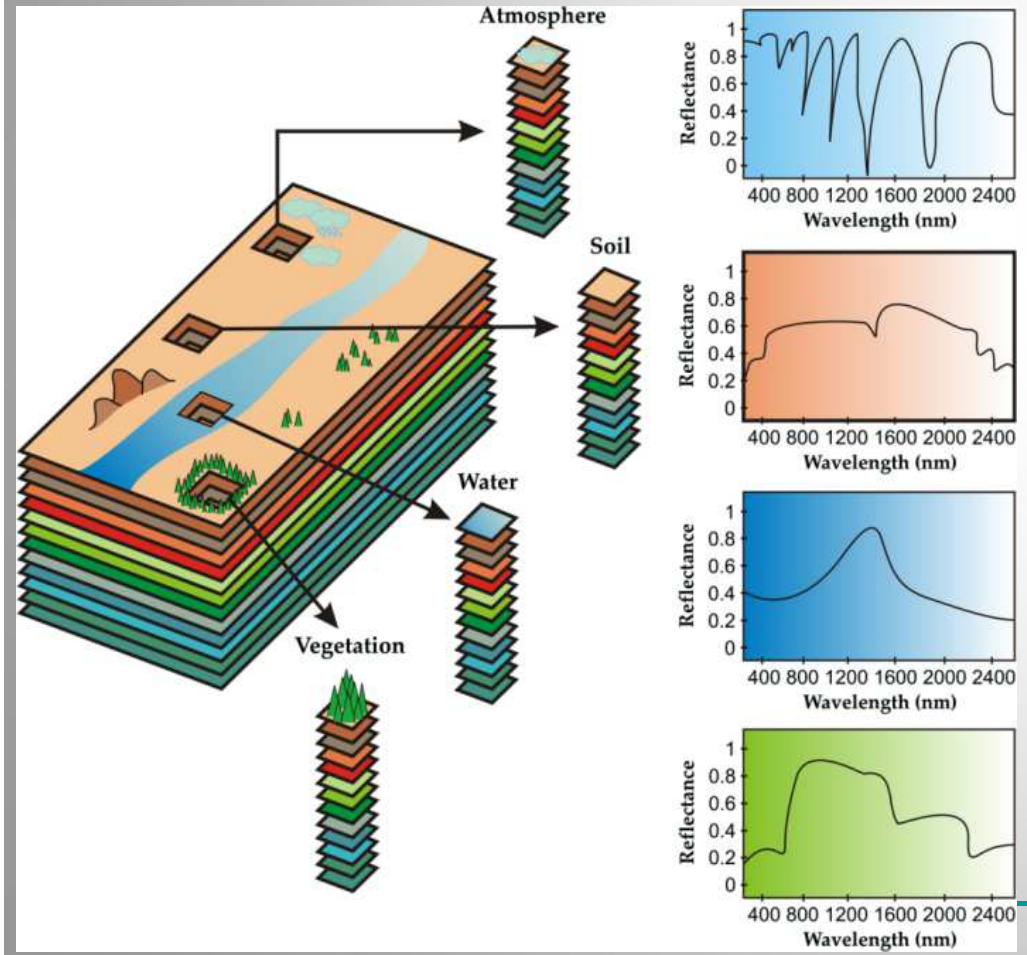
Measuring β-diversity by remote sensing: A challenge for biodiversity monitoring

Duccio Rocchini[1,2,3] | Sandra Luque[4] | Nathalie Pettorelli[5] | Lucy Bastin[6] | Daniel Doktor[7] | Nicolò Faedi[3,8] | Hannes Feilhauer[9] | Jean-Baptiste Féret[4] | Giles M. Foody[10] | Yoni Gavish[11] | Sergio Godinho[12] | William E. Kunin[13] | Angela Lausch[7] | Pedro J. Leitão[14,15] | Matteo Marcantonio[16] | Markus Neteler[17] | Carlo Ricotta[18] | Sebastian Schmidtlein[19] | Petteri Vihervaara[20] | Martin Wegmann[21] | Harini Nagendra[22]

Biodiversity mapping

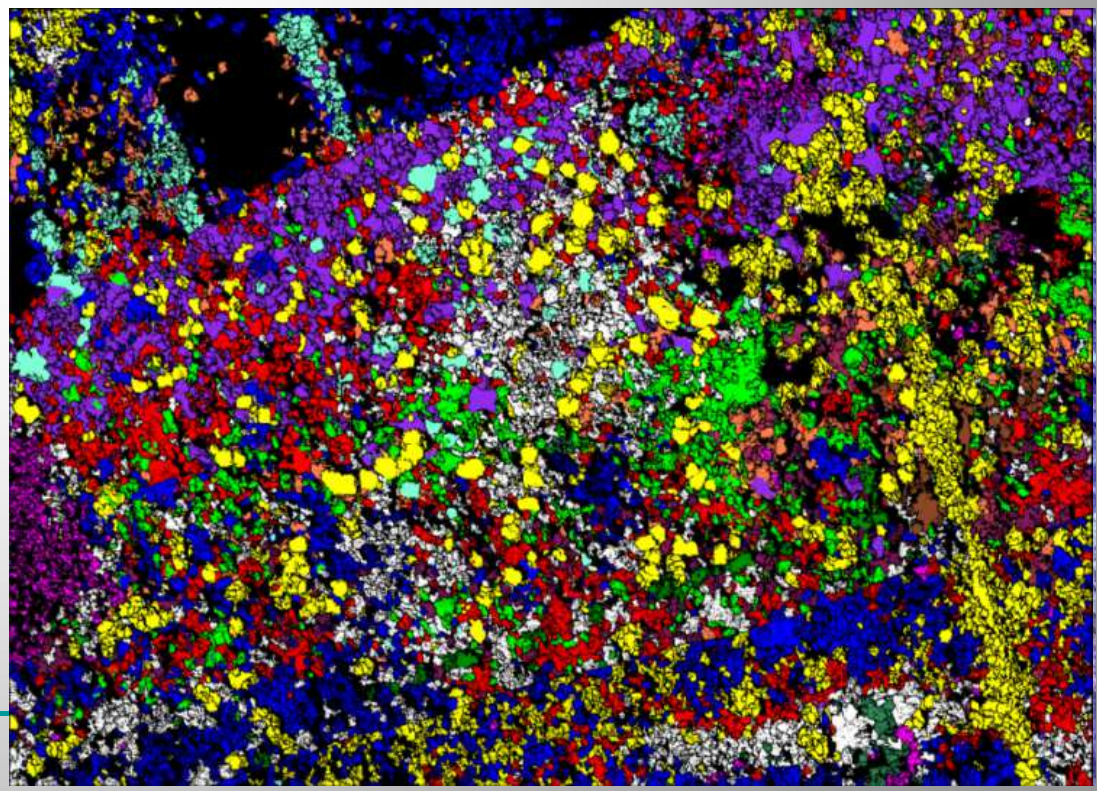
Instrumental specifications & methodological improvements to prepare satellite missions & assess Essential Biodiversity Variables (EBV)

(Pereira et al., 2013)



Molero et al., 2012. *Anomaly detection based on a parallel kernel RX algorithm for multicore platforms*, J. Appl. Remote Sens.

Tree species mapping in hterogeneous forests



Féret & Asner, 2013. TGRS

Biodiversity monitoring in tropical forests

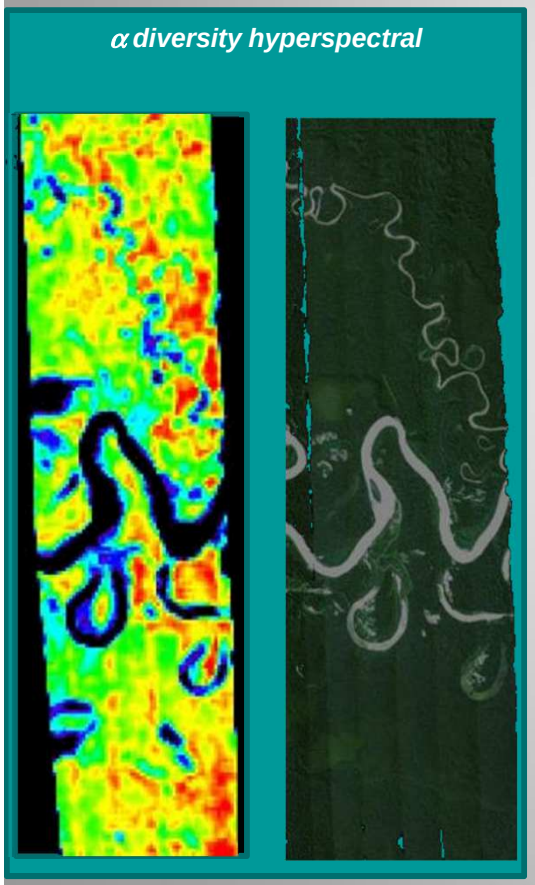
Mapping tropical forest canopy diversity using high-fidelity imaging spectroscopy

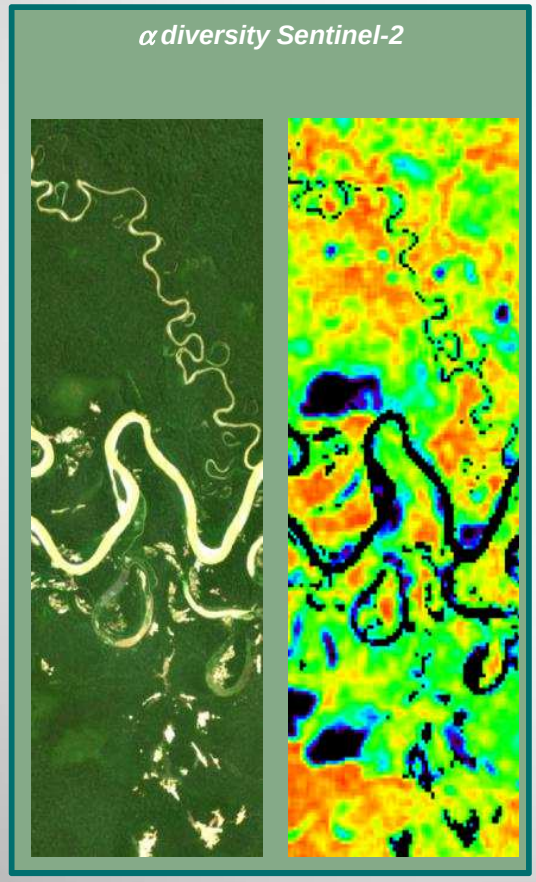
Jean-Baptiste Féret[1] and Gregory P. Asner

Féret & Asner, Ecological Applications 2014

Definitions :

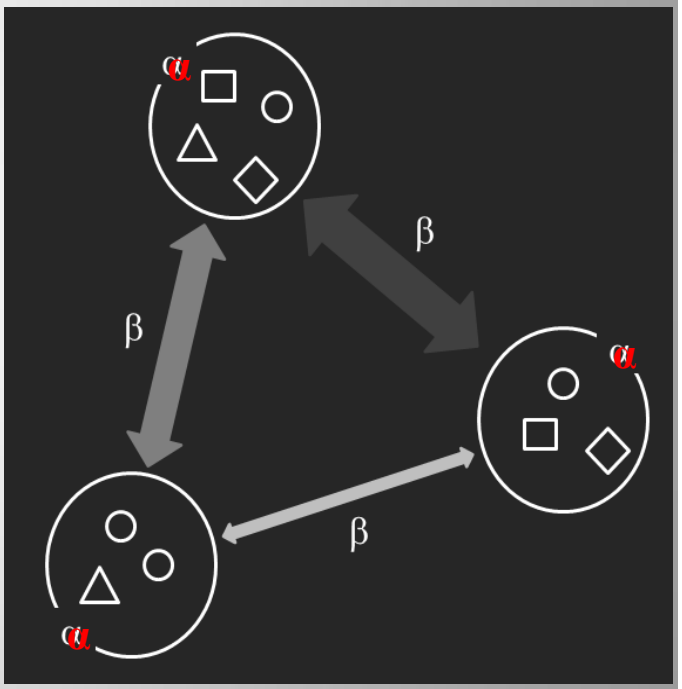
- **α-diversity : mean species diversity at local scale**





usual metrics for α-diversity :

- **Richness**
- ***Shannon index***
- **Simpson index**
- **Fischer index**
- **…**



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Biodiversity monitoring in tropical forests

Mapping tropical forest canopy diversity using high-fidelity imaging spectroscopy

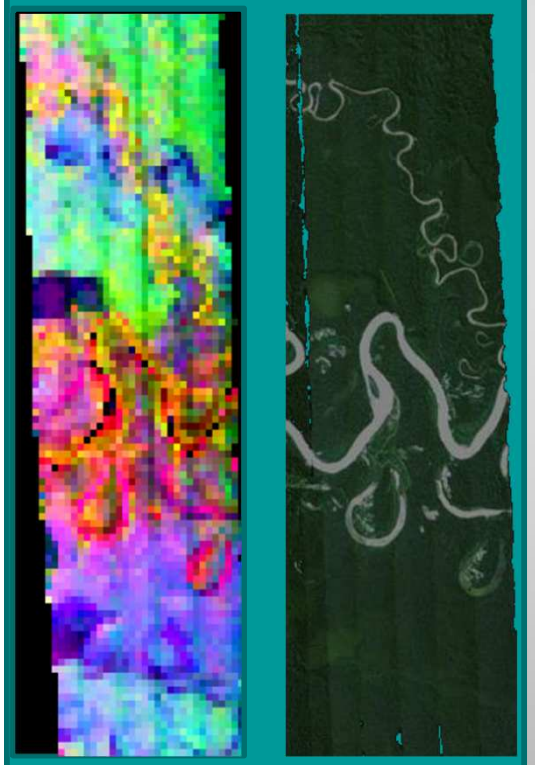
Jean-Baptiste Féret[1] and Gregory P. Asner

Féret & Asner, Ecological Applications 2014

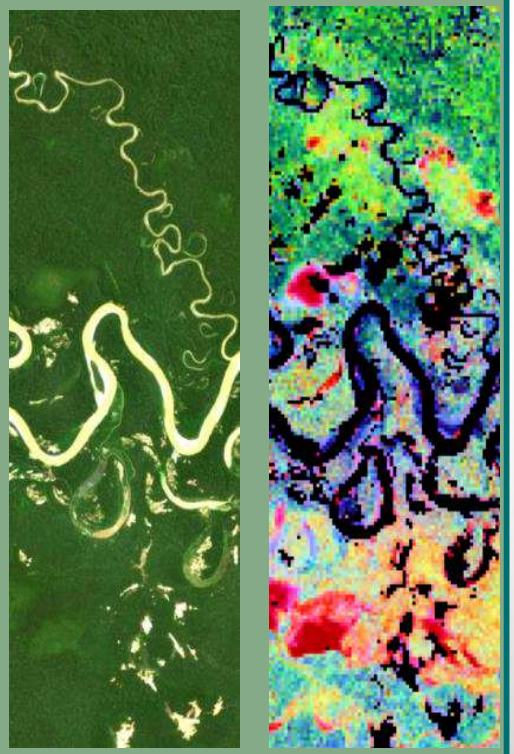
Definitions :

- **α-diversity : mean species diversity at local scale**
- **β-diversity : compositional turnover between sites**

β diversity hyperspectral



β diversity Sentinel-2

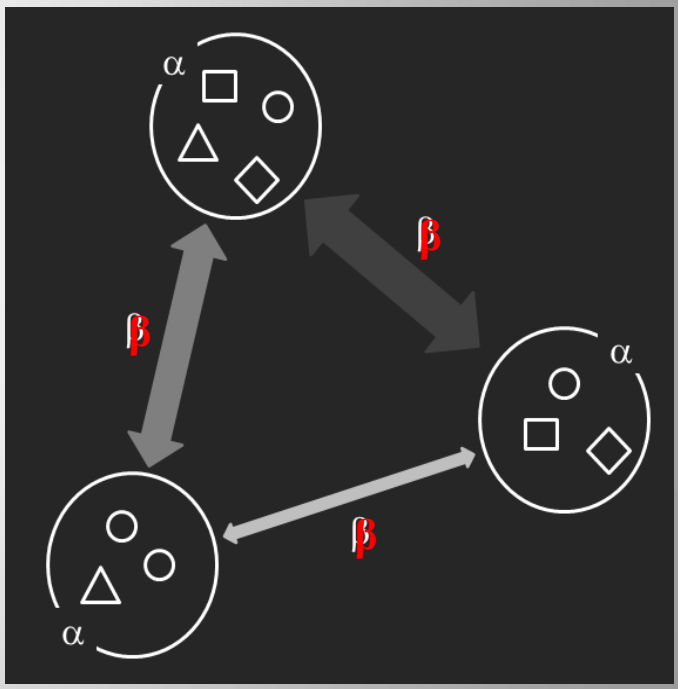


usual metrics for α-diversity :

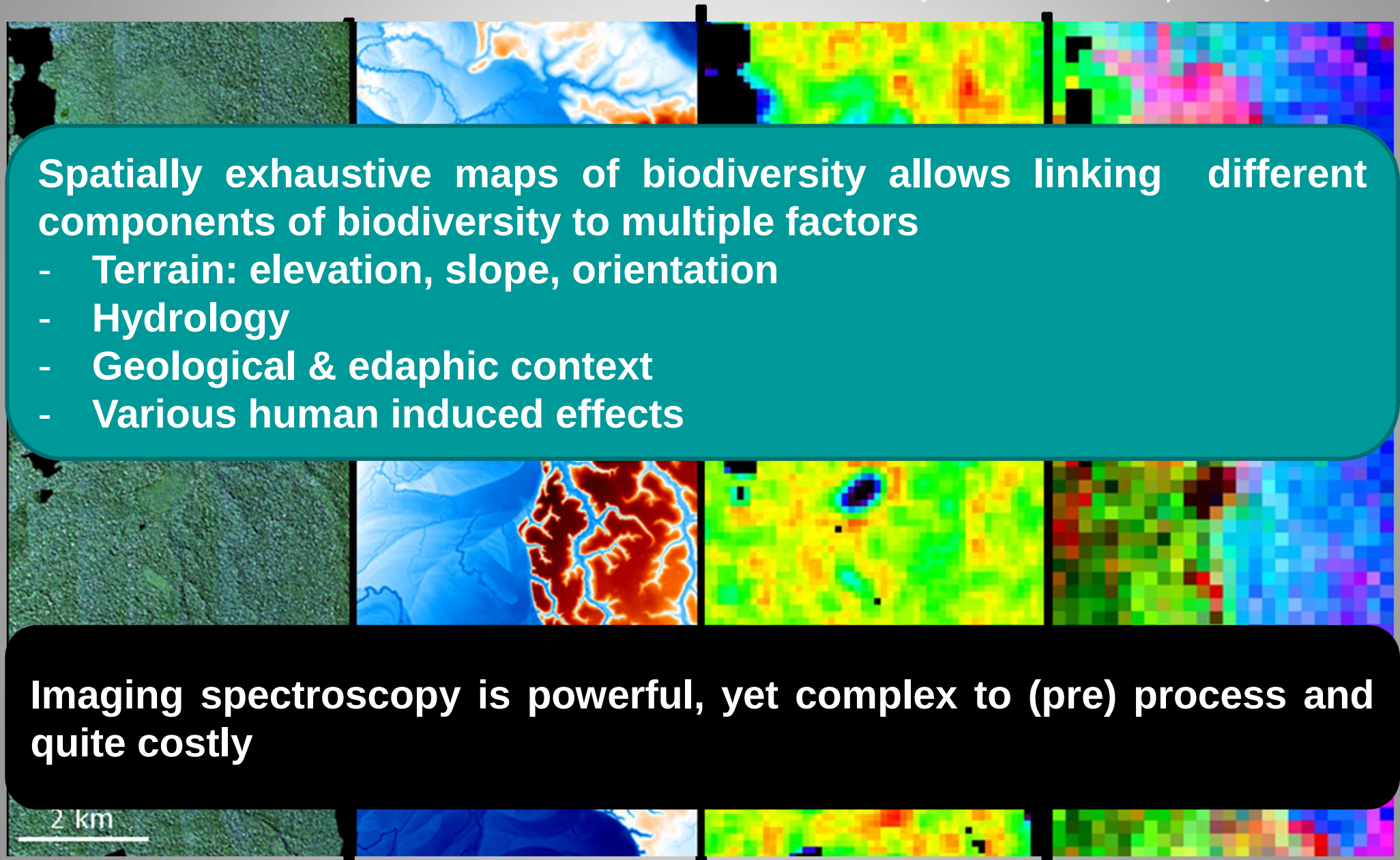
- **Richness**
- ***Shannon index***
- **Simpson index**
- **Fischer index**
- **…**

usual metrics for β-diversity :

- ***Bray Curtis dissimilarity***
- **Jaccard distance**
- **…**



Influence of environmental factors on species composition



Spatially exhaustive maps of biodiversity allows linking different components of biodiversity to multiple factors

- **Terrain: elevation, slope, orientation**
- **Hydrology**
- **Geological & edaphic context**
- **Various human induced effects**

Imaging spectroscopy is powerful, yet complex to (pre) process and quite costly

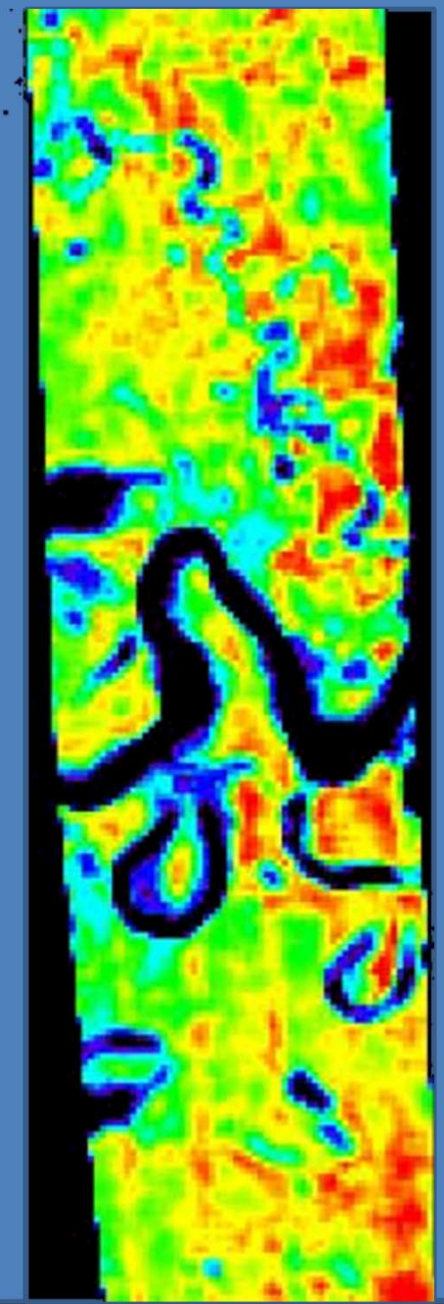
Details about the site: Asner & Martin, 2011 (New Phytol.)

Operationalization of Biodiversity mapping with satellite data

- **Other types of data may be considered for application of methods for diversity mapping based on spectral heterogeneity, but further studies required**
  - **Very high spatial resolution multispectral sensors**
    - **Worldview**
    - **LandSat-8**
    - **Sentinel-2** To be explored if interested in regional scale
  - **Other types of data**
    - **LiDAR: structural heterogeneity**
    - **Radar**

Example: diversity mapping with Sentinel-2

α-diversity



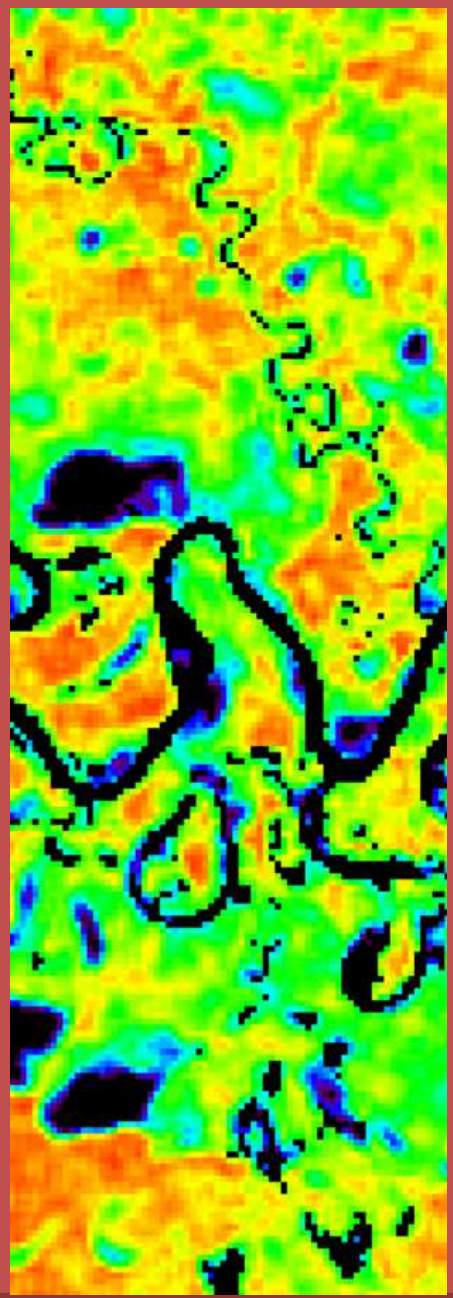
CAO AToMS

SR : 2 m

Sentinel-2

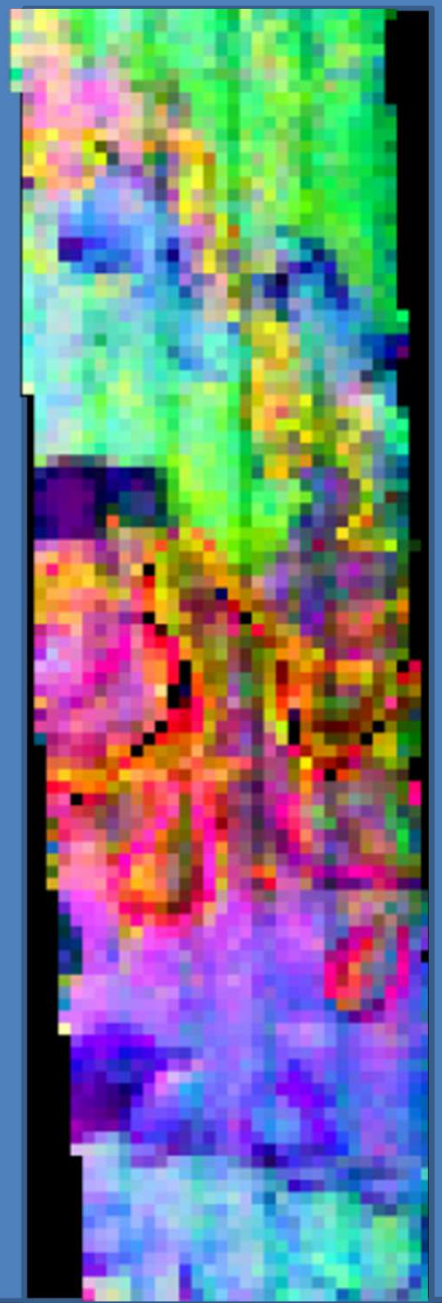
SR : 10 m

β-diversity



Example: diversity mapping with Sentinel-2

β-diversity



CAO AToMS

SR : 2 m

Sentinel-2

SR : 10 m

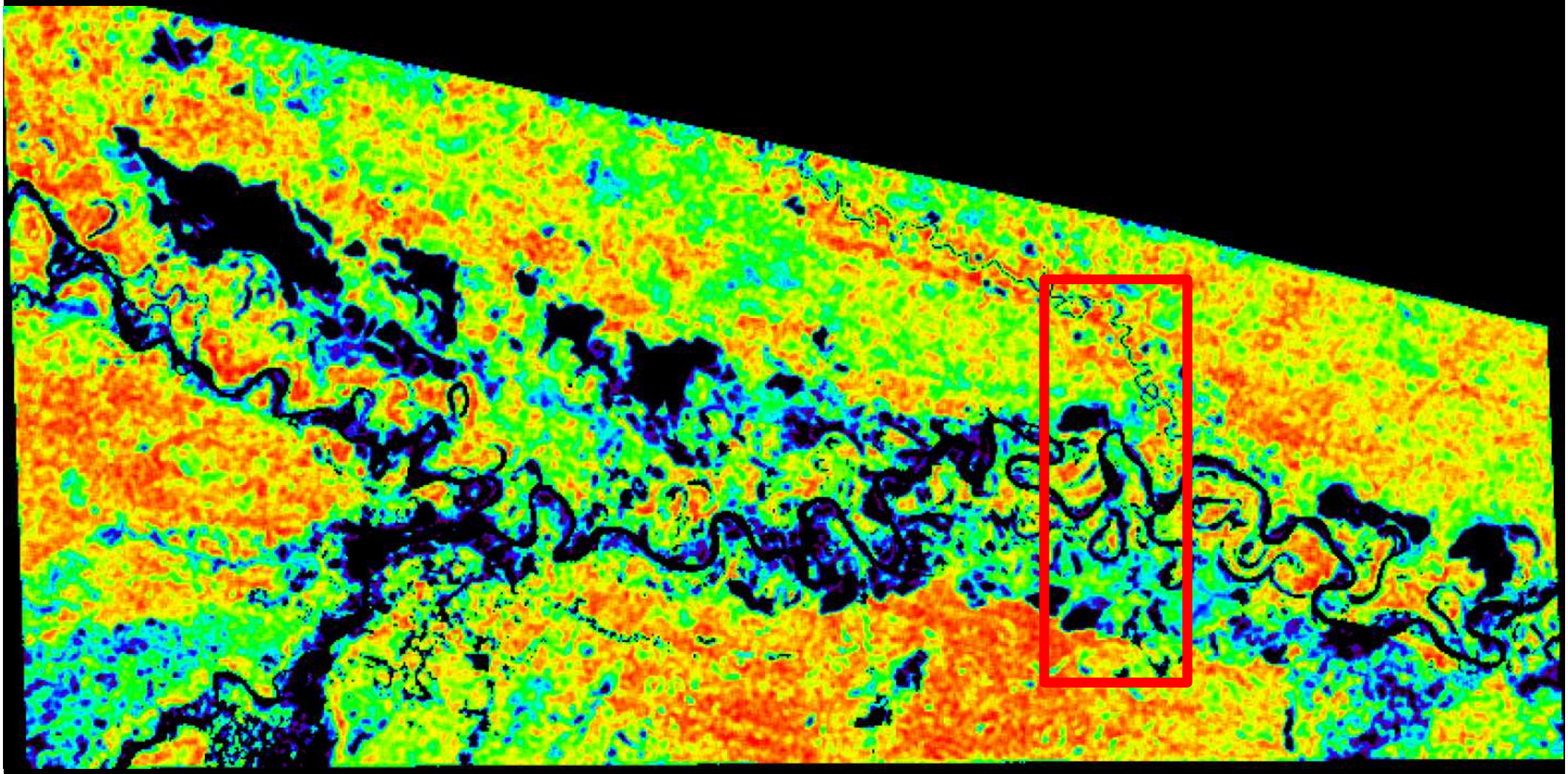
β-diversity

Example: diversity mapping with Sentinel-2

- **Landscape scale (80 km x 40 km)**

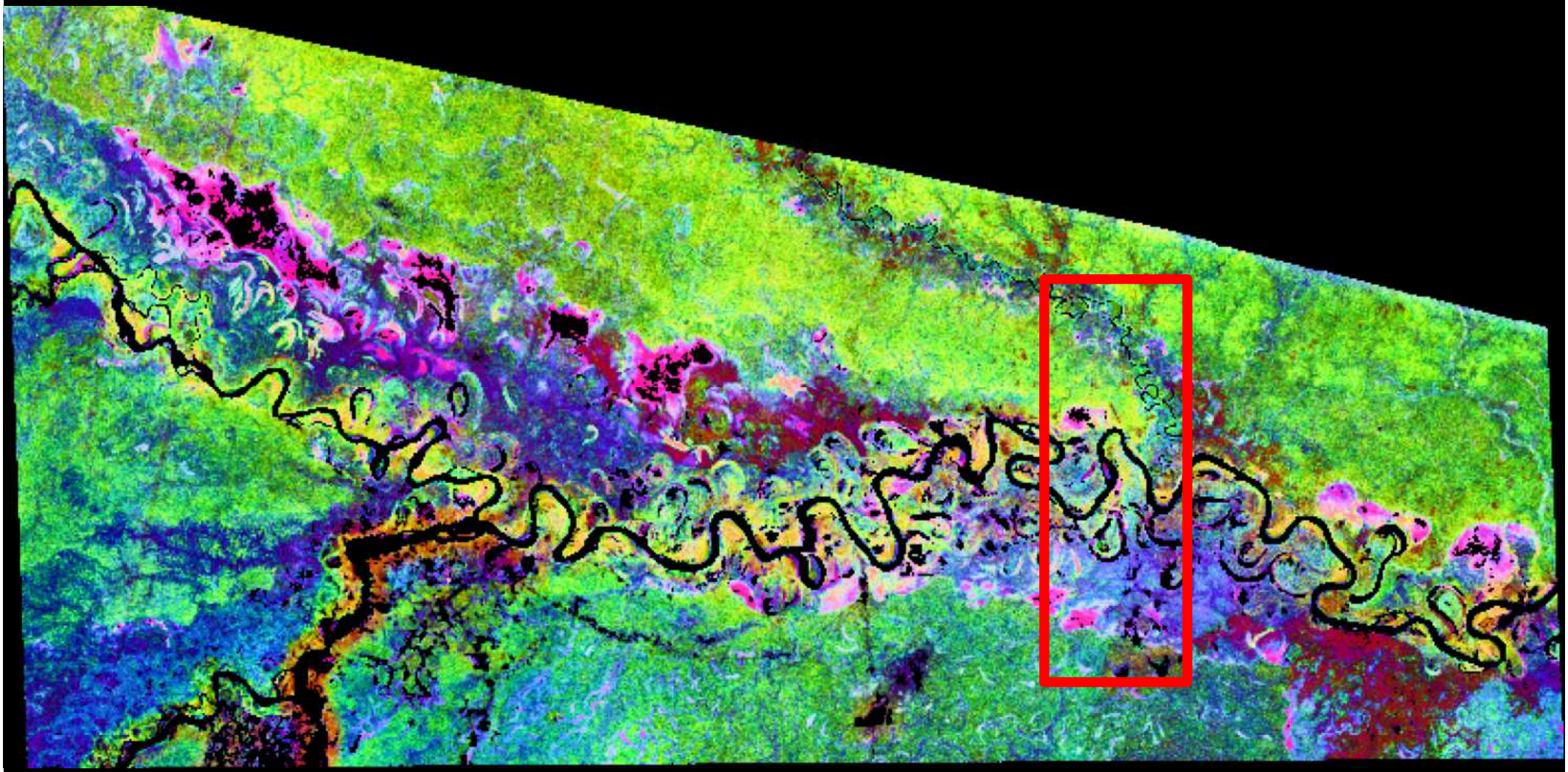
Example: diversity mapping with Sentinel-2

- Landscape scale (80 km x 40 km)



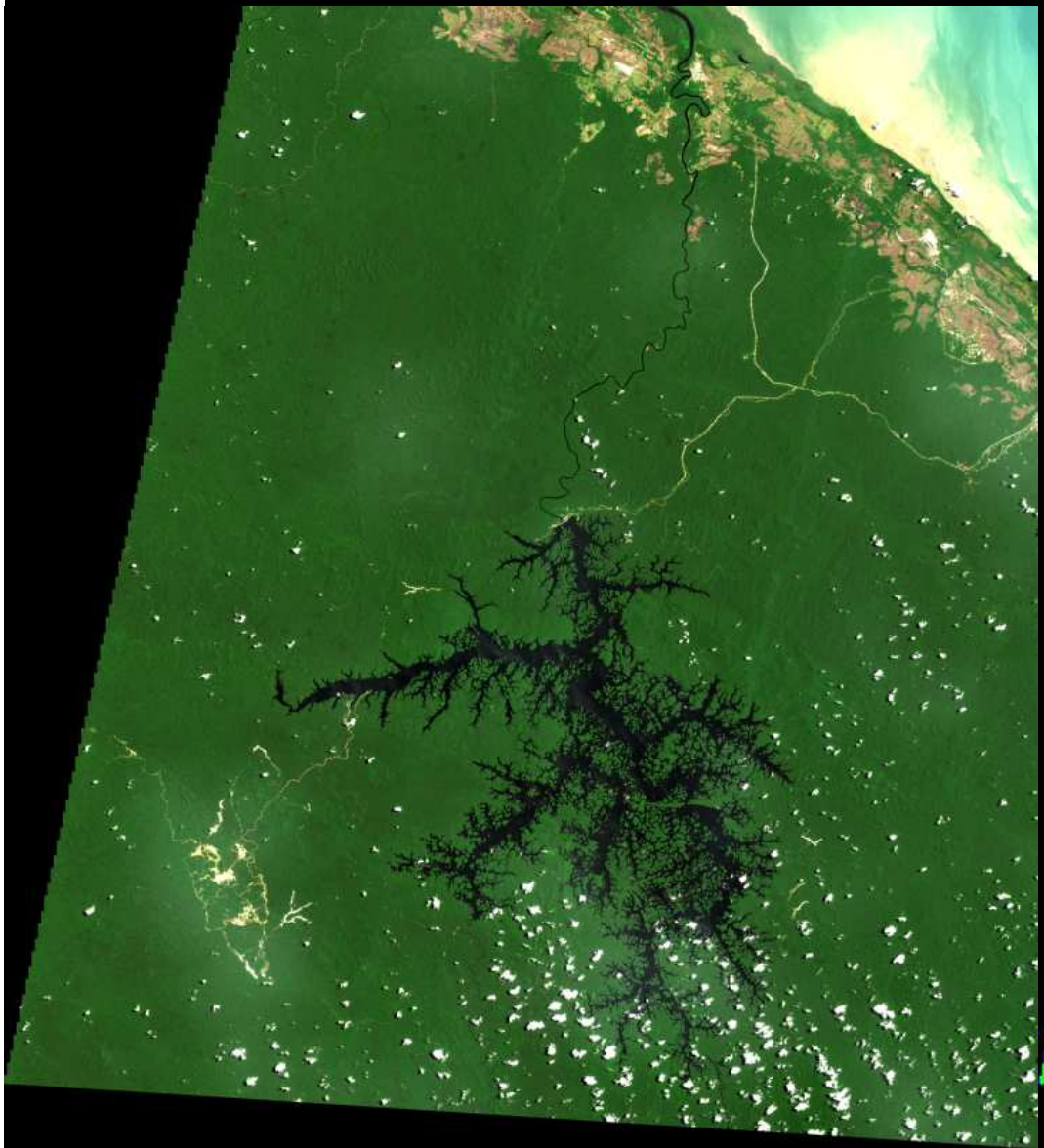
Example: diversity mapping with Sentinel-2

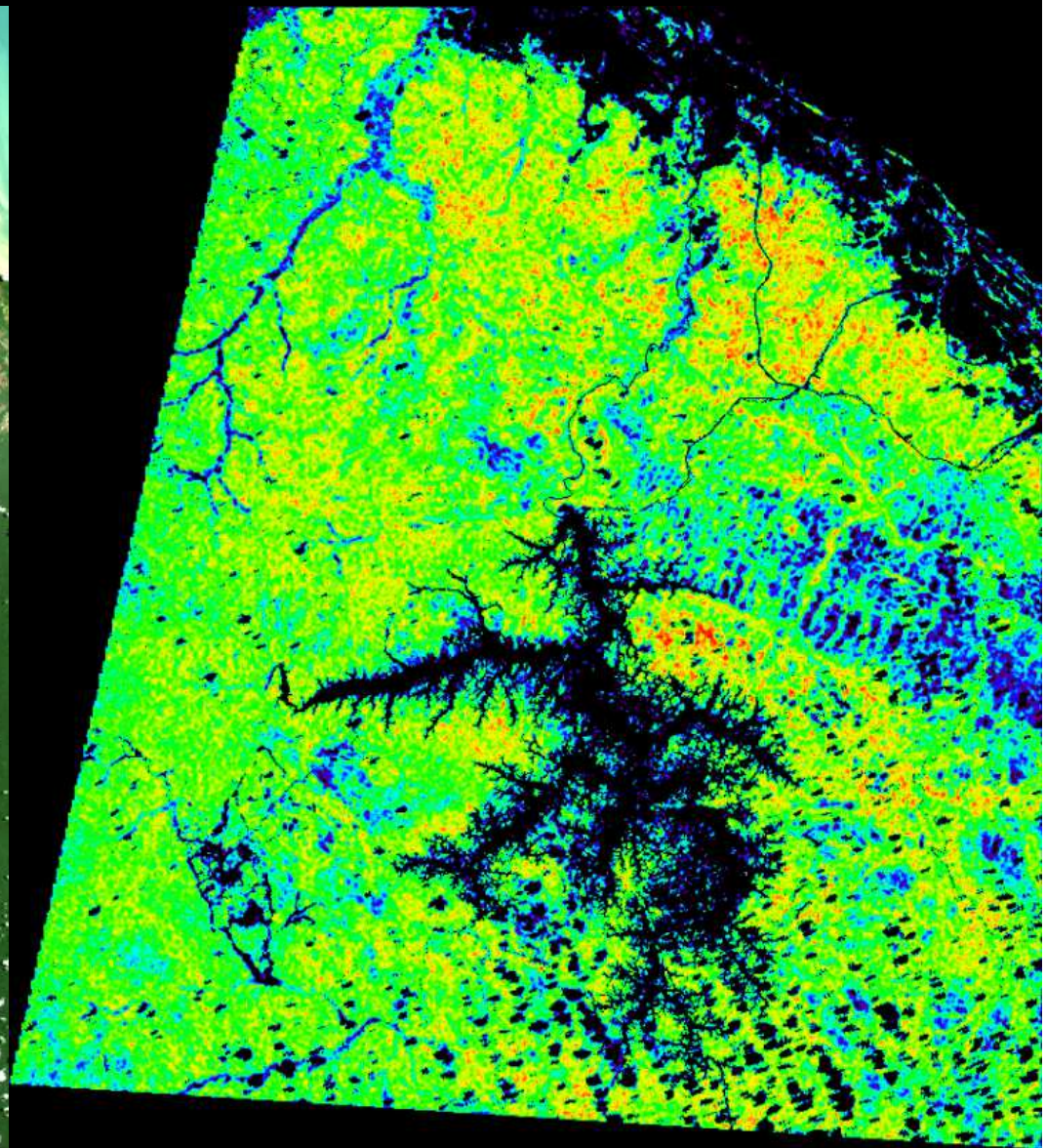
- **Landscape scale (80 km x 40 km)**



Example: diversity mapping with Sentinel-2

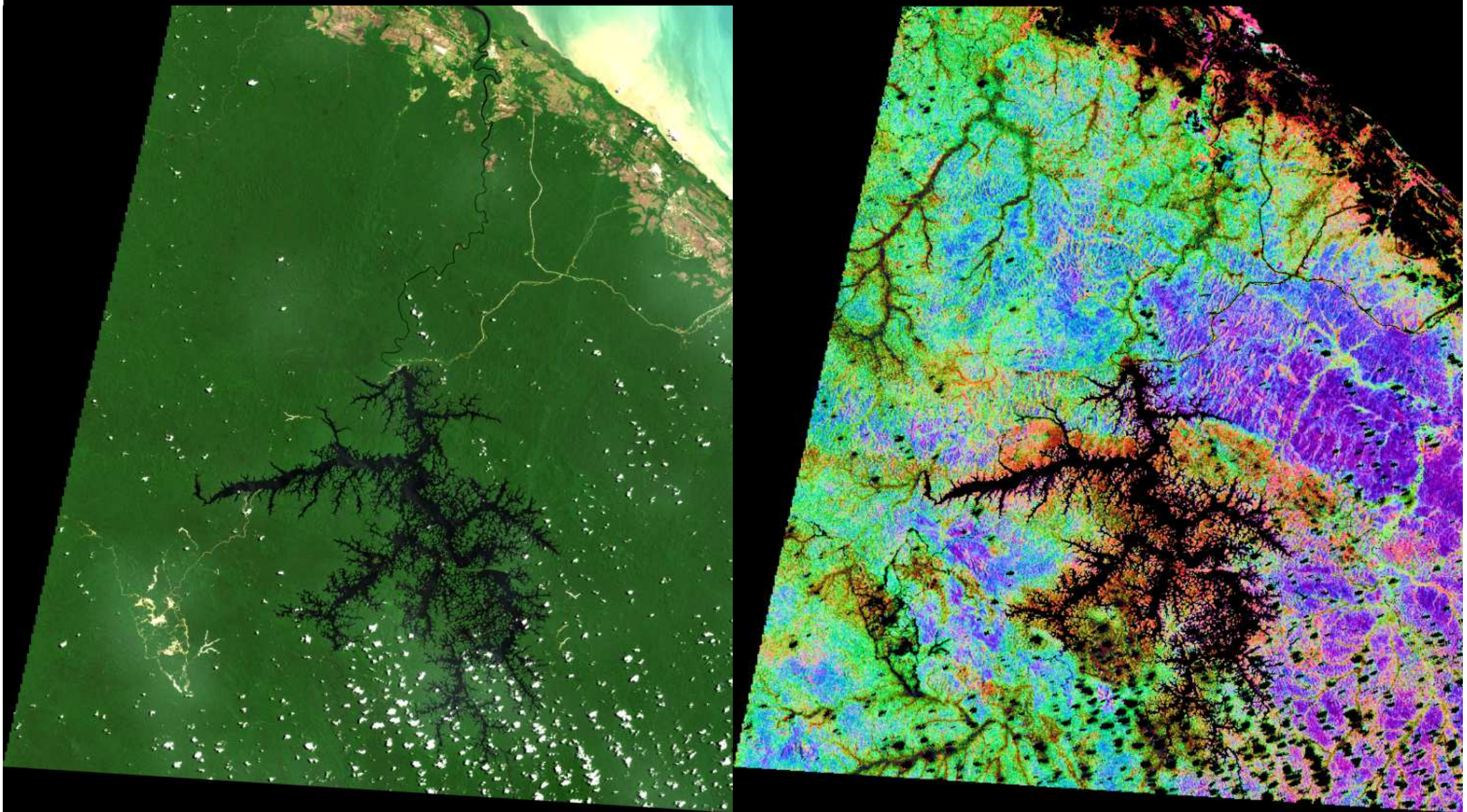
- **Landscape scale (100 km x 100 km)**





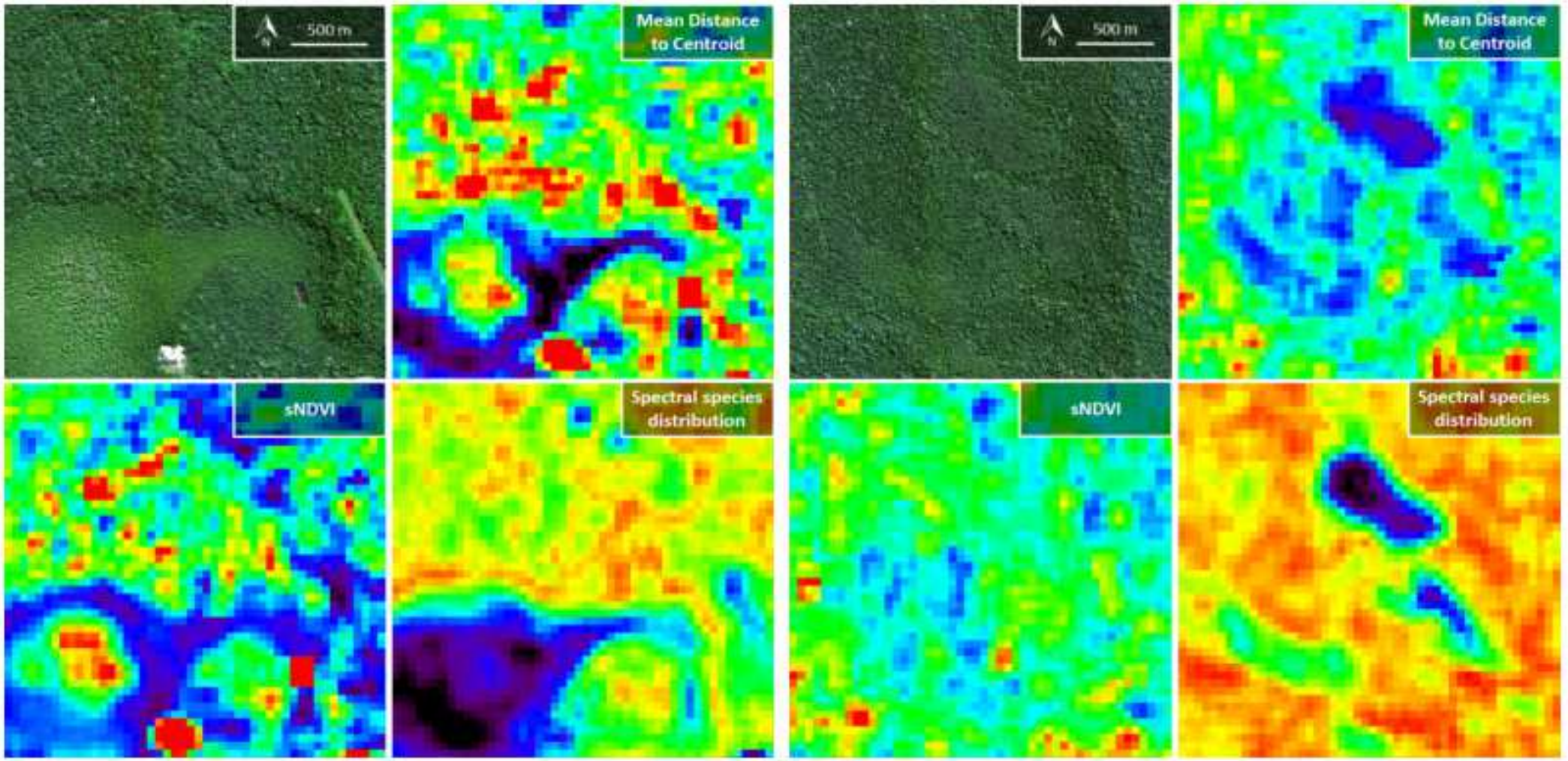
Example: diversity mapping with Sentinel-2

- **Landscape scale (100 km x 100 km)**



Spectral variation hypothesis

Comparison among spectral metrics

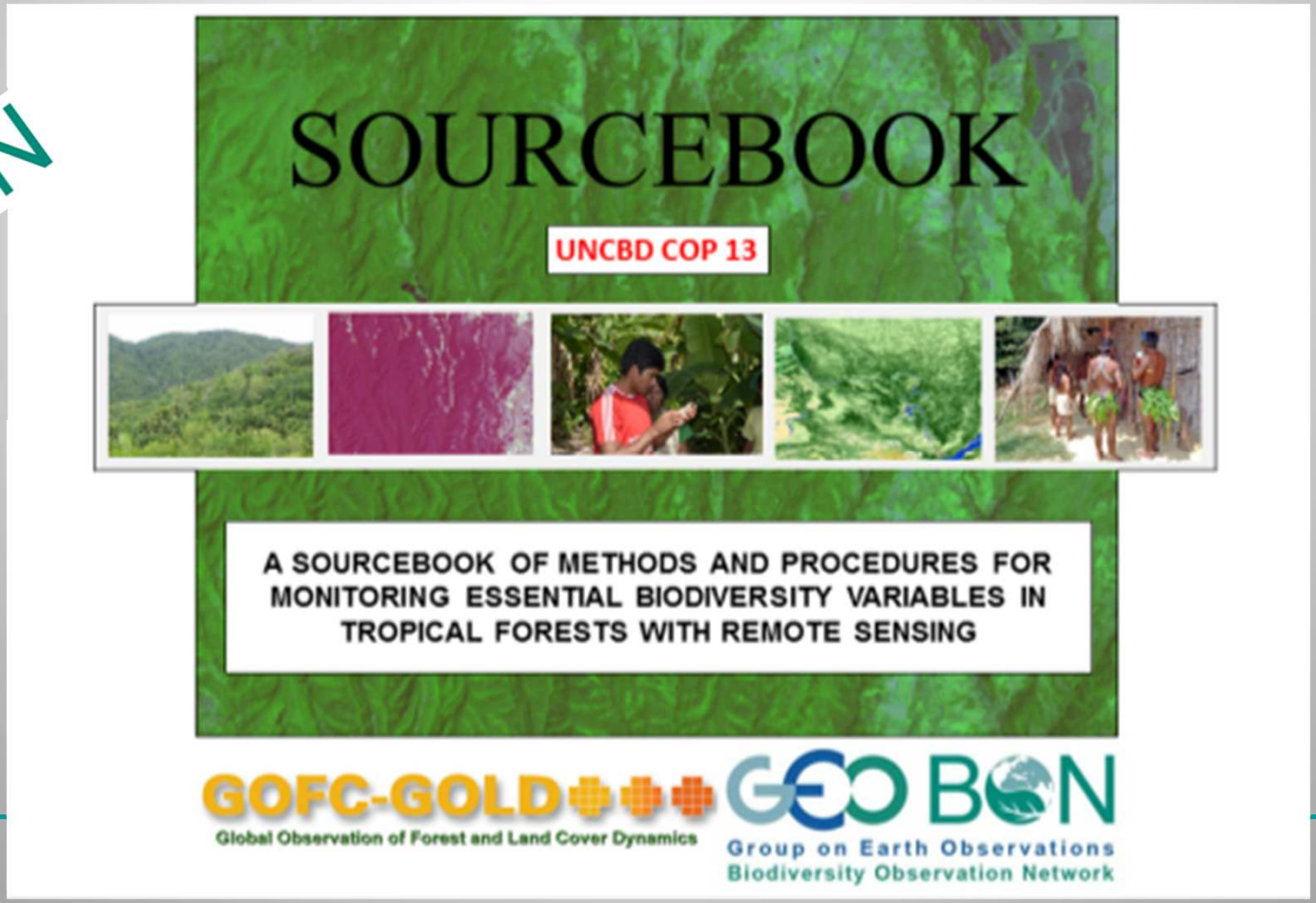


Structuring framework for present & future research on biodiversity: defining the Essential Biodiversity Variables (EBV)

International networks and collaborations

A Sourcebook of Methods and Procedures for Monitoring Essential Biodiversity Variables in Tropical Forests with Remote Sensing

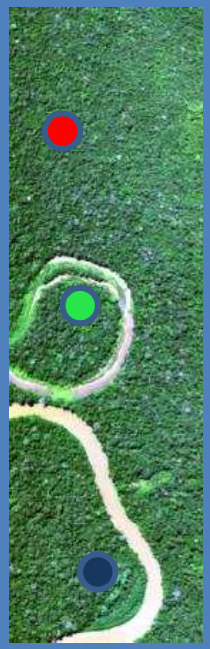
http://geobon.org/products/books/



Gill, M., Jongman, R., Luque, S., Mora, B., Paganini, M., Szantoi, Z. (Eds.)

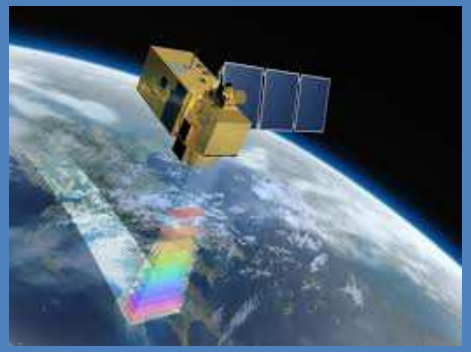
What's next? Combine data processing with physical modeling

Data driven approaches



In situ observations

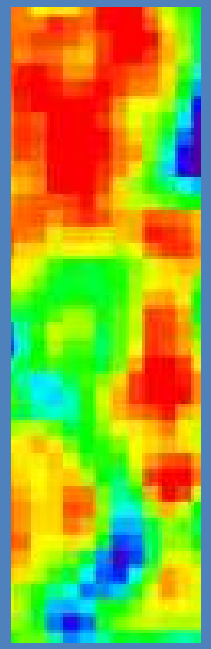
+



Remote sensing data

=

Statistics,
machine learning…



Generalization of
local info

☺ Computationally efficient
☺ Availability of methods and packages
☺ Good performances

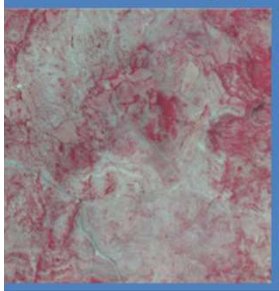
☹ Data demanding (bias in sampling, …)
☹ Possibly low generalization of models
☹ Interpretation of complex processes

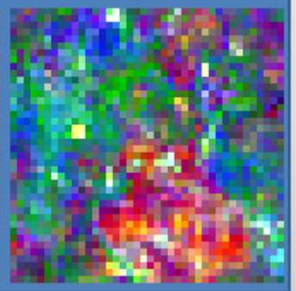
Over-arching research goals RS-EBV's

- Innovation & technology for improved biodiversity monitoring
- Higher landscape heterogeneity (possibly derived from RS) is related to higher amount of species occupying different niches
- Operational method to improve biodiversity monitoring despite assumptions
- Operational methods & tools to be linked to policies for improvement of public awareness and cost-effective management of biodiversity

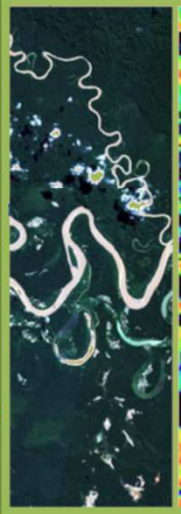


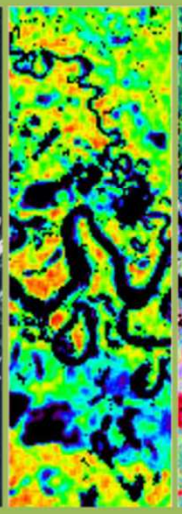

Mediterranean ecosystems:
Characterizing openness of vegetation





Tropical ecosystems:
Mapping taxonomic diversity & species communities

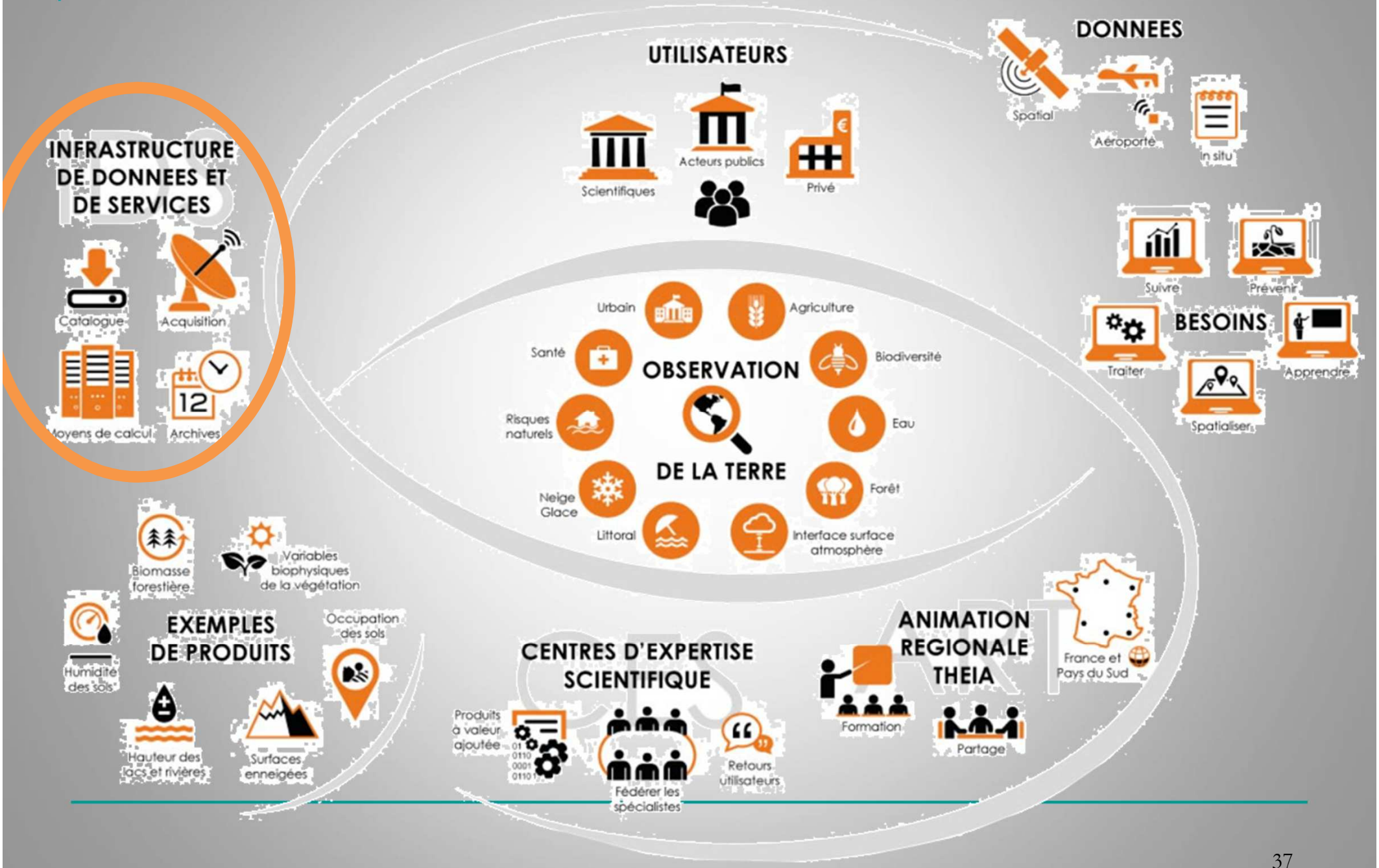




Alpine ecosystems:
Mapping habitats based on floristic inventory

MERCI !

Structure de Theia



Objectif général du CES Paysage

Anne-Elisabeth Laques (IRD) & Sandra Luque (Irstea)

Les territoires subissent de fortes perturbations d'origines humaines et naturelles.
Les paysages en portent les traces que l'on peut observer, suivre et mesurer par analyse des dynamiques spatiales de leurs compositions et de leurs configurations.

Le CES a pour objectif

d'apprendre à les décrypter pour mesurer l'ampleur des phénomènes en cours sur les dynamiques de biodiversité, la dégradation des forêts ou des terres, les interactions entre la santé et l'environnement, mais également pour suivre et estimer l'impact de certaines politiques publiques territoriales et environnementales.

CES Paysage

Les journées de lancement du CES Paysage se sont déroulées les 28 et 29 mars 2019 à Montpellier

Le séminaire a permis la concertation entre les laboratoires et institutions :

En France :

- **UMR ESPACE-DEV**
- **UMR TETIS**
- **UMR LTEG**
- **UMR AMAP**

Au Sud :

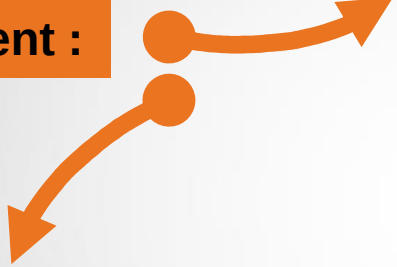
- **Dépt. Observation de la Terre (INPE, Brésil)**
- **Centre de recherche en agroforesterie d'Amazonie orientale (EMBRAPA, Brésil)**
- **Dépt. d'Ecologie et Centre du Développement Durable (université de Brasilia)**
- **Laboratoire d'Ecologie du paysage et modélisation des écosystèmes / ECOLMOD, Dept. de Biología (université de Bogota, Colombie)**

→ total de 77 participants.

CES Paysage

=> Domaines thématiques et produits à développer

Les orientations identifiées durant le séminaire de lancement :



Trois domaines thématiques :

1) « Biodiversité »,
2) « Santé & environnement »
3) « Agriculture ».

Trois catégories de produits à développer :

- Cartes d'aide à l'analyse de la structure et à la composition des paysages (texture de la végétation, MNT, humidité des sols, OS, etc.);
- Cartes de zonage du paysage par arbre hiérarchique, combinaison d'attribut par cellule, par segmentation d'image prétraitées, par analyse combinée « à dire d'expert » et traitement d'image). → Analyse du contenant du paysage
- Modèles de distribution spatiale, modèles spatialement explicites et indicateurs paysagers à différent échelles. → Analyse du contenu du paysage

Défis du CES Paysage

Associer des collaborateurs des pays du Sud et des pays européens avec l'ambition de concevoir ensemble des méthodes innovantes pour élaborer des produits qui répondent aux questions que soulèvent la gestion environnementale aux différentes échelles des territoires au Nord comme au Sud.

Exemple de six paysages représentatifs de l'empreinte anthropique en forêt amazonienne. Comment la prendre en compte ?

0 1 Km

Google Earth

Liste des CES Theia

- **22 CES à ce jour**
  - **Rayonnement**
    - **CES Réflectance de surface - O. Hagolle et al.**
    - **CES Albedo - Jean-Louis Roujean et al.**
    - **CES Température de surface et émissivité – L.Roupioz / A.Michel**
  - **Sols**
    - **CES Occupation du sol – J. Inglada et al.**
    - **CES Artificialisation-urbanisation des sols - A. Puissant et al.**
    - **CES Cartographie numérique des sols - Ph. Lagacherie et al.**
    - **CES Détection de changements à haute fréquence - P. Gançarski et al.**
  - **Végétation**
    - **CES Variables végétales décamétriques - F. Baret et al.**
    - **CES Biomasse forestière - Thuy Le Toan et al.**
    - **CES Biodiversite– S. Alleaume et al.**
    - **CES Incendie – M. Jappiot et al.**
    - **CES Paysage – A.E. Laques / Sandra Luque et al.**