



Approches couplées par télédétection
pour produire des indicateurs de suivi
de l'impact des changements globaux
sur les écosystèmes

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ART THEIA – La télédétection au service de la prospective environnementale et territoriale

18/10/2022



Menaces sur les écosystèmes face aux changements globaux

ARTICLE

Global effects of land use on local terrestrial biodiversity

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Human activities, especially conversion and degradation of habitats, are causing global biodiversity declines. How local ecological assemblages are responding is less clear—a concern given their importance for many ecosystem functions and services. We analysed a terrestrial assemblage database of unprecedented geographic and taxonomic coverage to quantify local biodiversity responses to land use and related changes. Here we show that in the worst affected habitats, these pressures reduce within-sample species richness by an average of 76.5%, total abundance by 39.5% and rarefaction-based richness by 40.3%. We estimate that, globally, these pressures have already slightly reduced average within-sample richness (by 13.6%), total abundance (10.7%) and rarefaction-based richness (8.1%), with changes showing marked spatial variation. Rapid further losses are predicted under a business-as-usual land-use scenario: within-sample richness is projected to fall by a further 3.4% globally by 2100, with losses concentrated in biodiverse but economically poor countries. Strong mitigation could deliver much more positive biodiversity changes (up to a 1.9% average increase) that are less strongly related to countries' socioeconomic status.

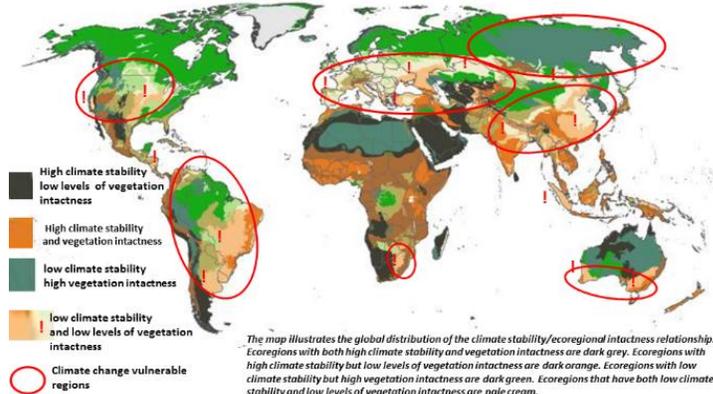
Biodiversity faces growing pressures from human actions, including habitat conversion and degradation, habitat fragmentation, climate change, harvesting and pollution¹. As a result, global assessments show that species extinction risk is increasing on average while population sizes are declining². Such assessments have usually focused on data-rich vertebrates, or might not reflect broader biodiversity³. Furthermore, most have concentrated on the global status of species, whereas the long-term security of many ecosystem functions and services—especially in changing environments—is likely to depend upon local biodiversity⁴. Average trends in local diversity remain unclear: analyses of temporal changes in assemblages have suggested no systematic change in species richness⁵, but the available times series data might underrepresent transitions between land use types⁶ and population trends suggest vertebrate populations have declined sharply in recent decades⁷. Spatial comparisons provide an alternative source of evidence on how human pressures affect biodiversity, assuming that differences in pressure intensity have caused observed biodiversity differences between otherwise matched sites⁸. The resolution of published spatial comparisons makes it possible to go beyond particular taxa or regions^{9,10} to develop global, taxonomically representative models. Furthermore, the willingness of

many researchers to share their raw data makes it possible to consider multiple aspects of biodiversity, rather than the single, simple metrics of most existing models¹¹, which cannot capture all key aspects of diversity¹². We present the most geographically and taxonomically representative models to date of how several aspects of the composition and diversity of terrestrial assemblages respond to multiple human pressures. The explanatory variables in our models most directly measure land use and infrastructure, but might correlate¹³ with two other important pressures, harvesting and invasive species, for which comparable high-resolution spatial data are unavailable globally. We exclude climate change effects because they are not captured well by spatial comparisons. We use our models to infer past and future changes in assemblages since the year 1950, project future changes over this century under different socioeconomic scenarios of land use, and reframe projected national biodiversity trends.

Our models of local within-sample species richness (hereafter 'richness'), rarefaction-based species richness (hereafter 'rarefied richness'), total abundance, compositional turnover and average organism size are

Ecosystem climate change vulnerability and conservation

Mapping vulnerability and conservation adaptation strategies under climate change James E. M. Watson, Nature Climate Change September 2013



The map illustrates the global distribution of the climate stability/ecoregion intactness relationship. Ecoregions with both high climate stability and low levels of vegetation intactness are dark grey. Ecoregions with high climate stability but high vegetation intactness are dark orange. Ecoregions with low climate stability but high vegetation intactness are light orange. Ecoregions that have both low climate stability and low levels of vegetation intactness are pale green.

La forêt d'Amazonie vers un « point de non-retour »

Les chercheurs prévoient, lors du début de décembre, une hausse importante de la déforestation par rapport à 2019



Un incendie dans la forêt amazonienne à São Francisco, État de Pará, au Brésil.

Les scientifiques s'accrochent à l'espoir que la déforestation en Amazonie s'arrête avant d'atteindre un point de non-retour. Mais les données les plus récentes indiquent que la déforestation continue à augmenter à un rythme alarmant. Les chercheurs prévoient que la déforestation pourrait atteindre un niveau critique d'ici la fin de l'année, ce qui pourrait déclencher un point de non-retour. Les scientifiques appellent à une action urgente pour protéger la forêt amazonienne.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

BIOLOGICAL SCIENCES

Climate change and ecosystems: threats, opportunities and solutions

A theme issue compiled and edited by Janet Franklin, Yadvinder Malhi, Nathalie Seddon, Martin Solan, Chris Field, Nancy Knowlton and Monica Turner

Published January 2020



THE ROYAL SOCIETY PUBLISHING

The most sensitive (so vulnerable) regions to climate change

We find ecologically sensitive regions with amplified responses to climate variability in the:

- o Arctic tundra,
- o boreal forest belt,
- o tropical rainforest,
- o alpine regions worldwide,
- o steppe and prairie regions of central Asia and North and South America,
- o the Caatinga deciduous forest in eastern South America, and
- o eastern areas of Australia.

Sensitivity of global terrestrial ecosystems to climate variability
A. Seddon Nature 17 Feb 2016



The areas that are most sensitive to climate change,

Remaining great world forests



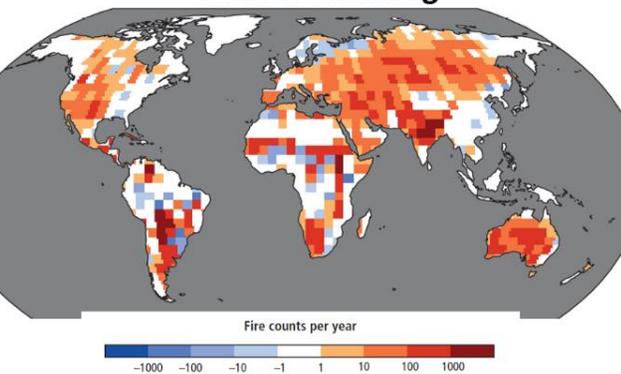
Peter Carter Climate Emergency Institute

Climate Change Impacts on Tropical Forests in Central America

AN ECOSYSTEM SERVICE PERSPECTIVE

Large Global Forest Fire Increase at 1.8°C Warming

Global mean from 1850



IPCC AR5 WG2 Figure 4-6 | Projected changes in meteorological fire danger, fire probability, and fire frequency

Les pressions principales en Europe

What are the main pressures on Europe's nature?

Europe's biodiversity continues to be shaped by human activity. Pressures to habitats and species remain high and more than 67 000 individual pressures have been reported at the EU level.

With 21 %, agriculture is

the most frequently reported pressure for habitats and species.

Abandonment of grasslands and intensification is particularly impacting pollinator species, farmland birds and semi-natural habitats.



Urbanisation and leisure activities account for 13 % of all reported pressures, representing

48 % of all marine pressures.

Invasive alien species

such as the False Indigo-bush, particularly affect dunes and sclerophyllous scrubs as well as species such as breeding seabirds.



The modification on water regimes, physical alterations of water bodies and removal of sediments predominantly affect

freshwater habitats and fish.

Forestry activities represent 11 % of all

pressures, particularly affecting forest habitats, and woodland species.



13 % of all pressures

for birds stem from the exploitation of species, mainly relating to illegal killing and hunting.

In Europe, the annual hunting bag amounts to at least **52 million birds.**

Climate change

is reported as a rising threat, particularly due to ongoing changes in the temperature and decrease of precipitation.



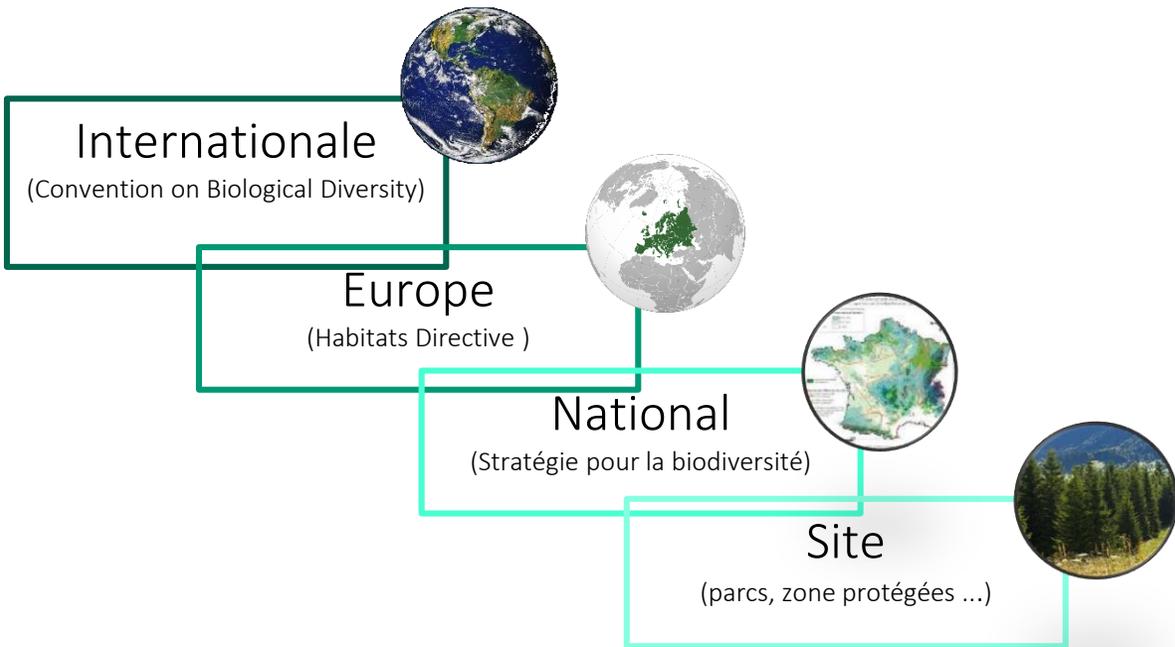
Almost 50 % of all pressures related to pollution

can be attributed to air, water and soil pollution caused by agriculture.

Besoins d'outil pour évaluer l'état des écosystèmes

La préservation des écosystèmes est devenu un défi majeur pour le développement durable

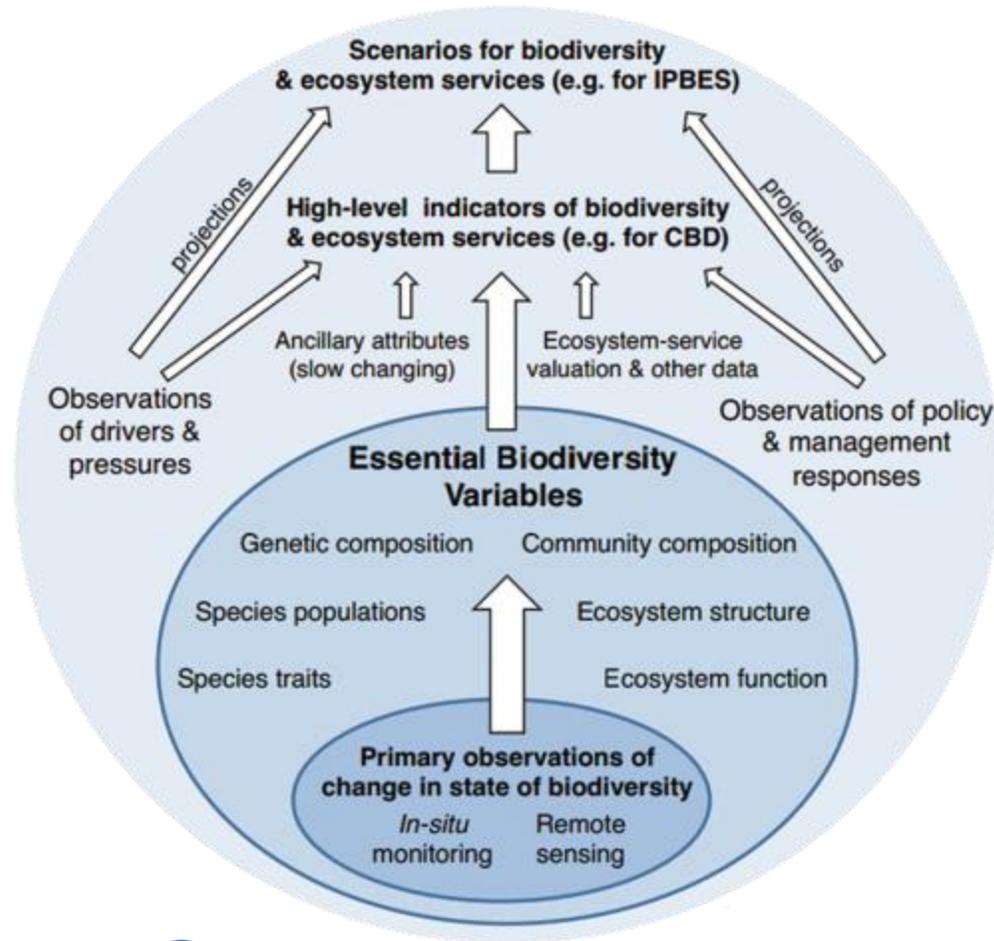
Face à l'érosion de la biodiversité
=> Politiques publique



=> Besoin d'outils pour appliquer ces politiques



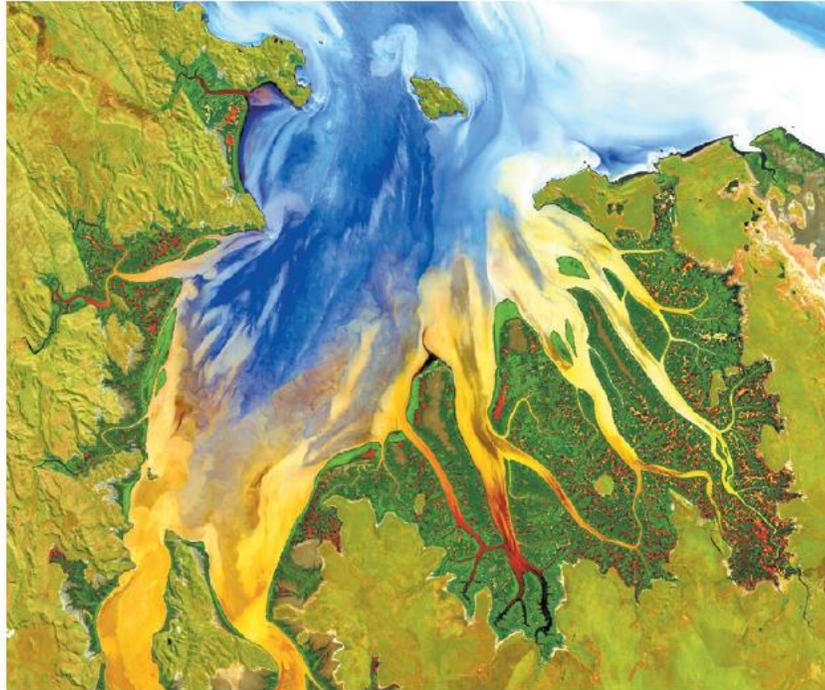
Des variables essentielles au suivi de la biodiversité



- EBV : variables dérivées des observations nécessaires pour **étudier, rendre compte et gérer** la biodiversité
- Une EBV « idéale » doit
 - Permettre de saisir les **échelles** et les dimensions critiques de la biodiversité
 - Être une variable d'état **sensible aux changements**
 - Être **techniquement accessible, économiquement viable** et durable

La télédétection comme source de données essentielle pour le suivi de la biodiversité

RS-enable-EBVs



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.

TRACKING BIODIVERSITY

Ten variables

Proposed variables for satellite monitoring of progress towards the Aichi Biodiversity Targets.

Species populations

- Species occurrence

Species traits

- Plant traits (such as specific leaf area and leaf nitrogen content)

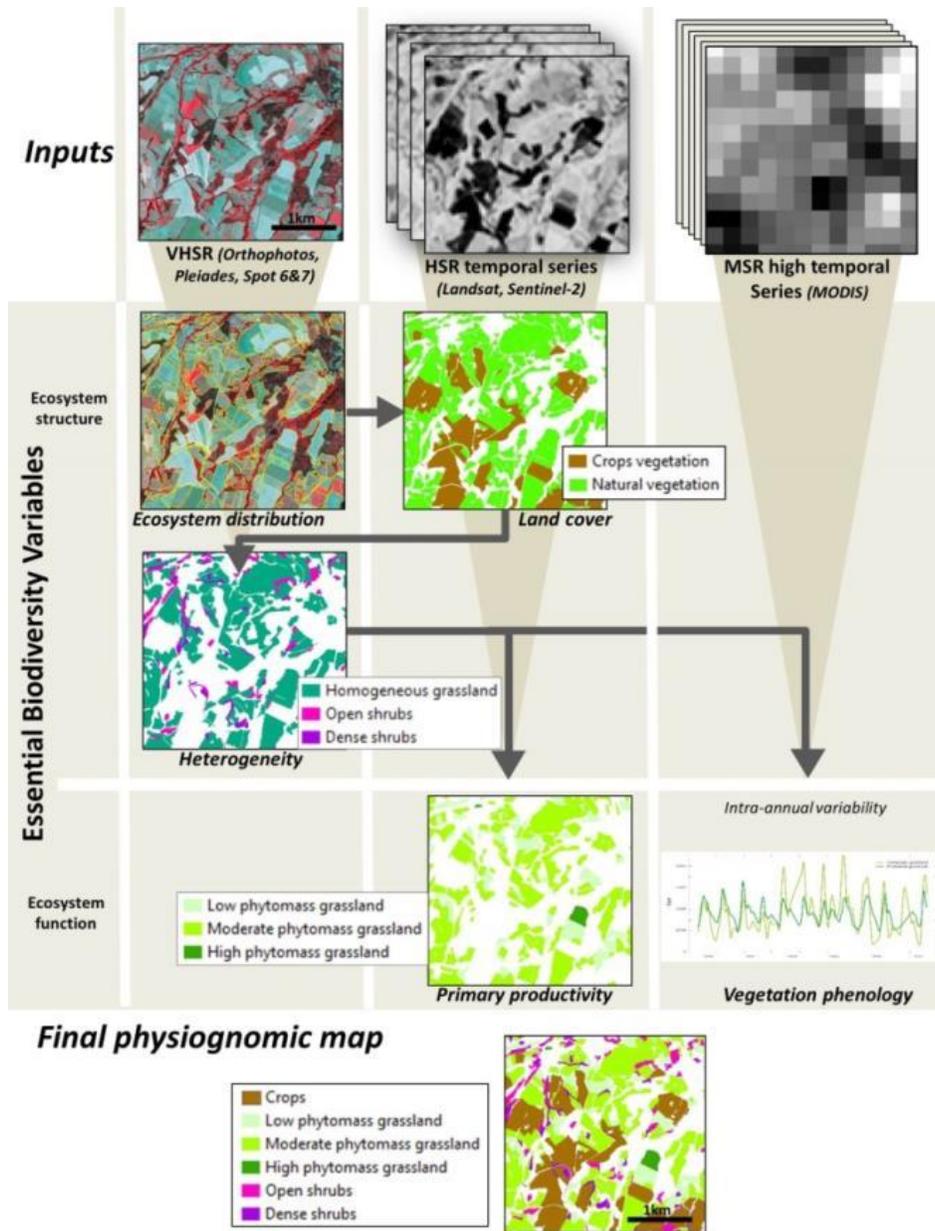
Ecosystem structure

- Ecosystem distribution
- Fragmentation and heterogeneity
- Land cover
- Vegetation height

Ecosystem function

- Fire occurrence
- Vegetation phenology (variability)
- Primary productivity and leaf area index
- Inundation

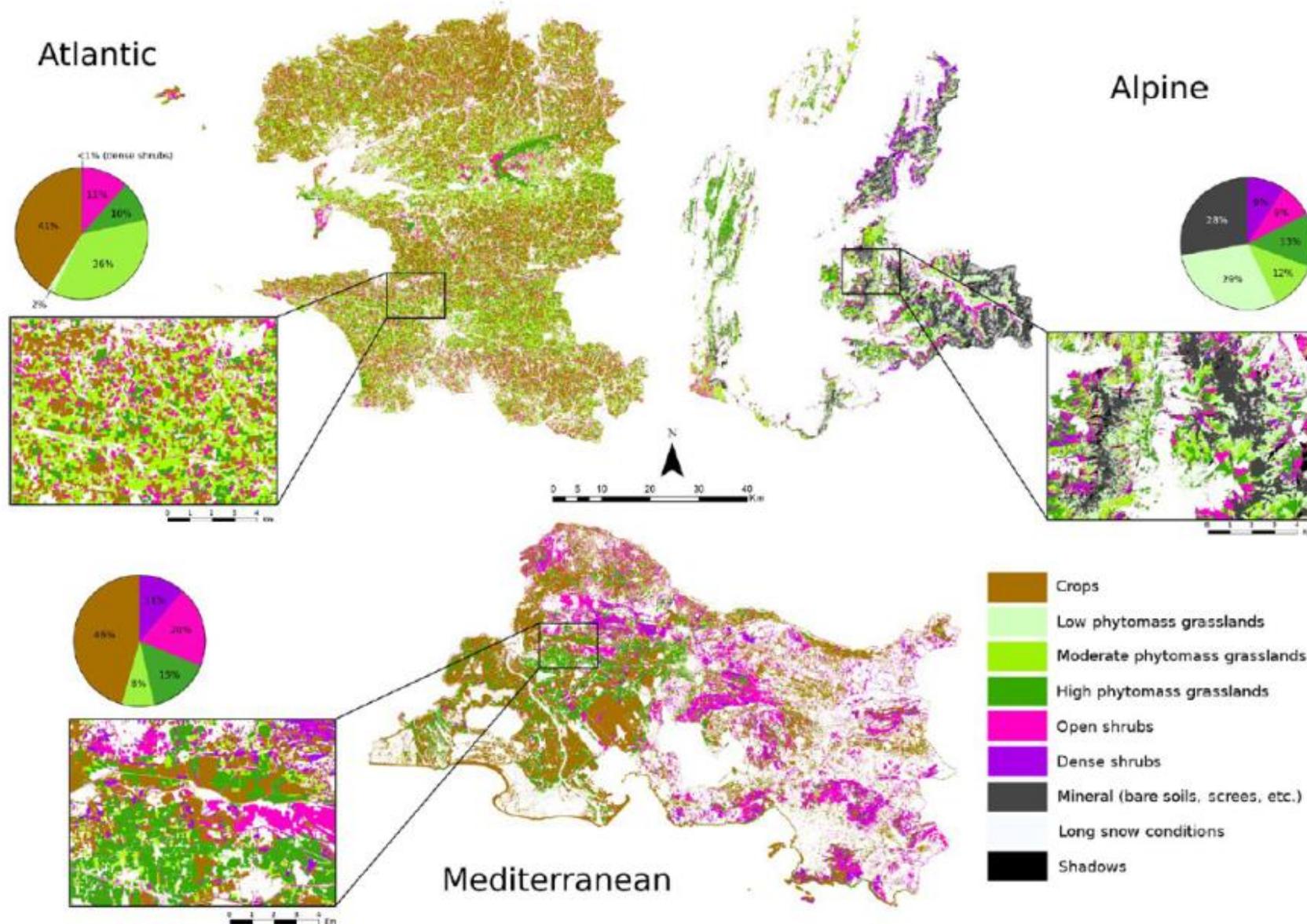
Caractériser la physionomie des habitats naturel par fusion multi-capteurs



Méthode utilisant le couplage d'images multi-capteurs et permettant d'extraire des informations pour caractériser les écosystèmes

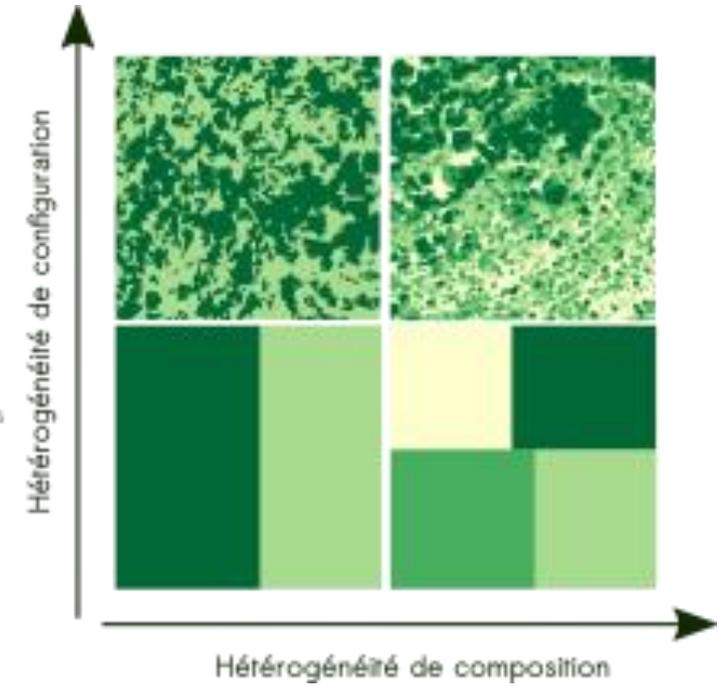
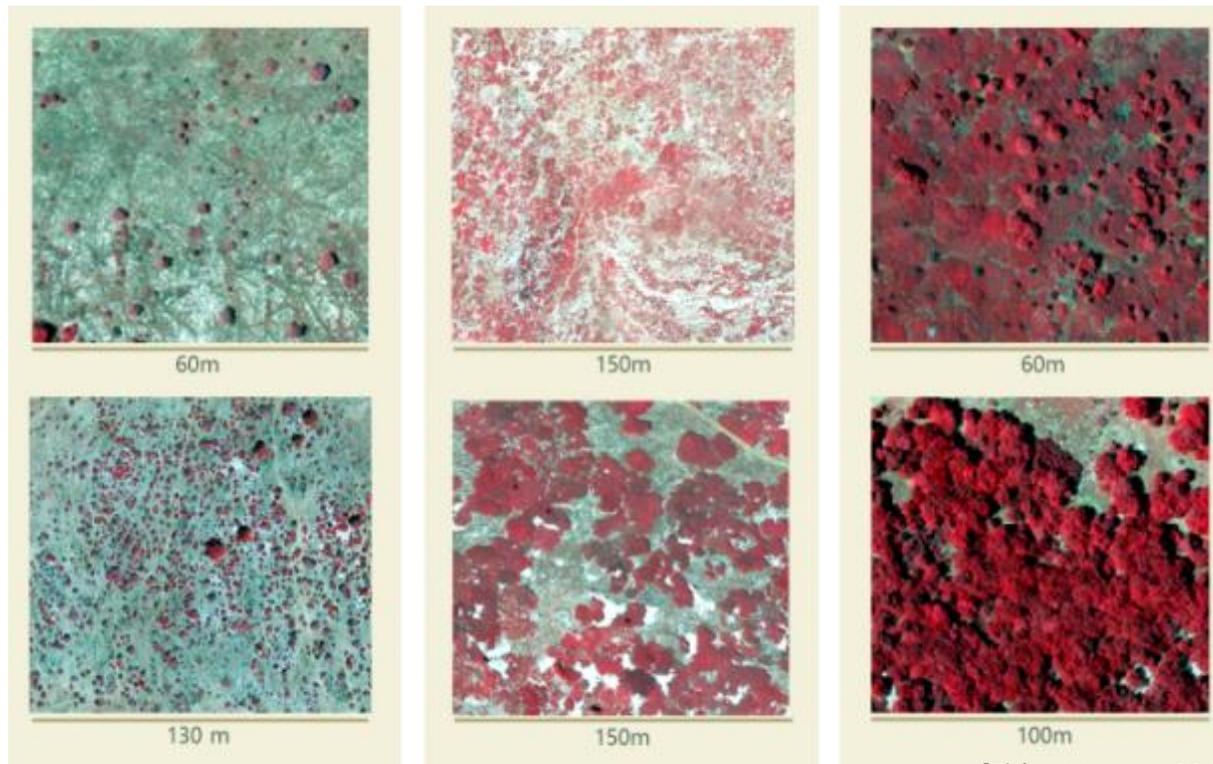
- ✓ Etendue
- ✓ Occupation du sol
- ✓ Hétérogénéité
- ✓ Structure des habitats
- ✓ Phénologie de la végétation

Caractériser la physionomie des habitats naturel par fusion multi-capteurs



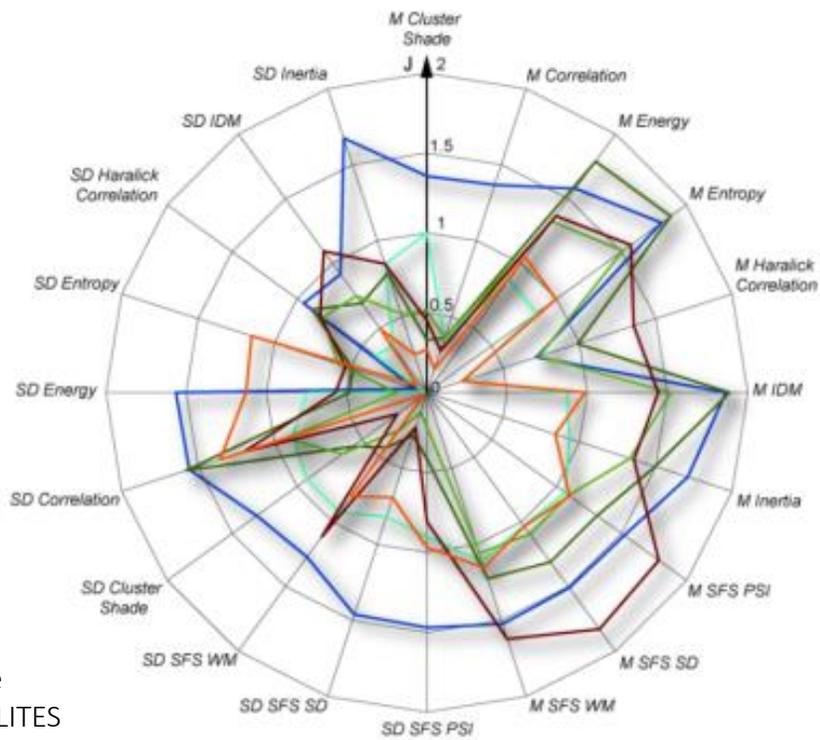
Alleaume S., Dusseux, P., Thierion, V., Commagnac, L., Laventure, S., Lang, M., Féret, J.B., Hubert-Moy, L., Luque, S. 2018 . A generic remote sensing approach to derive operational Essential Biodiversity Variables (EBVs) for conservation planning. MEE.

Coupler les données de télédétection et les observations de terrain ... pour suivre l'hétérogénéité des écosystèmes

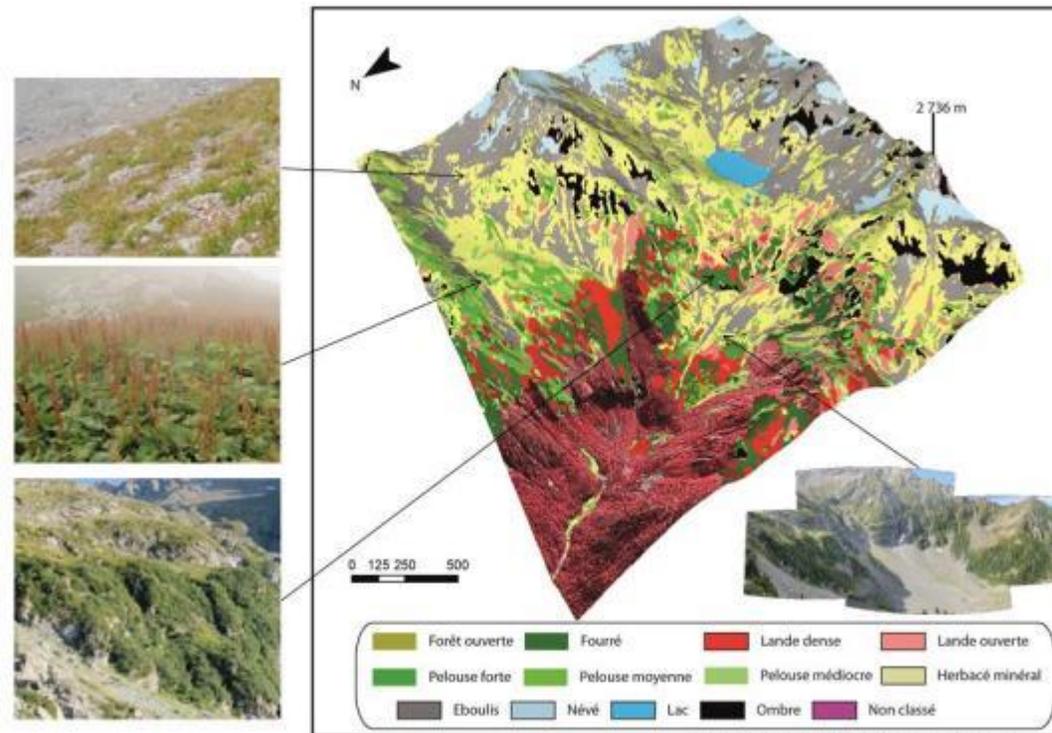


Hétérogénéité des écosystèmes de montagne pour discriminer des habitats naturels

Analyses de textures : textures d'Haralick / images Pleiades



Type I	Type II	Type III
Coarse - fine scree	Homo. - Hete. grassland	Grassland - Shrub
Medium - fine scree	Hete. - sparse grassland	Shrub density



Suivre l'hétérogénéité d'un écosystème méditerranéens pour mieux le gérer



Biodiversity
conservation



Pastoralism



Fire risk management



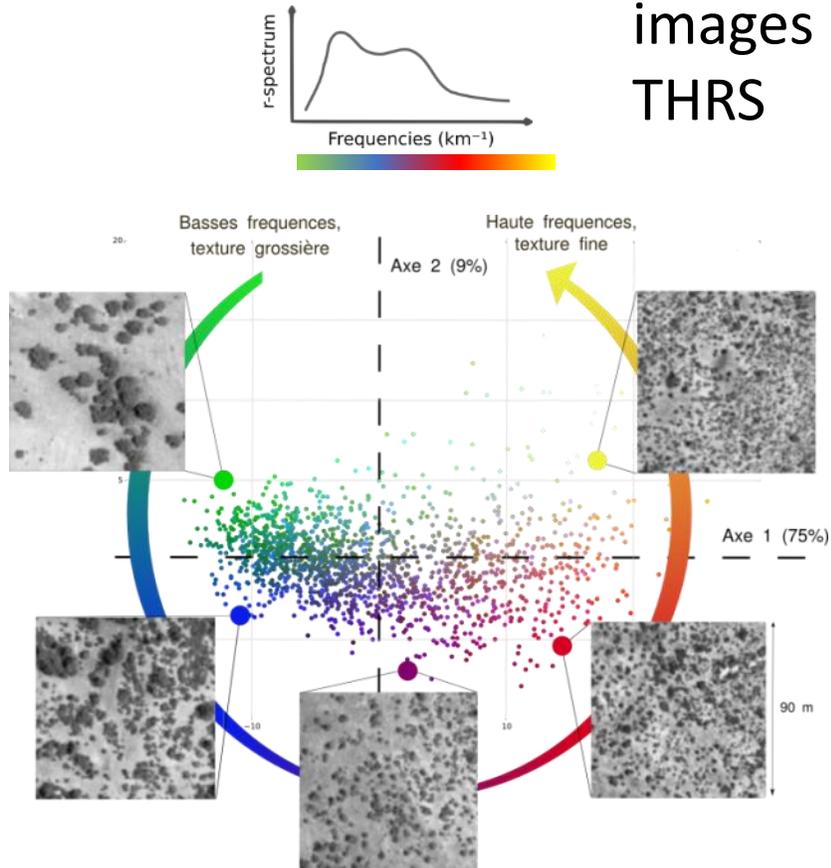
Cultural heritage



Mediterranean
forested
landscape

Indices de textures continus pour caractériser la structure des végétations méditerranéennes

Analyse de la structure de la végétation structure par
approche FOTO (Fourier textural ordination) (Couteron 2006)



images
THRS

IN SITU

- Terrain
- Télédétection
- Drones



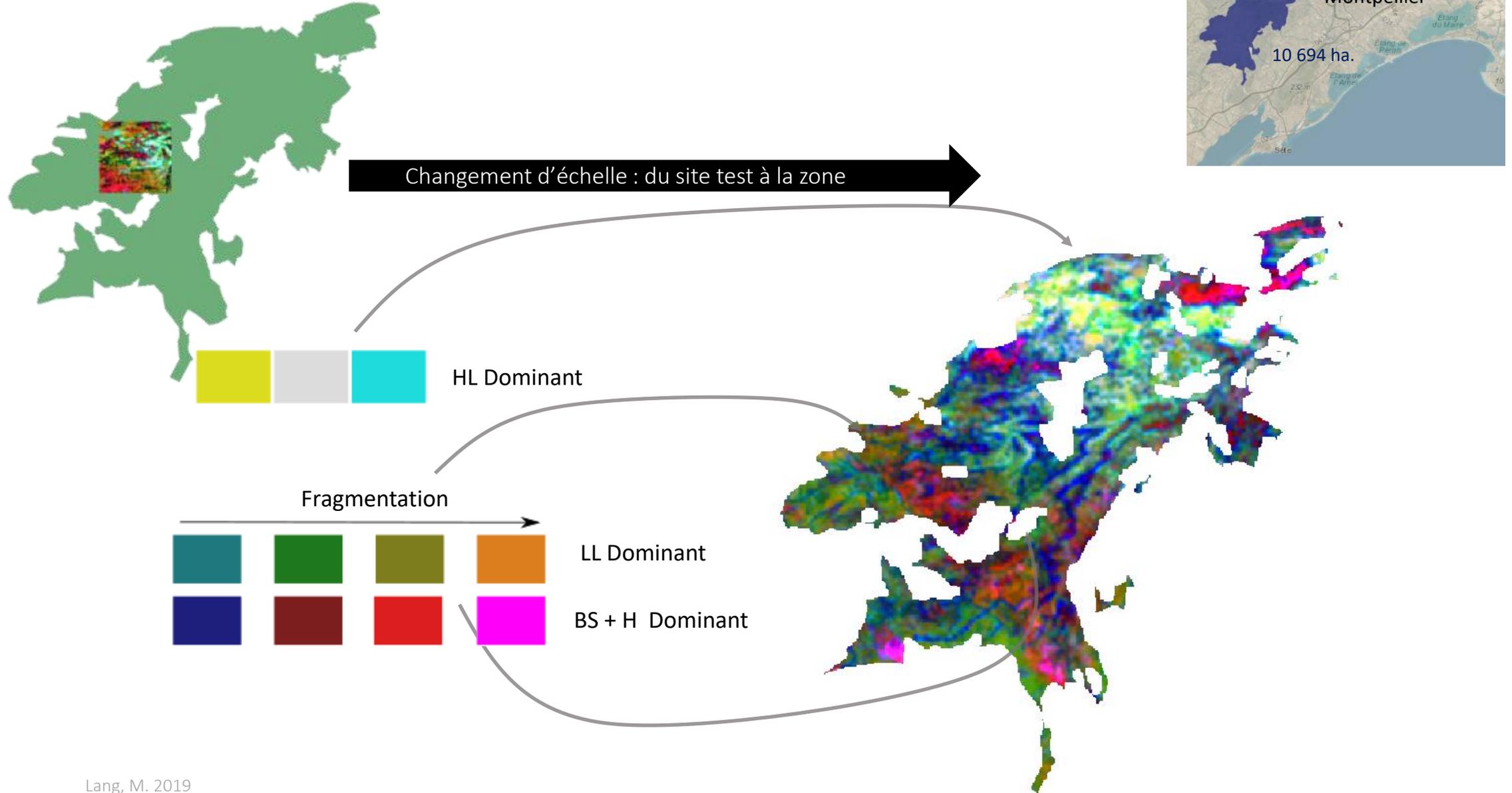
METRIQUES PAYSAGERES

- Proportions
- Densité des patches
- Compacité
- Fragmentation



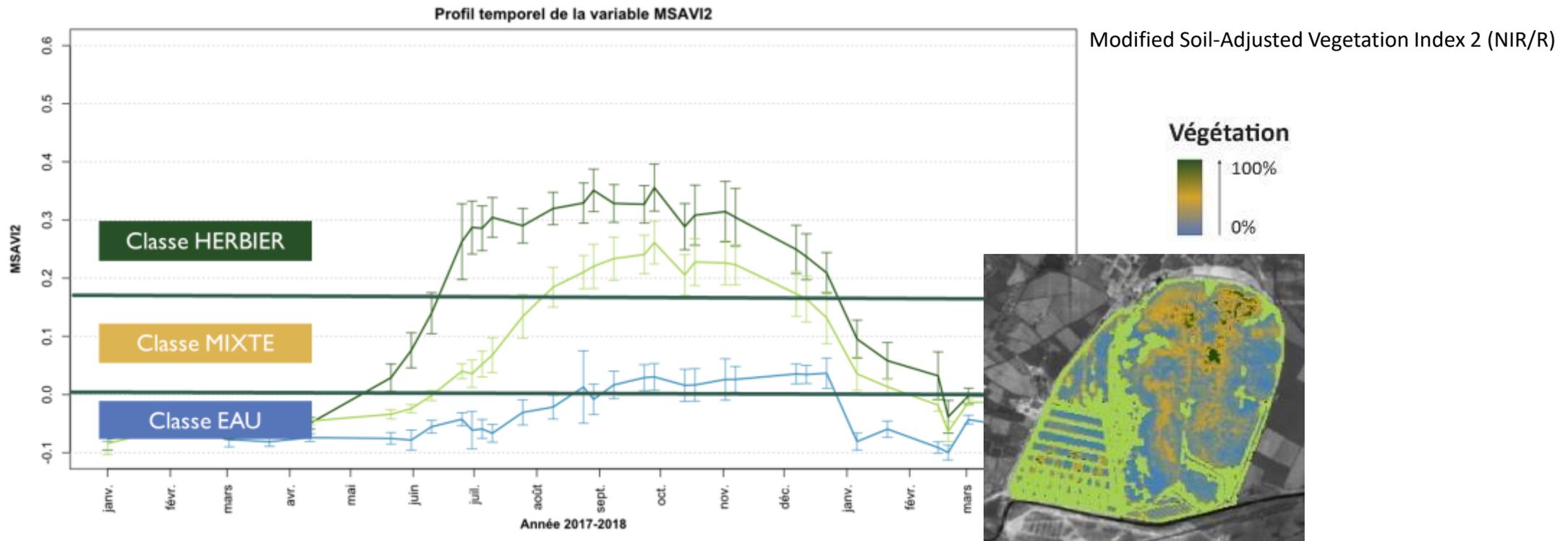
<https://framagit.org/benjaminpillot/fototex>

Carte de la structure des végétations

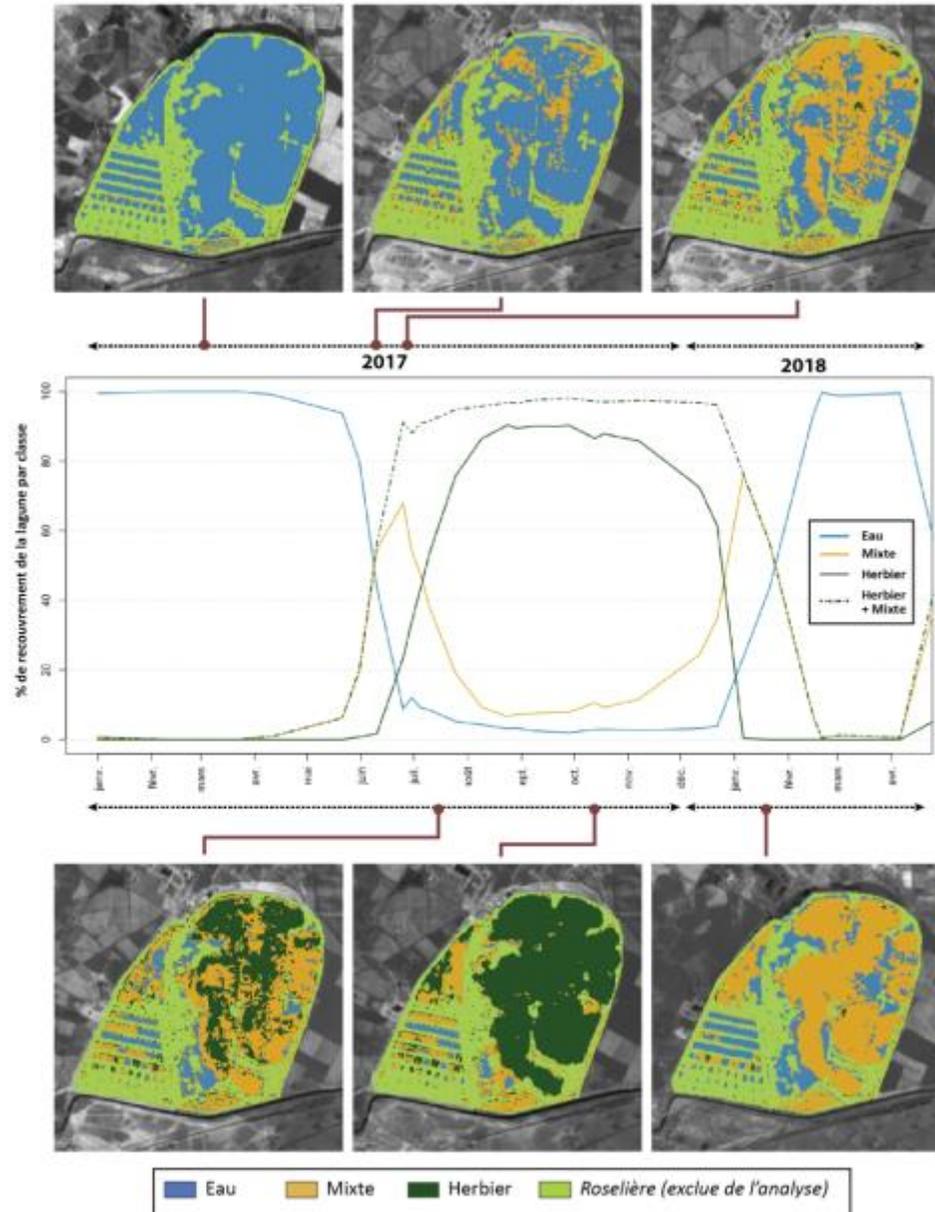


Séries temporelles pour suivre l'évolution des écosystèmes

Dynamique spatio-temporelle de l'herbier du Grand Bagnas (Hérault) par télédétection satellitaire (Sentinel-2)



Séries temporelles pour suivre l'évolution des écosystèmes



webmapping



Menu, M., Papuga, G., Andrieu, F., Debarros, G., Fortuny, X., Alleaume, S., Pitard, E., 2021, Towards a better understanding of grass bed dynamics using remote sensing at high spatial and temporal resolutions. Estuarine, Coastal and Shelf Science, vol. 251. <https://doi.org/10.1016/j.ecss.2021.107229>.

- Donne des indications sur la dynamique des habitats naturels, sans les classer, à travers le calcul de 3 composantes issues de la télédétection.
- Devient une référence pour prédire des patrons de diversité à large échelle à partir d'images satellites (Radeloff et al. 2019).
- Les 3 composantes peuvent être dérivées d'une série temporelle annuelle de fAPAR (variable biophysique) ou de NDVI (Coops et al., 2018)

1. **DHI cum** : cumul du NDVI sur l'année (soit l'aire sous la courbe). Il informe sur le **niveau de productivité annuelle** de la végétation.

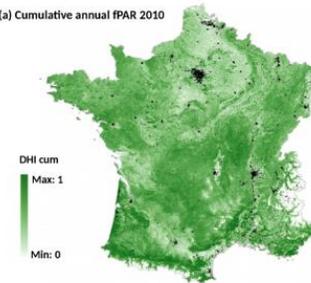
2. **DHI min** : valeur minimale du NDVI sur l'année. Il informe sur le **niveau le plus bas de productivité** de la végétation.

3. **DHI cv** : coefficient de variation des valeurs du NDVI de l'année. Cette composante reflète la **saisonnalité** de l'habitat.

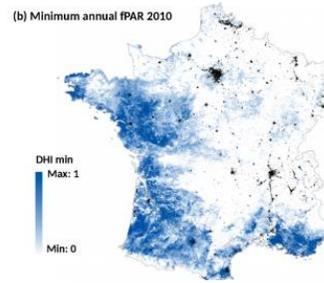
Les 3 composantes du DHI peuvent être reliées à des théories écologiques (diversité-productivité, diversité-stabilité, hypothèse de stress environnemental).

Elles peuvent ainsi être utilisées comme **proxy** pour estimer des indicateurs de biodiversité.

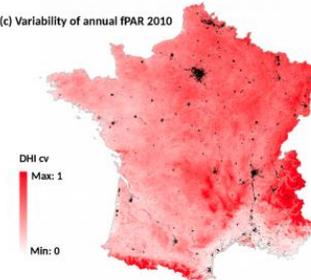
(a) Cumulative annual fPAR 2010



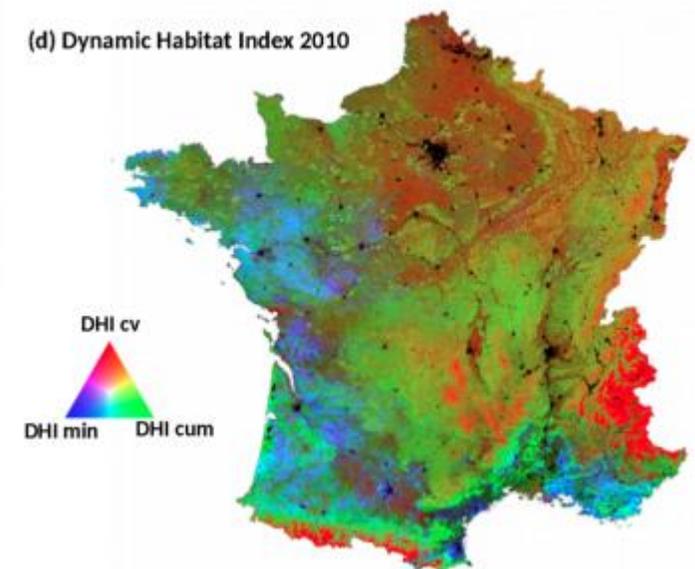
(b) Minimum annual fPAR 2010



(c) Variability of annual fPAR 2010



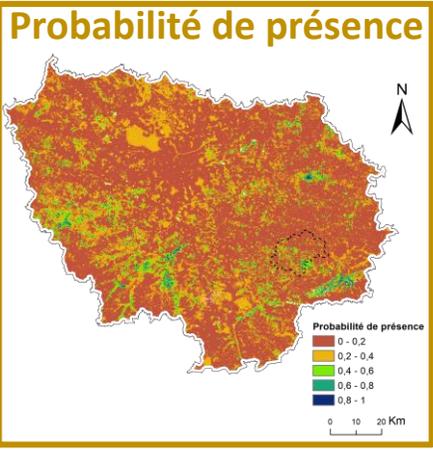
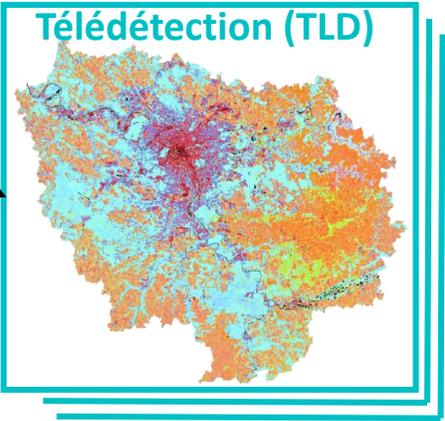
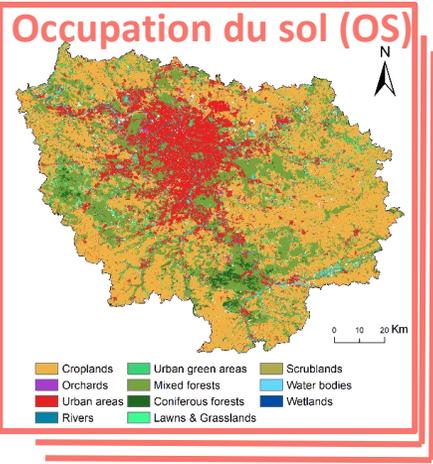
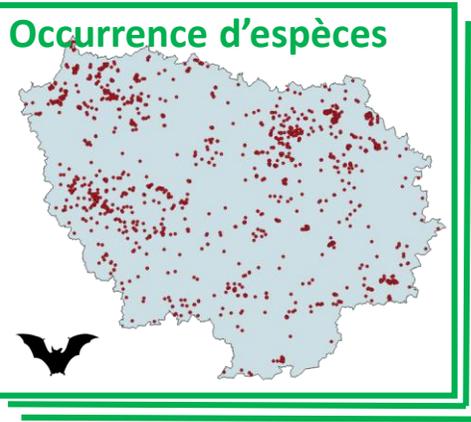
(d) Dynamic Habitat Index 2010



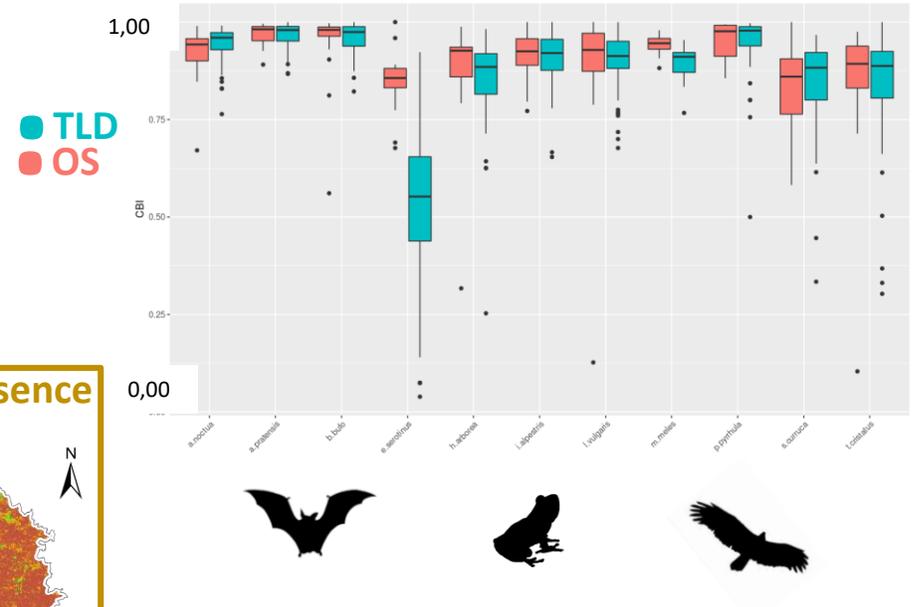
Bonthoux S., Lefèvre S., Herrault P.-A., Sheeren D. 2018. Spatial and Temporal Dependency of NDVI Satellite Imagery in Predicting Bird Diversity over France. *Remote Sensing*, 10(7), 1136.

Distribution d'espèces: couplage télédétection modélisation

Corrélation entre la présence des espèces et variables environnementales



Evaluation Continu Boyce Index CBI



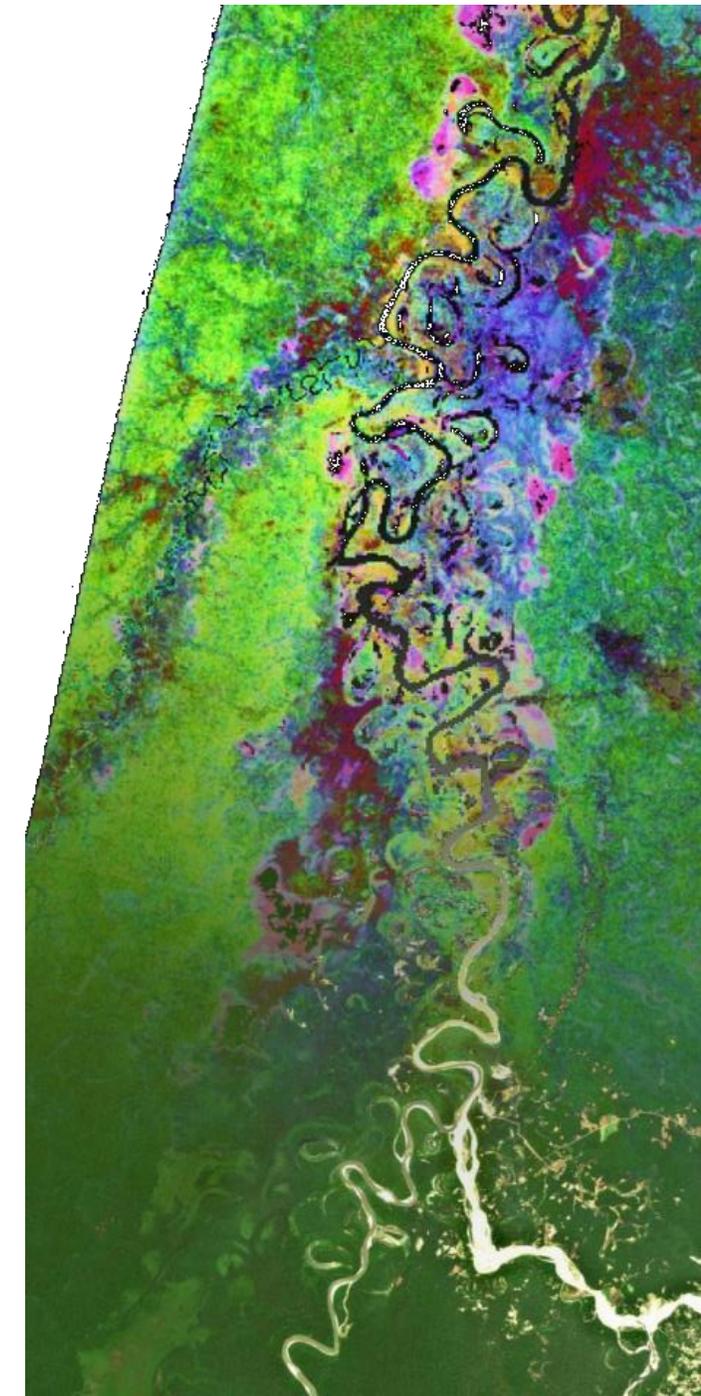
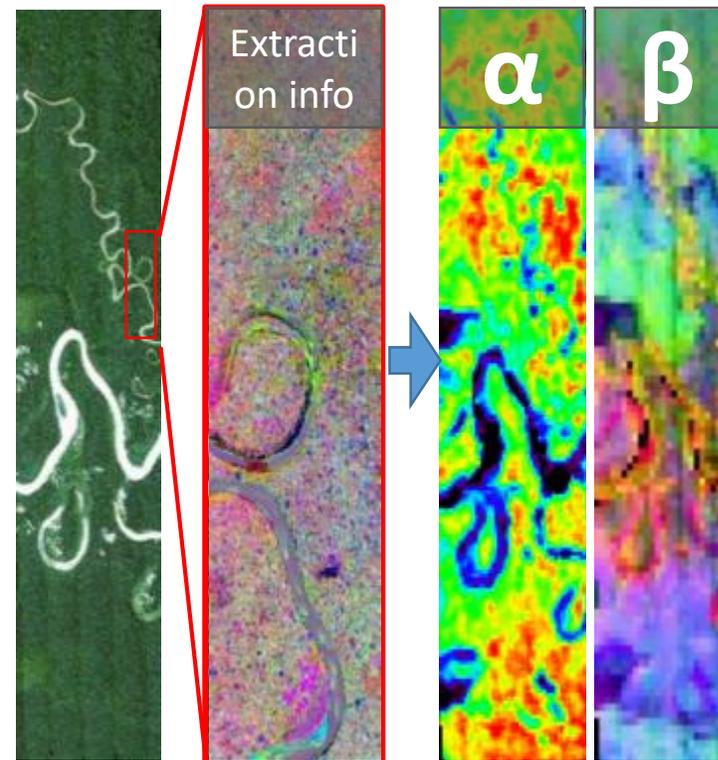
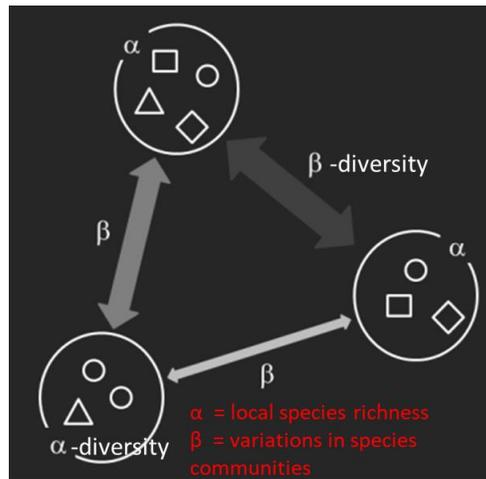
- Même niveau de prédiction OS et TLD
- Surestimation de la distribution spatiale par TLD (ou sous estimation OS ?)

Indices de biodiversité

Création d'espèces spectrales par

- couplage lidar & hyperspectral
- utilisation de série temporelles S2

- α and β Biodiversité



Féret & Asner, 2014. Ecological Applications -- Rocchini et al 2018 MEE

Féret, J.-B., de Boissieu, F., 2019. biodivMapR: an R package for α - and β -diversity mapping using remotely-sensed images. Methods Ecol. Evol. 00:1-7. doi.org/10.1111/2041-210X.13310



jbferet.github.io/biodivMapR/index.html

Bilan: télédétection et écosystèmes

Le potentiel de l'utilisation d'informations issue de la télédétection pour l'étude de la biodiversité a été discuté et exploré durant les 20 dernières années

- 😊 **Acquisitions satellites peu coûteuses (une fois le satellite en orbite...)**
- 😊 **Information spatialement exhaustive, potentiellement adaptée pour un suivi sur sites de taille limitée aussi bien que sur des régions entières**
- 😞 **Un certain nombre de défis techniques a relever**
- 😞 **Améliorer l'adéquation entre besoins des écologues et solutions techniques**
- 😞 **Disponibilité d'information terrain souvent réduite a prendre en compte**
- 😊 😞 **Dimensions spatiale, temporelle et spectrale potentiellement intéressantes**

Bilan: télédétection et écosystèmes



	TYPE DE CAPTEUR DE TELEDETECTION					
	Très grande résolution spatiale Pleiade Spot 6&7	Moyenne à haute résolution spatiale / résolution temporelle Landsat, Sentinel 2	Résolution spatiale grossière et très grande AVHRR MODIS	Hyperspectrale PRISMA HISUI (ALOS-3)	Balayage Laser Lidar HD Gedeye	Capteur micro-ondes actif (ex. SAR) Sentinel 3
Structure	++	+	+	+	++	+
Diversité (richesse)	++	+	-/+	++	-	-
Fragmentation	++	++	+	+	+	+
Détection de changement	+	++	+	-/+	-/+	+

Adapté de Corbane, C., Lang, S. Pipkins, K., Alleaume, S. Deshayes, M. García Millán, V.E. , Strasser, T., Vanden Borre, J., Spanhove, T. et Förster, M, 2015. "Remote Sensing for Mapping Natural Habitats and Their Conservation Status – New Opportunities and Challenges." International Journal of Applied Earth Observation and Geoinformation 37 (2015): 7–16.

An aerial photograph of a circular field, possibly a pasture or a specific agricultural plot, with a large tree in the center. The field is surrounded by dense green forest. The word "MERCI" is overlaid in white text in the upper right corner.

MERCI

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