Utrecht University, Faculty of Geosciences
[1]Copernicus Institute of Sustainable Developement &
[2]Department of Physical geography

Universitat Autònoma de Barcelona
[3]CREAF-CSIC, Global Ecology Unit

Sensing nitrogen and phosphorous concentrations in vegetation across different scales

Yasmina Loozen[1,2], K.T. Rebel[1], D. Karssenberg[2], M.J. Wassen[1], S. Wang[1], J. van Dijk[1], J. Sardans[3], J. Peñuelas[3], S.M. de Jong[2]

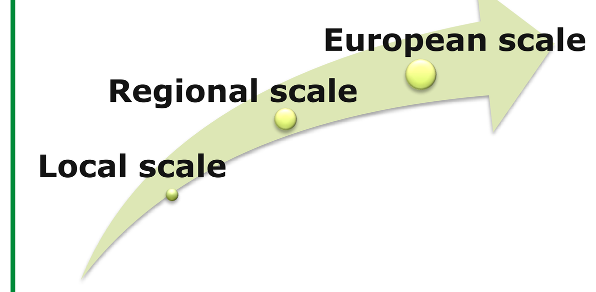
Motivation Using remote sensing for canopy N and P detection?

- **Nitrogen** (N) and **Phosphorus** (P) are essential nutrients for plant growth. These nutrients are linked to vegetation processes and to carbon (C) assimilation by vegetation
- **Accessing information about plant trait data** for the N- and P- cycles, e.g. canopy N and canopy P, is thus essential.
- **Canopy N and P concentration** data are usually obtained by destructive methods and **are lacking for larger scales**

=> Remote sensing has already been used to detect canopy N at local scale and offers the possibility to investigate the estimation of canopy N and P concentrations across different scales

Objectives and approach Sensing canopy N and P across scales

We investigated the remote sensing of canopy N and P in vegetation across different scales using **vegetation indices** (VIs)



1. At the **local scale**, we tested and developed VIs for canopy N and canopy N to P ratio (N:P) detection on a grass species using in situ reflectance measurements
2. At the **regional scale**, we used the spaceborne MERIS Terrestrial chlorophyll Index (MTCI) to study the relationship with canopy N in Mediterranean forests
3. At the **European scale**, we used three VIs (MTCI, NDVI and EVI) from MERIS and MODIS spaceborne sensors to sense canopy N in temperate forests

1. Local scale VIs tested for canopy N:P detection

Holcus lanatus grasses were grown under different N to P ratio (N:P) nutrients supply. Foliar canopy N, P and N:P were analyzed with existing VIs. We studied the influence of the sensors bandwidth using VIs calculated from the original narrow band spectra and the spectra resampled to the bandwidth of 4 satellite sensors

Fig 1. In situ reflectance measurement using a spectroradiometer

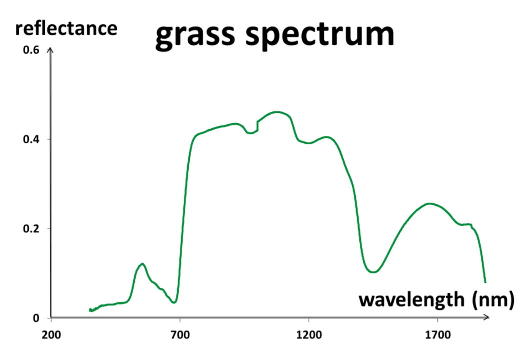


Fig 2. Obtained grass spectrum used for VIs calculation

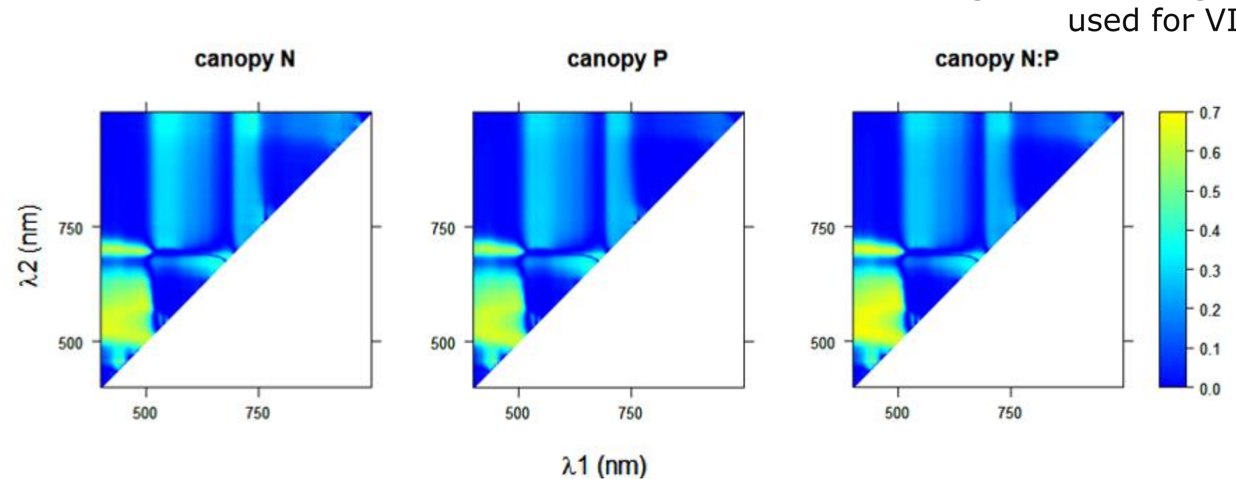


Fig 3. Heatmaps showing the r^2 between canopy N, canopy P and canopy N:P and each combination of two reflectance bands ratio ($\frac{\lambda 1}{\lambda 2}$) between 400 – 1000 nm. Higher correlation for reflectance bands in the blue (400 – 500 nm) and green-red (500 – 700 nm) regions of the spectrum

VI (wavelength)	r^2 canopy N	r^2 canopy P	r^2 canopy N:P
TB (R498, R413, R442)	0.42	0.52	0.48
TB (R434, R496, R401)	0.38	0.48	0.44
ND (R1220, R710)	0.44	0.37	0.41
ND (R693, R1770)	0.39	0.34	0.40
ND (R735, R1285)	0.44	0.30	0.40

Table 1. r^2 obtained between VIs and canopy N, canopy P and canopy N:P. VIs calculated using blue wavelength perform better

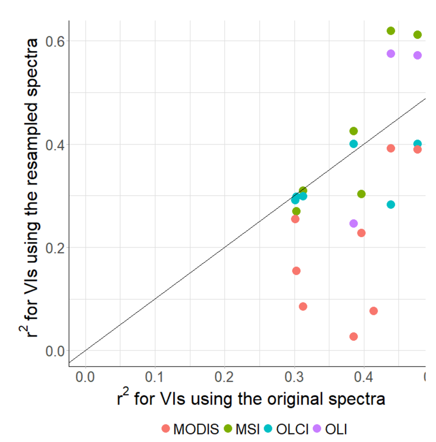


Fig 4. Comparison between the r^2 obtained for canopy N:P and VIs calculated with the original reflectance spectra or the spectra resampled to the bandwidth of 4 satellite sensors (Terra-Aqua – MODIS, Sentinel 2 – MSI, Sentinel 3 OLCI and LANDSAT 8 – OLI)

2. Regional scale sensing canopy N in Mediterranean forests

We studied the relationship between canopy N measurements from 846 forest plots and the MERIS Terrestrial Chlorophyll Index (MTCI) at 1 km spatial resolution

$$MTCI = \frac{R_{band10} - R_{band9}}{R_{band9} - R_{band8}} = \frac{R_{753.75} - R_{708.75}}{R_{708.75} - R_{681.25}} \quad (1)$$

Fig 5. MERIS spaceborne sensor and MTCI equation, based on a combination of Band 8, 9 and 10 from MERIS

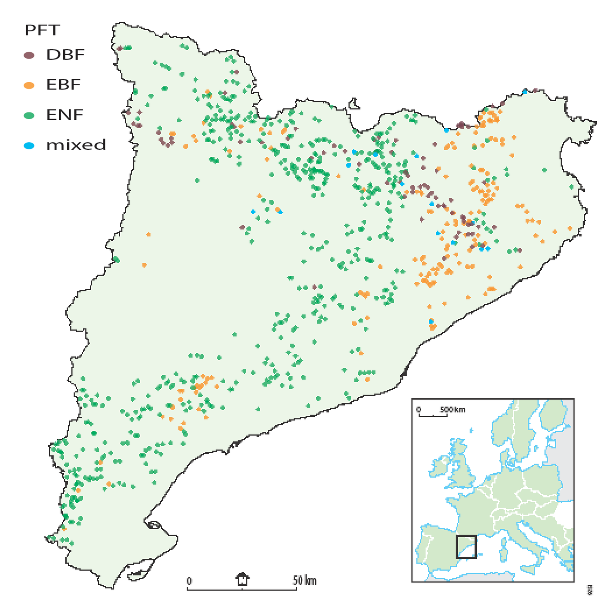


Fig 6. Locations of the forest plots in the region of Catalonia, NE Spain. Colors represent different plant functional types (PFT). DBF = Deciduous Broadleaf; EBF = Evergreen Broadleaf; ENF = Evergreen Needleleaf; mixed = mixed PFT

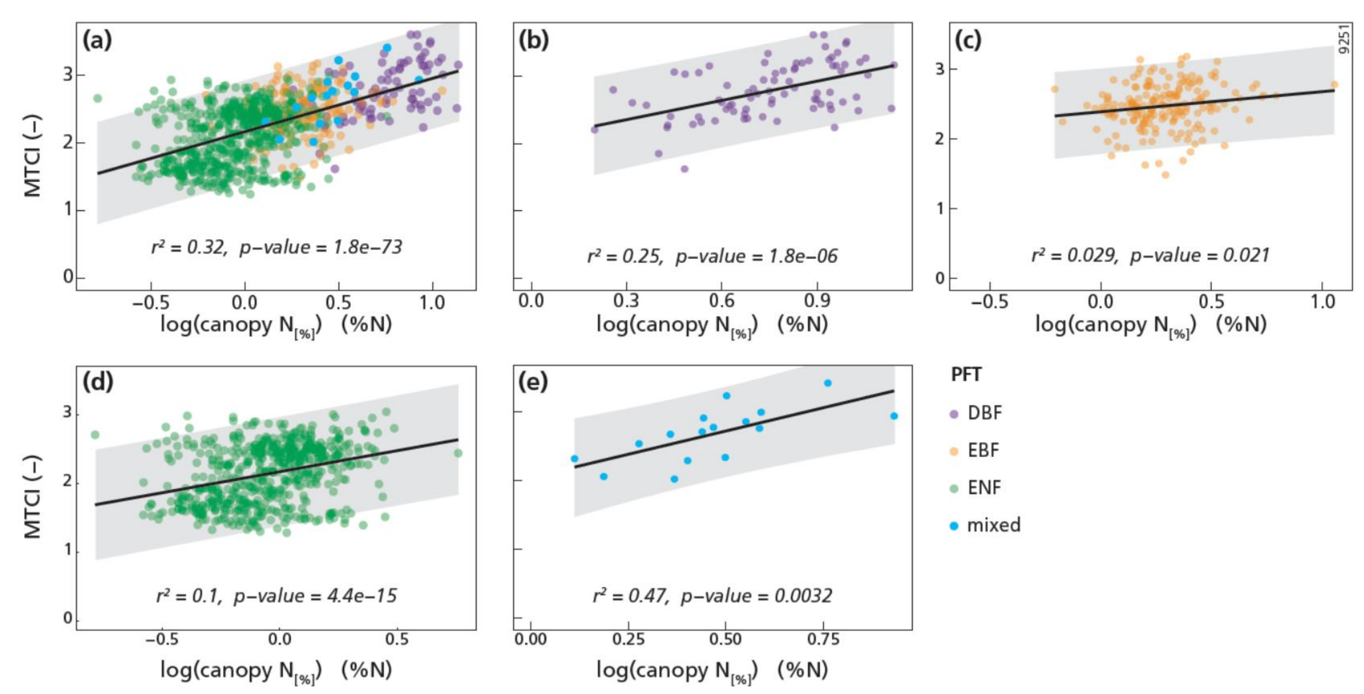


Fig 7. Log linear regression between MTCI and canopy N for different plant functional types (PFT). The relationship is significant when all the plots are included (r^2 = 0.32) and stronger for Deciduous broadleaf (DBF) and mixed plots compared to evergreen broadleaf (EBF) and evergreen needleleaf (ENF) plots

3. European scale influence of sensor spatial resolution

Using the ICP-Forests database, we investigated the relationship between canopy N measurements from > 1000 European forests plots with different VIs from MERIS and MODIS sensors at 1 km and 250 m spatial resolution

Vegetation indices included:

- MERIS MTCI (1 km)
- MODIS NDVI (1 km)
- MODIS EVI (1 km and 250 m)

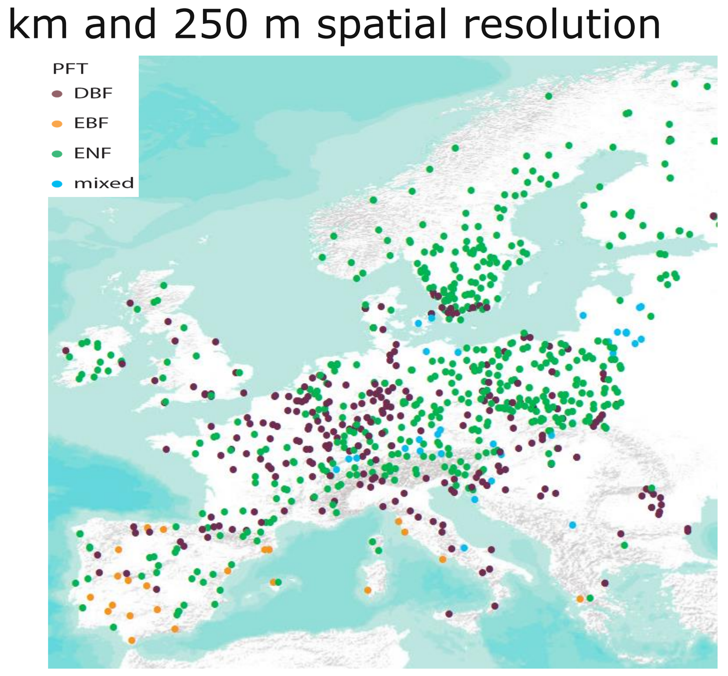


Fig 8. European forest plots from ICP-forests. Colors represent different plant functional types (PFT). DBF = Deciduous Broadleaf; EBF = Evergreen Broadleaf; ENF = Evergreen Needleleaf; mixed = mixed PFT

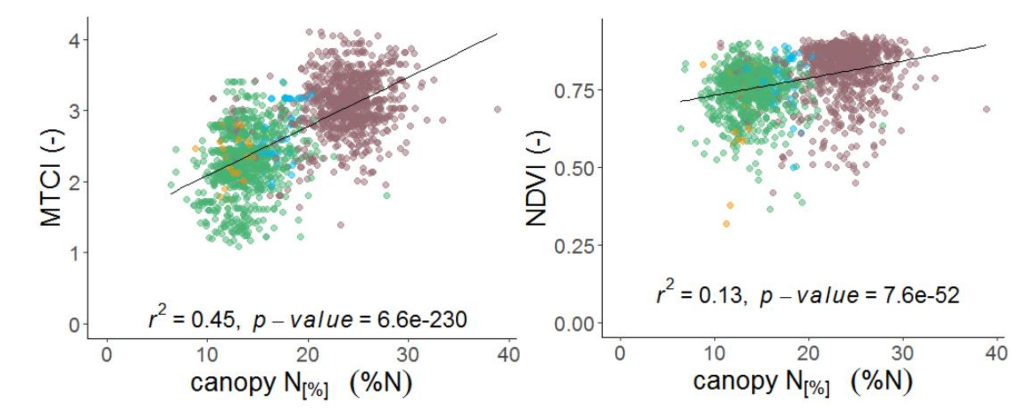


Fig 9. Linear relationship between MTCI or NDVI and canopy N. Stronger relationship between MTCI and canopy N compared to NDVI. Strong influence of the plant functional type on the results

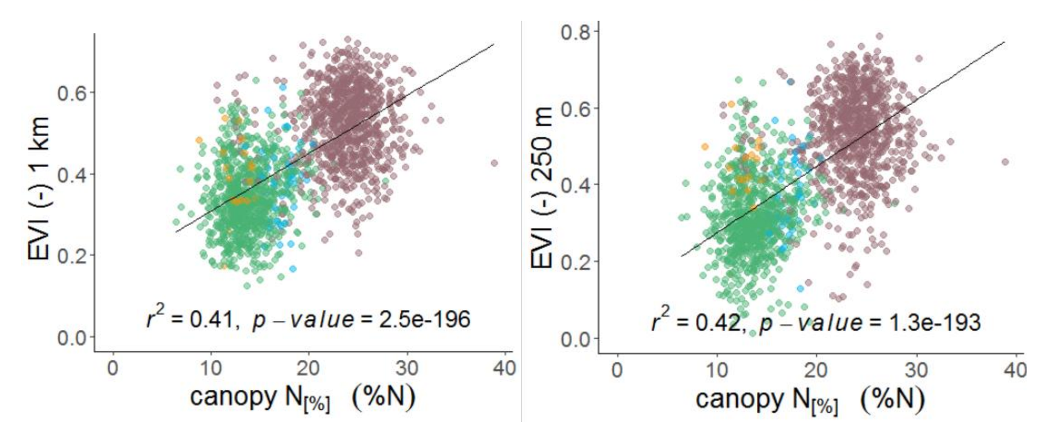


Fig 10. Linear relationship between EVI at either 1 km or 250 m spatial resolution and canopy N. The spatial resolution of the EVI VI does not greatly influence the results

Conclusion and perspectives

Vegetation indices showed significant relationships with canopy N, P and N:P at local scale and with canopy N across different scales and in different ecosystems. In these results, the forest type had a great influence on the relationships.
A next step will be to include ancillary variables in the European scale analysis, such as climate variables, soil types, altitude and forest density. This will allow us to better understand the variability within the relationship for each plant functional type.

Yasmina Loozen
y.m.a.loozen@uu.nl
orcid.org/0000-0002-9896-2704

Acknowledgement
This project was funded by NWO under the project number NWO ALW-GO-AO/14-12.

Netherlands Organisation for Scientific Research