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Earth and Life Institute

A Machine Learning Approach for Green Area Index Retrieval from Multi-Polarization C- and L-band SAR Data

Jean Bouchat [1], Emma Tronquo [2], Anne Orban [3], Xavier Neyt [4], Niko E.C. Verhoest [2] and Pierre Defourny [1]

[1] Earth and Life Insitute, Université catholique de Louvain
[2] Hydro-Climate Extremes Lab, Ghent University
[3] Centre Spatial de Liège, Université de Liège
[4] Signal and Image Centre, Royal Military Academy

Background

- Green area index (**GAI**) is a key variable for agricultural monitoring
- The most accurate GAI estimation methods exploit optical data and are rendered ineffective in the case of frequent cloud cover
- Synthetic aperture radar (**SAR**) could allow the remote estimation of GAI at the parcel level, on a large scale and regardless of cloud cover

Data

L-band from **BELSAR**
$\sigma^0_{HH}, \sigma^0_{HV}, \sigma^0_{VV}, \theta$

Bio-geophysical variables
GAI & Surface Soil Moisture (**SSM**)

C-band from **Sentinel-1**
$\sigma^0_{VH}, \sigma^0_{VV}, \theta$

from **BELSAR-Campaign [1]**

Water Cloud Model

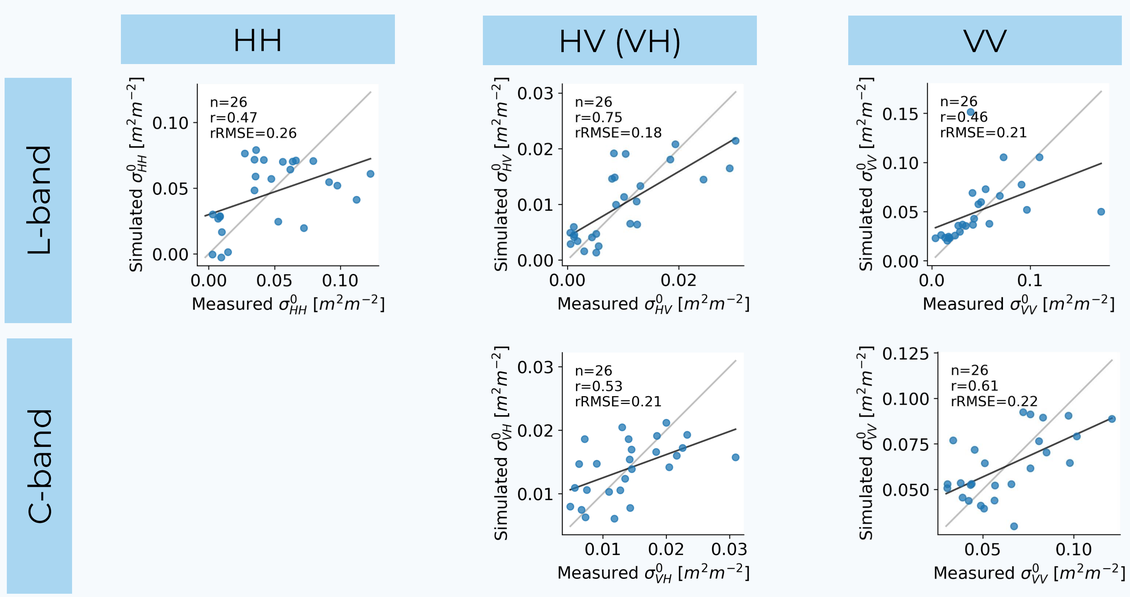
The Water Cloud Model (**WCM**) [2] is a semi-empirical model that simulates the backscattering coefficient in polarization pq of a vegetated field as

$$\sigma^0_{tot,\,pq} = \sigma^0_{veg,\,pq} + \tau^2 \sigma^0_{soil,\,pq}$$

- Contribution of the vegetation : $\sigma^0_{\mathrm{veg},\,pq} = A_{pq}\cos(\theta)(1-\tau^2)$;
- Contribution of the soil : $\sigma^0_{\mathrm{soil},\,pq} = C_{pq}\mathrm{SSM} - D_{pq}$;
- Two-way attenuation through the canopy : $\tau^2 = e^{-2B_{pq}\,\mathrm{GAI}\sec(\theta)}$;
- $A_{pq}, B_{pq}, C_{pq}, D_{pq}$ are model parameters & θ the incidence angle.

Find it online

Calibration – σ^0



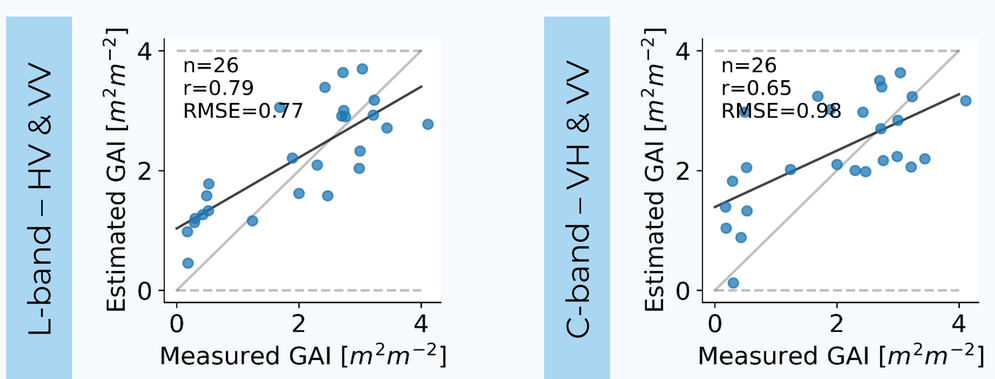
Random Forest Regressor

Several combinations of GAI and SSM can generate the same backscatter. The inversion of the WCM is therefore ill-posed. This problem can be solved using dual-polarized radar measurements :

1. Calibrate two WCMs with σ^0 in two distinct polarizations (pq, rs)
2. Build a synthetic data set with the WCMs by forward modelling
3. Train a random forest regressor with this data set
4. Estimate GAI (and SSM simultaneously) from σ^0_{pq}, σ^0_{rs}, and θ

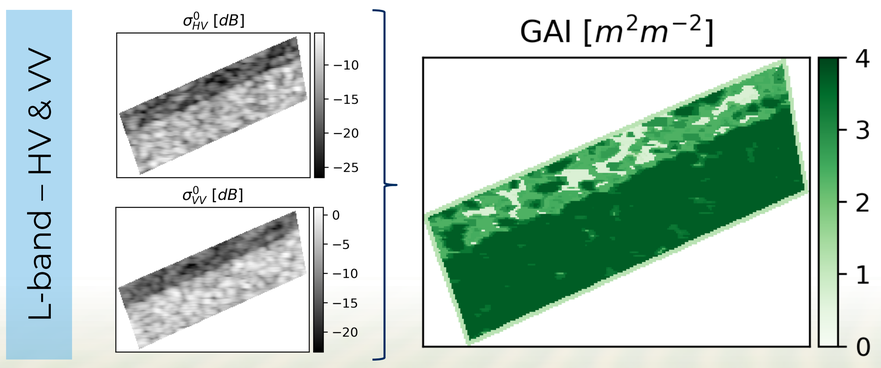
Validation – GAI

- The most accurate GAI estimates were obtained with the polarization pair HV(VH) and VV
- L-band yielded more accurate estimates than C-band, with r-values of 0.79 and 0.65 and RMSEs of 0.77 m^2m^{-2} and 0.98 m^2m^{-2} respectively
- The method proved to be inadequate for soil moisture retrieval in the drought conditions of the field campaign



Conclusions

- These promising results indicate that GAI estimation using dual-polarized radar data could successfully substitute for estimates derived from optical data
- The effectiveness of L-band for GAI monitoring pleads for the further development and exploitation of spaceborne L-band SAR with a short revisit period for agriculture



References

(1) J. Bouchat, E. Tronquo, A. Orban, N. E. C. Verhoest and P. Defourny, "Assessing the Potential of Fully Polarimetric Mono- and Bistatic SAR Acquisitions in L-Band for Crop and Soil Monitoring," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 15, pp. 3168-3178, 2022.
(2) Attema, E.; Ulaby, F.T. Vegetation modeled as a water cloud. Radio science 1978, 13, 357–364.

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