

The SPAGHYTI project - Assessing the nitrogen status and monitoring the (a)biotic stress levels of winter wheat using hyperspectral satellite imagery

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Challenge

Agriculture is at once a cause, a victim and a solution to climate change. A drastic evolution in agricultural practices is needed to mitigate their negative environmental impacts and ensure their resilience, while maintaining acceptable levels of productivity. Digital agriculture is a promising approach that brings together a wide range of modern technological tools like hyperspectral imaging. The SPAGHYTI project aims at developing services for agriculture in the form of applications that provide farmers with relevant and actionable information at the parcel level. These applications will rely on hyperspectral satellite imagery, enabling access to high-value information at a marginal cost with frequent revisits. Currently, two applications are defined in the user segment. These applications aim at assessing the nitrogen status and monitoring the (a)biotic stress levels of winter wheat.

Methodology

An intensive field campaign was organised in 2023 from March to July. Data were collected both in field trials and in farmers' fields located in Wallonia (southern part of Belgium). Field trials included fertilization trials, post-inscription variety trials (under conventional and organic management) and fungicide trials. Ground-based measurements included reflectance data acquired using a portable spectrometer working in the visible and near-infrared wavelength range (ASD FieldSpec 4), characterisation of canopy cover and LAI using digital hemispherical imagery, and disease severity scorings. Wheat samples were also collected and sent to the laboratory for the assessment of dry matter and total nitrogen using near infrared spectroscopy (FOSS NIR XDS). In parallel, satellite images were acquired from the EnMAP and PRISMA missions, depending on the weather conditions. The on-board sensors have a spatial resolution of 30 m and a revisit time of 4 to 27 days, depending on the tolerated off-nadir angle.

The development of the two applications are implemented using field data and hyperspectral data acquired by ASD and satellite sensors. First, the most relevant wavelengths, wavelength combinations and spectral indices are identified (Figure 1). Then, the different existing models are tested and assessed. Based on these two previous analyses, new algorithms are developed and calibrated.

Results

We initially focused on the assessment of the nitrogen status (nitrogen content) using ASD ground-based reflectance. The collected field data were divided into a training dataset ($n=112$; 3 trials) and an independent validation dataset ($n=108$; remaining trial and farmers' fields). A Generalized Additive Model (GAM) was used to model the nitrogen content (N) according to spectral variables. The spectral variables were preselected using the Pearson correlation. These variables corresponded to three wavelengths (645, 683 and 1656 nm), spectral indices of the literature ($NDVI_{1220_610}$) and new spectral indices (R_{747_988} , $NDVI_{747_988}$ and $NDVI_{550_1721}$). The nitrogen content was predicted with a R^2 value of 0.88, a bias of 0.00 and a RMSE of 2.06 (Figure 2A). Concerning the independent validation, the accuracy was a little lower: the R^2 , the bias and the RMSE were equal to 0.32, 0.63 and 3.44, respectively (Figure 2B).

Outlook for the future

The next steps are going to focus on the assessment of the nitrogen status using satellite imagery and the monitoring of (a)biotic stress levels. The data processing from the first field campaign is still ongoing. Based on data collected in 2023, the potentialities of using hyperspectral data for monitoring (a)biotic stresses and for characterizing grain protein will be investigated. Preliminary results will also be presented at the conference.

In order to complete the field dataset and validate our first analyses, a second field campaign will be organized in 2024.

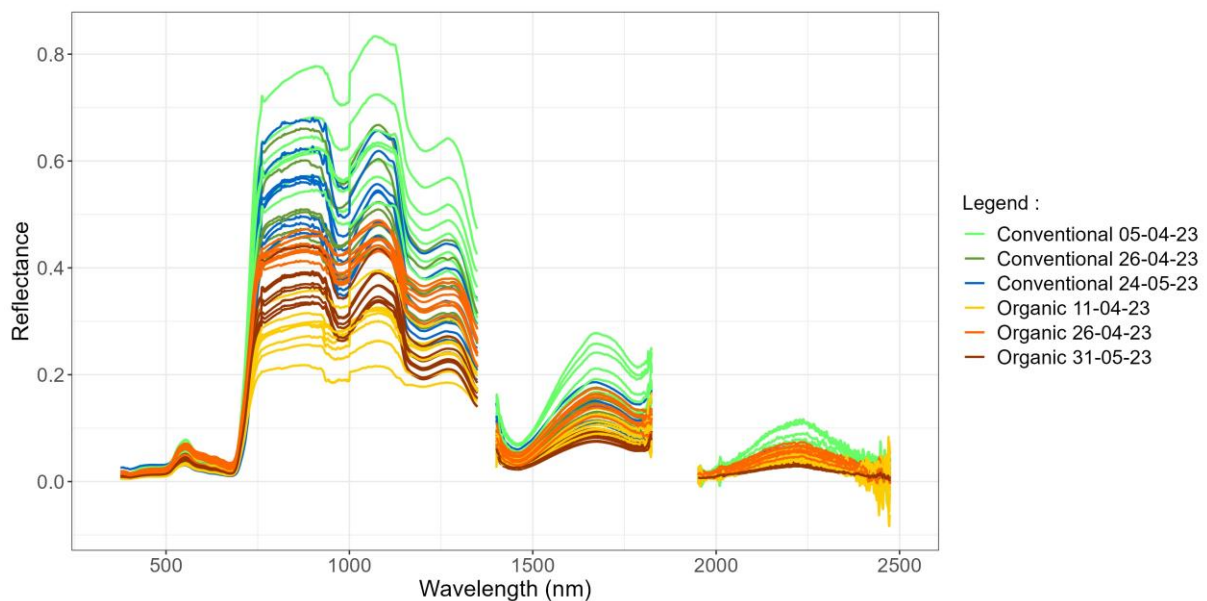


Figure 1. Spectra collected within variety trials under organic and conventional management during the fertilization application period using the ASD FieldSpec 4.

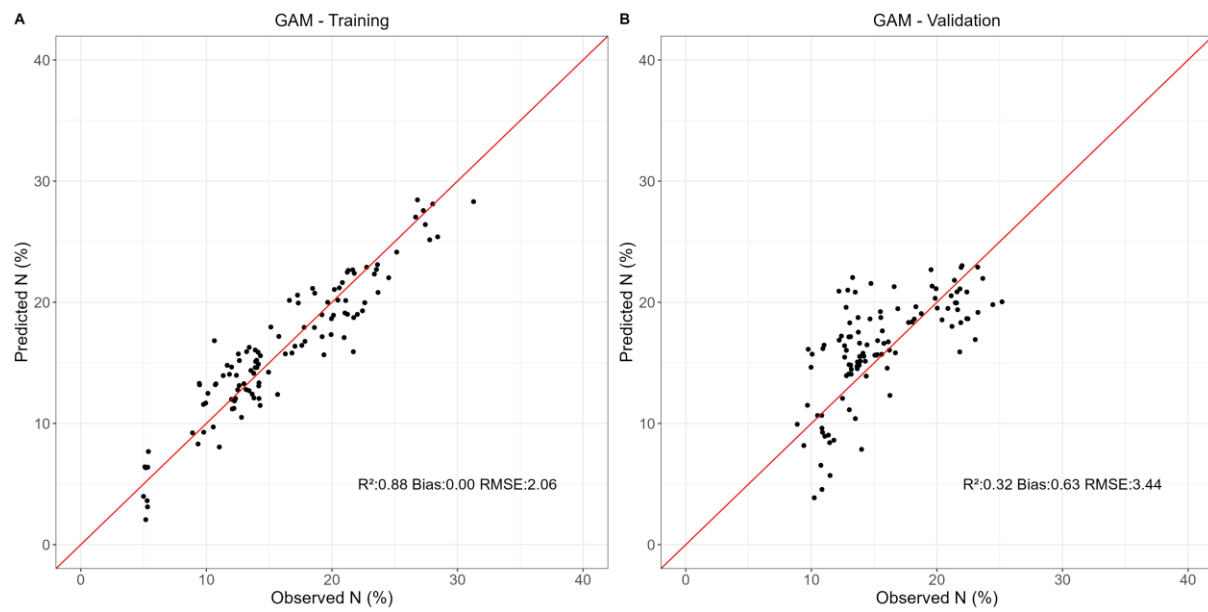


Figure 2. GAM accuracy for the training (A) and independent validation (B) datasets.