Exploring Sentinel-2 dense image time series to identify cover crop emergence and destruction dates in France: Towards the development of an approach for biomass estimation

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EXPLORING SENTINEL-2 DENSE IMAGE TIME SERIES TO IDENTIFY COVER CROP EMERGENCE AND DESTRUCTION DATES IN FRANCE: TOWARDS THE DEVELOPMENT OF AN APPROACH FOR BIOMASS ESTIMATION

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INTRODUCTION

Mitigating climate change is an unavoidable challenge for the coming years. Agriculture is an activity that presents a great opportunity to reduce the impacts of climate change, particularly through the implementation of agricultural practices that promote the sequestration of carbon in the soil. The implementation of cover crops (Fig. 1) such as oat, rye, phacelia, crimson clover, vetch seed, and/or niger between cash crops, aims to limit the disadvantages observed in periods of bare soil (e.g., risk of drainage and nitrate leaching) while offering a set of direct and indirect benefits (e.g., soil C storage, albedo effects, increase biodiversity, ...). In France, many farmers are implementing such practices, either voluntarily or in response to territorial regulations. In this context, the monitoring of cover crops requires the estimation of key vegetation descriptors in order to quantify their actual benefits. The project EASY4AG, developed as a partnership between EarthDaily Agro and CESBIO (*Centre d'Etudes Spatiales de la Biosphère*), aims to create a methodology for estimating the biomass of cover crops in France, using remotely sensed data and a ground-based observation network. To develop a robust and scalable methodology for estimating cover crops biomass over the whole country, it is first necessary to discriminate between the different main cropping practices. For doing so, it is important to derive the phenology of cover crops, and consequently properly determine the beginning and the end of the cover crops cycle, which is comprised between the emergence and termination of the cover crops, as cover crops can be destroyed before the senescence. Dense optical satellite image time series have already been successfully used for identifying such phenological events in agriculture for main cash crops, and for classifying different cropping practices, but there´s still the need to develop a robust method focusing on cover crops. In this first assessment, we aim to investigate the possibility of using Sentinel-2 vegetation indices time series to determine the beginning and end of the cycle and to determine the optimal period for biomass estimation, which corresponds to the period of higher vegetative development.

STUDY AREA, MATERIAL AND METHODS

Agricultural fields distributed over various agricultural regions in France are being monitored since the end of the crop summer season in 2022 (Fig. 3a). We collected data about sowing dates, percentage of each cover crop species, and measurements of biomass before destruction. We selected 78 fields distributed representative of the different regions in France and analyzed the Normalized Difference Red Edge Index (NDREI). This index was derived from the Sentinel-2 images, obtained from Google Earth Engine (GEE), between June 2022 to the late February 2023, when the cover crops are starting to be destroyed.

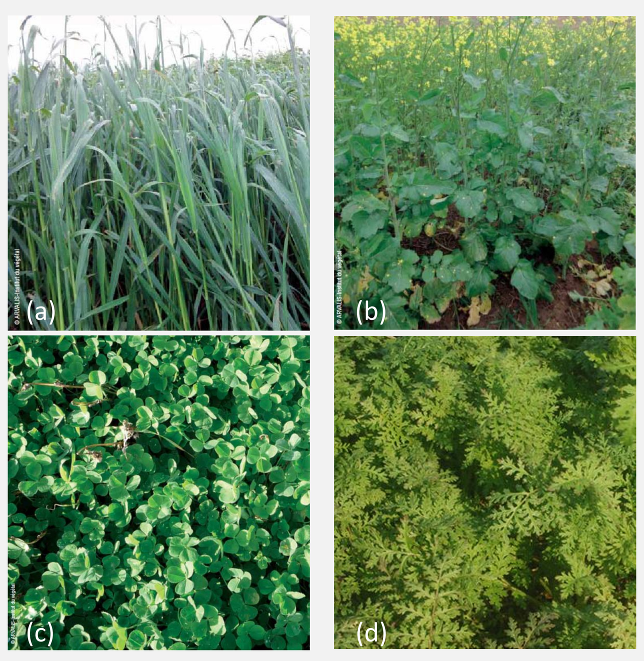

Figure 1. Examples of cover crops of the main representative families. (a) Poacea; (b) Brassicaceae, (c) Fabaceae and (d) Boraginaceae. *ARVALIS - Institut du végétal (PERSPECTIVES AGRICOLES - N°390 - JUIN 2012)*

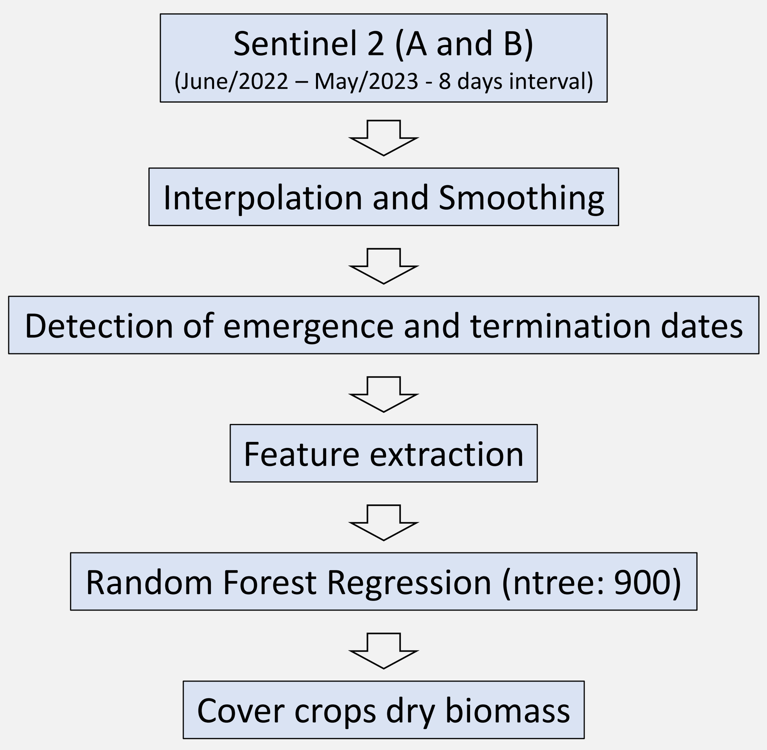

Figure 2. (a) Fluxogram of the conceptual framework for the cover crops biomass estimation.

We used the QGIS Plugin GEE Time Series Explorer (Rufin et al., 2021) to extract the time series, and for the cloud and shadow masking. We used the Radial Basis Function (RBF) Schwieder et al., 2016; Bendini et al., 2019) for interpolating the time series in order to correct for the residual noisy observations caused by cloud and shadow cover. Then, for estimating the emergence dates we applied the Whitaker smoother (Eilers, 2003) to eliminate false peaks and then, from the inverse smoothed time series we detected the valleys, considering a minimum interval of 10 observations between them. The first valley lower than 0.2 was considered as the emergence date. For the termination dates we applied a moving average (order = 4) to the interpolated time series and the last intersection between the moving average and the interpolated series was considered as the termination date (Fig. 3b). We compared the detected dates to the ground truth data as informed by the farmers to evaluate the results' accuracy.

RESULTS AND DISCUSSION

The average difference between the ground truth dates and the detected dates was of 18 days. For the termination dates, we didn´t have the ground truth because it was not provided by the farmers. Although the results are promising, many outliers were observed. Those outliers occurred mainly when there were overlaps within the crop calendar, with a full cycle of cash crops still observed while cover crops starts, and when frost events happened, leading to false valleys in the time series. We also observed that the difference between the planting dates and the emergence can vary depends on the fields conditions (mostly climate conditions), which leads to higher differences between the ground truth dates and the detected dates. In the case of the termination, depending on the farmers practices (winter-kill, mowing, tillage, a combination of mowing and tilling), we observed by a visual inspection on the time series that the approach didn´t perform very well, so other methods should be considered.

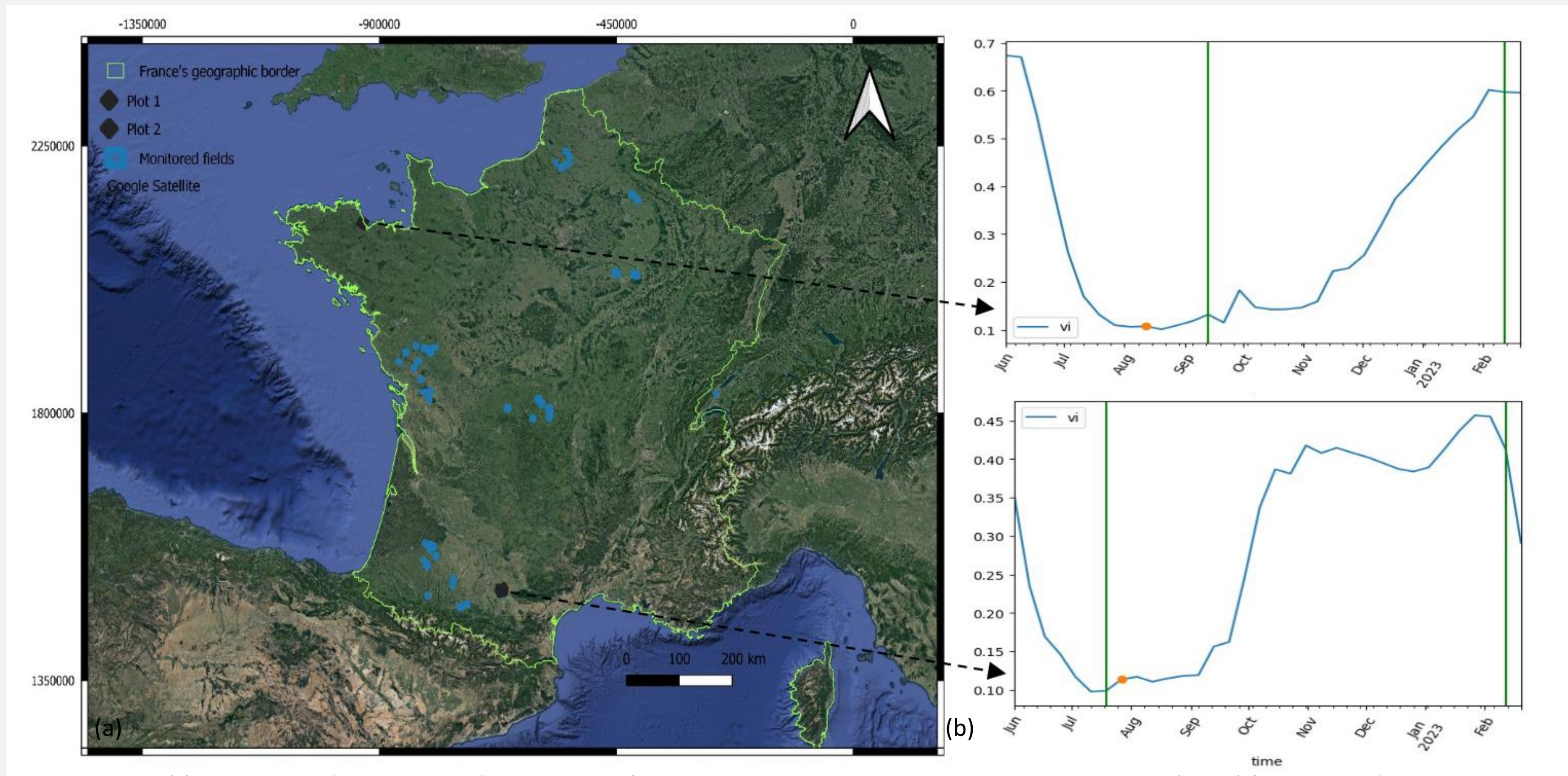

Figure 3. (a) Distribution of the monitore fields in France (Europe Albers Equal Area Conic Projection, ESRI: 102013) and (b) examples of NDREI time series with the detected emergence and the ground thruth dates of both sowing and destruction of the cover crops.

In order to demonstrate the conceptual framework towards the development of the approach for the biomass estimation (Fig. 2), after the end of the cover crops cycles, we updated the time series (Fig. 4), following the same procedure used before, and used the complete time series between the detected emergence and termination dates as input for a Random Forest (RF) regression model (ntree = 900) (Figure 6), also testing different vegetation indices (Fig. 5).

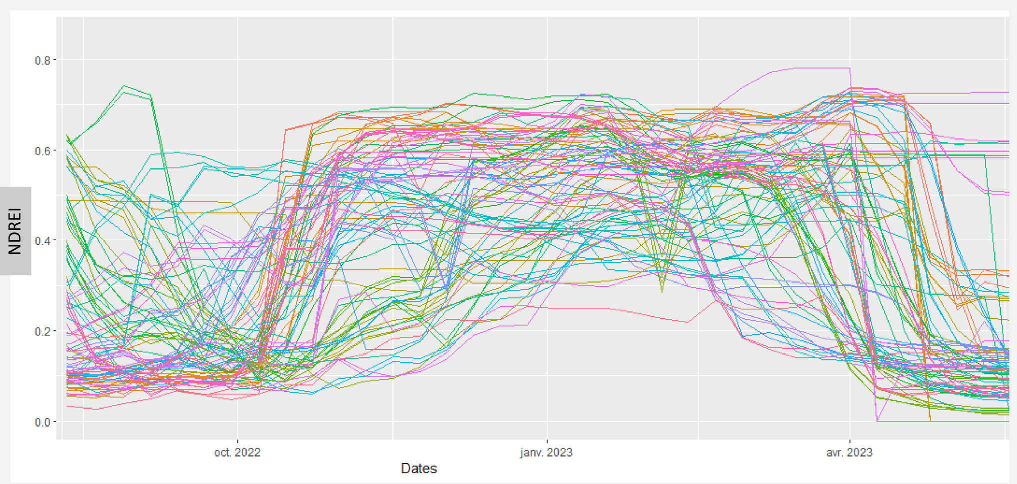

Figure 4. NDREI fitted time series of the target points.

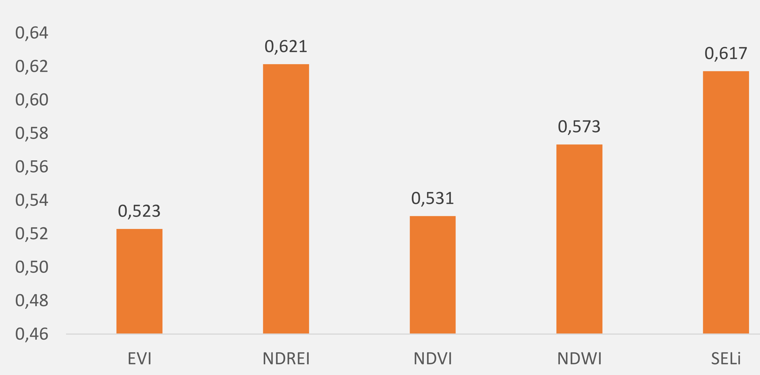

Figure 5. Comparison of the R^2 obtained for each model between different vegetation indices.

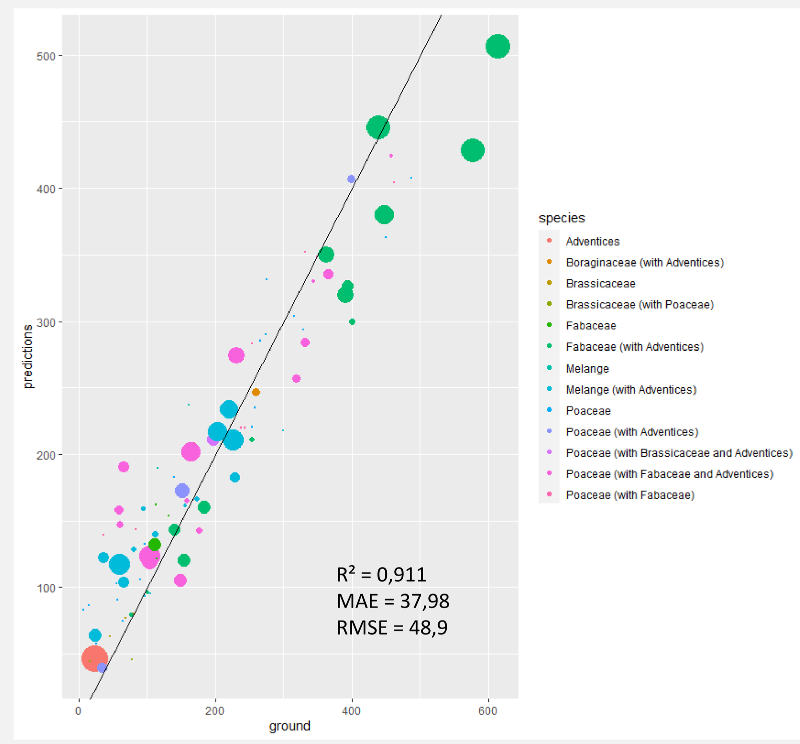

Figure 6. RF Scatterplot of the best model applied to the complete dataset. The size of the dots are related to weed percentage.

We evaluated the model results by spliting the dataset on 75% for training and 25% for testing, and measuring the mean R^2 of 500 random iterations.

OUTLOOKS AND ACKNOWLEDGEMENTS

These are the very first results of the EASY4AG project, which aims to develop a methodology for estimating cover crops biomass. Many challenges still need to be tackled, but the results are encouraging. As future works we aim to advance on the analysis considering other methods for the phenological events detection, and also improve the modelling approach including different time series metrics and variables. This project has been financed by the French government as part of the France 2030 program.

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