

Methodological Framework for Developing a UAV Based Dataset to Validate EO Based Fractional Vegetation Cover Estimates

Kevin Kühn¹, Paul Karlshöfer¹, Peter Schwind¹, Uta Heiden¹

¹ German Aerospace Center (DLR), Earth Observation Center (EOC), Weßling, Germany

Keywords (5): UAV, Validation, Hyperspectral, Fractional vegetation cover, Time Series

Challenge

Validating fractional vegetation cover (fCover) at a large scale is challenging because so far in situ measurement availability is often very local, limited and fragmented. Furthermore, existing methodologies show limitations in producing consistent fractional vegetation cover validation data from RGB UAV imagery across the extremely diverse surface appearances encountered in agricultural fields. The proposed methodology addresses this gap by employing an ensemble approach that integrates the complementary strengths of image segmentation and classification techniques. This framework is further supported by derived surface parameters, resulting in a unified processing chain. At the same time, the validation approach is cost and time efficient, easy to perform and works regardless regional characteristics. Taken advantages of the ESA CaRMA campaign, the DLR collected ~15.000 UAV RGB images between 03th of March until 31st of October (~weekly) under a variety of illumination conditions, covering a complete vegetation cycle in ~87 fields. By explicitly choosing a lightweight consumer UAV, no expert knowledge for operating the UAV is necessary, neither it require maintains or calibration of the camera system. It can be transported in a backpack to maximize fast, cost-effective data acquisitions to create a comprehensive dataset for the validation of EO based fractional vegetation cover products. This study, described the developed process to design a comprehensive dataset and outlines the methodology for validating fractional vegetation cover products.

Methodology

Data acquisition was performed using a DJI Air 3 UAV at flight altitudes between 3–8m above ground, depending on vegetation height, at a constant flight speed of 8 m s⁻¹ along predefined flight tracks. The same ground tracks were repeatedly captured in nadir (~weekly) with an accuracy of approximately ±0.5 m, constrained by the UAV's GPS precision. Image processing involved two U-Net models. The first U-Net model called VEG-Net (Precision=0.97, Recall=0.81), was trained on the VegAnn dataset (Madec et al., 2023) to identify photosynthetic active vegetation (PV). The second U-NET called DRY-Net (Precision=0.65, Recall=0.63), was trained on a set of 250 manually labelled UAV images to segment non-photosynthetic active vegetation (NPV) with a particular focus on crop residues. Further, a Support Vector Machine (SVM) was trained and applied to classify each pixel based on predefined colour spaces: greenish tones PV, yellowish–brownish tones for NPV or bare soil, and grey–black tones for shadow. The SVM makes it possible to assign blurred, shaky, or out-of-focus images/pixels to the specific classes. Surface parameters were derived from the original imagery on a per-pixel basis using a moving-window approach, including texture metrics, to capture spatial patterns and local structural information. These parameters enhance the discrimination between NPV and bare soil (BS). Each model shows strengths and weaknesses in special cases. Therefore, the produced binary masks from each model were

subsequently combined to a final fractional vegetation cover mask per image. This methodology was applied to all ~15,000 images creating a dense dataset that contains high-resolution RGB imagery with corresponding labelled data.

Study area and data

The agricultural landscape surrounding Puch is characterized by a mosaic of cultivated fields, grassland parcels and scattered tree- and hedge structures. Vegetation is dominated by crop species typical of temperate Central European farming systems, including cereals such as corn, summer/winter wheat, barley, triticale as well as maize and rapeseed.

Discussion and Conclusions

The major challenge remains the reliable discrimination between NPV and bare soil (BS), which is largely caused by the limited spectral resolution of the RGB camera system. To address this limitation, multiple methodologies were combined to extract as much information as possible for accurately distinguishing the fCover components. Although the preliminary results indicate a strong potential, individual methods still show shortcomings in consistently and accurately labelling pixels correctly. This underscores the necessity for continued methodological refinement and evaluation to further improve classification/segmentation performance. The proposed method demonstrates the capability to overcome the limitations of time-consuming and spatially sparse field data collection compared to traditional ground-based approaches such as frame sampling or single-image acquisitions. The developed dataset can subsequently be applied to the validation of fractional vegetation cover products derived from EO data over the Puch study area.

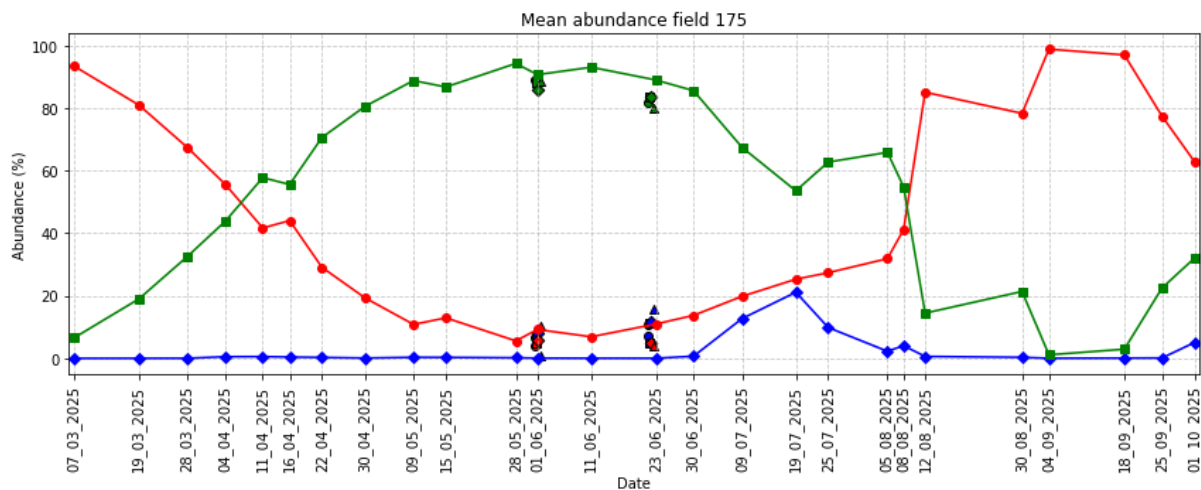


Figure 1. Fractional vegetation cover abundances for one example field (Puch-175) across 26 UAV data acquisitions between March and October 2025. Fractional vegetation cover values were derived with the proposed methodology ensemble, showing NPV abundance (blue), PV abundance (green), and BS abundance (red). The growth phase of the vegetation in the field (slowly rising PV values with simultaneously falling BS values) and the time of harvest (abrupt drop in PV and sharp rise in BS values) are clearly visible.

Literature:

MADEC, S., IRFAN, K., VELUMANI, K. *ET AL.* VegAnn, Vegetation Annotation of multi-crop RGB images acquired under diverse conditions for segmentation. *Sci Data* **10**, 302 (2023). <https://doi.org/10.1038/s41597-023-02098-y>