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Abstract
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Developing an automatic approach for validating fractional cover of soils in agricultural fields using UAV and cellphone images

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Challenge (800 - 1000 characters incl. spaces)

Fractional Vegetation and Soil Cover (fCover) is an important land surface parameter especially, in agricultural systems. It provides quantitative cover of photosynthetically active vegetation (PV), non-photosynthetically active (NPV), and bare soil (BS) to serve the data needs for soil parameter modeling, soil erosion monitoring and the identification of land degradation. Further, it supports the observation of the impact of climate-friendly tillage practices on carbon stocks in agricultural systems (farming practices). With the increasing accessibility of hyperspectral data, the mapping of fCover is possible with significant accuracy due to the high spectral information content, especially in the SWIR wavelength region. Thus, large-scale validations are becoming necessary. However, validating fCover is challenging because so far ground data availability is very limited and fragmented. Nevertheless, for operational L3 processors, large-scale validation approaches are necessary and required to provide reliable accuracy and uncertainty measures for the land product. At the same time, the validation approach should be easy to implement, operate globally and should be cost and time-efficient. The idea of this study is to test and enhance a fCover validation method that is suitable to validate the separation between bare soils and non-photosynthetically active vegetation (NPV) with the perspective of transferring this approach in space and time.

Methodology (1200 – 1500 characters incl. spaces)

The idea is to use a deep learning model that produces fCover abundance information from RGB images, such as from UAV and cellphone images. Once the model is robust and transferable, it can be used for future validation campaigns by using RGB images from the validation area. Pioneer work has been done by a research group in France (INRAE) that have prepared the VegAnn dataset and developed the two stage SegVeg approach using RGB images (Serouart, Mario et al. 2022, Madec et al., Scientific Data, 2023). First, the whole RGB image is classified into a background and vegetation mask using a U-Net deep learning network with encoder-decoder architecture (semantic segmentation). Second, the predicted vegetation pixels are classified into PV and NPV using SVM. Both binary model outputs are merged to create a 3-class mask that provides pixel-wise information about PV, NPV, and BS.

In this study, we test and adapt this approach with priority to separate NPV and BS. The first step is the development of a suitable database to train the used convolutional neural network (U-Net). The tests start with RGB images of different cellphones and RGB images from the DJI Air 3 UAV camera system. The non-homogeneous images pose a particular challenge to equally capture different brand-specific image software optimization. Further, most of the soils contain stones that additionally need to be considered. To overcome these challenges, preprocessing steps are required. Recorded images have strong geometric distortions which made it necessary to crop the outer margins up to 30% depending on the acquisition height. Out of each preprocessed image, 10 patches with a size of 256*256 pixels are randomly cut out for labeling. To implement a consistent and standardized labeling workflow the Software "Sample Point" with an equally distributed 7*7 grid was used. In the proposed method it will be tested if the combination of a convolutional neural network and support vector machine can distinguish PV, NPV and BS based on different image sources.

Results (1200 – 1500 characters incl. spaces)

So far, we have just preliminary results. There are fCover results from several EnMAP images across Germany. For this purpose, we used an in-house processor that retrieves NPV, PV and BS on a subpixel level. The validation is done per agricultural field, so we assume to have constant values across a field. This makes it possible to compare these results with an RGB image transect acquired by an UAV. For the model development, we created a database composed of 268 cellphone images from 5 different individuals, areas and times during the day and year with a visible variability in brightness. Further, we used the UAV and tested different flight heights. The best balance between area coverage and separability of fCover was at an acquisition height of about 5 meters. The first results reveal the general suitability of the proposed approach. However, additional classes need to be considered such as stones and shadow. Shadow is creating a large spectral/brightness variety that needs to be incorporated. Since semantic segmentation classifies each pixel, we will first evaluate the model accuracy by, a) using three standard classification metrics, Precision, Recall and F-1Score to quantify the performance at the class level. In addition, the overall F-1 score and the overall accuracy were calculated for a more global evaluation of the segmentation performance. If sufficient model robustness, accuracy and reliability are achieved, we will feed the model with UAV data of large sites for a real accuracy assessment of the outcome of our fCover processor developed at DLR.

Outlook for the future (800 - 1000 characters incl. spaces)

The successful validation of the DLR fCover products is of major importance. It is planned to use the validated fCover abundance maps for several purposes. Bare soils are exposed to erosion effects as well as to carbon sequestration processes that should be prevented for more carbon-conserving agriculture. In contrast, soils with dry vegetation are still protected from erosion due to the root zone. Thus, the duration of soil exposure is one parameter describing the soil quality and health. Additionally, we use the validated fCover products for a data fusion approach in which the EnMAP-based fCover outputs are used to improve Sentinel-2 based fCover products. Since Sentinel-2 does not have enough spectral information in the SWIR to distinguish between BS and NPV, EnMAP-based products can help to develop a deep learning-based model. This work will be presented by P. Schwind et al., 2024 at the EARSeL. In the future, it is planned to increase the data base for the U-Net model, including also the worldwide distributed VegAnn data set and new cellphone images from regions that are still underrepresented.

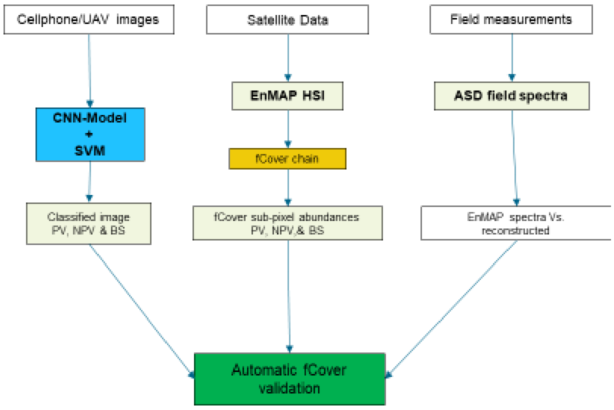

Figure (a) Integration of proposed method in the fCover framework.

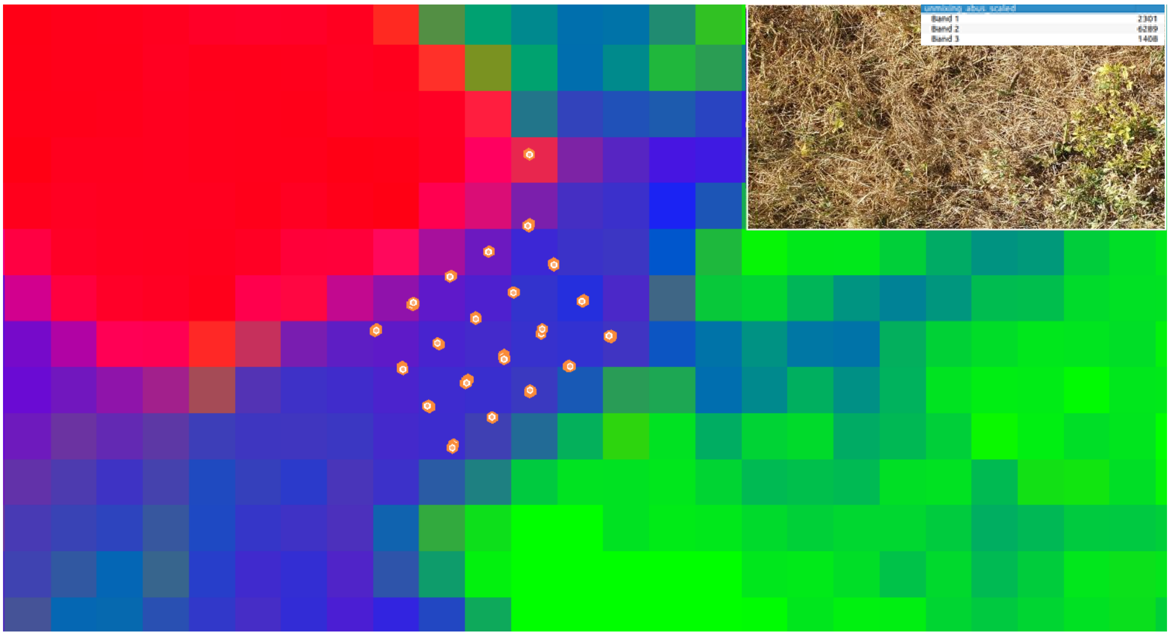

Figure (b) The basemap is a fCover sub-pixel abundance map. Bare Soil (red), NPV (blue) and PV (green). Orange dots represent the location of recorded cellphone RGB images that are used for the validation. Example image top right corner + derived subpixel fraction of each class.