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Abstract
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Creating Temporal Hyperspectral Regional Endmember Bundles (THREBs): Automatic imaged based EM extraction and library reduction to derive regional fractional vegetation cover

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Challenge

With the increasing availability of hyperspectral images (HSI) through missions like PRISMA, DESIS, and EnMAP, as well as the upcoming CHIME mission, the opportunities for large scale analyses are now being realized. Simultaneously, the establishment of operational processing chains is becoming increasingly important. With that in mind, the Earth Observation Centre at DLR has developed an fCover processor which extracts and classifies endmembers from HSI and, following a spectral unmixing step, generates soil and vegetation cover maps. To generate homogeneous fCover maps over large areas it is necessary to overcome challenges like generalized EM libraries, incoherent unmixing, and unintentional use of false EMs that can occur in single scene processing. The methodology presented here alters the established fCover processor by exploring the potential of processing multiple scenes, thereby creating temporal hyperspectral regional endmember bundles (THREBs) and generating coherent region-wide fractional vegetation cover maps in an automated fashion.

Methodology

To create THREBs and fCover maps, the following methods were used. First, from each HSI within a predefined region, EMs are extracted using the SSEE method (D.M. Rogge et al. 2007 Remote Sens 3, no 110). After the extraction of the pure spectra, the EMs are labelled using a well-trained Random Forest classifier and stored in a preliminary THREB. These steps are performed for multiple scenes in a defined region. To ensure maximum spectral variability, the preliminary THREB is pruned regarding scene-specific features of individual but consecutive HSIs using the AMUSES approach (Degerick, et al. 2017, Remote Sens 9, no 6). This method adds a spectral separability measure to the workflow of MUSIC-PA to decrease internal redundancy by a) selecting EMs that best represent the spectral variability by using the HySime algorithm b) calculating the Euclidean distance between estimated image subspace and EM spectrum and c) choosing spectra with the lowest projection error between the image and EMs. After sorting all library spectra by their distance to the HSI, only a fraction of the highest ranking spectra are retained based on predefined thresholds. The eligible spectra are assessed one by one using a spectral separability measure by combining the Jeffries Matusita distance and Spectral Angle (JMSA). Only if a signature is sufficiently dissimilar from an already chosen spectra, will it be included in the THREB. The final THREB is the resulting pruned EM library from all HSIs and is used as input to the linear spectral unmixing using the µMESMA approach. As a result, Fractional Cover Maps with subpixel abundances of photosynthetically active vegetation (PV), non-photosynthetically active vegetation (NPV) and Bare Soil based on a regional THREB are generated.

Results

In a first comparison EnMAP scenes around Munich (29.6.23 & 25.09.23) and scenes from Camarena Spain between April and October 2022 were processed and unmixed by a) using EM extracted from single scenes and b) creating and using THREBs. Single scene processing reveals good results overall. However, even with small temporal or spatial differences between acquisitions, fCover abundances can differ substantially by ±5%PV, ±11%NPV, ±8%BS for two or more consecutive observations (25.09.23). Using THREBs showed a significant improvement concerning unmixing coherence of fCover abundances and RMSE values (by 0-18%). By combining region specific EMs (SSEE) in one preliminary THREB, reducing the preliminay THREB scene specific (AMUSES), and then unmixing all HSI of one region one by one (µMESMA) with THREBs, the results improve compared to single scene processing. Additionally, ground truth data acquired near Munich in Oct 2023 confirm the assumption that THREBs increase the quality of large-scale analyses.

Outlook for the future

In the next step, Germany will be defined as a region by taking all available EnMAP scenes from 2022 and 2023 into account. THREBs will be compiled (annually and at 3-month intervals) as well as the corresponding fractional vegetation cover maps. These results will be compared to the outcomes of single scene processing to evaluate strengths and weaknesses and to further improve the proposed method. In this process, additional constraints can be explored and adjusted. In the second half of 2023, ground truth data were collected with simultaneous EnMAP overflights for validation. These measurements from an ASD field spectrometer and RGB cellphone images will be further integrated and used as a starting point for fCover/THREB evaluation. Through the development of expanding/evolving THREBs, the SSEE and machine learning steps in the fCover processor could be skipped and HSIs from existing (EnMAP) and future mission (CHIME) could be unmixed directly from a set of well characterized and consistent THREBs.

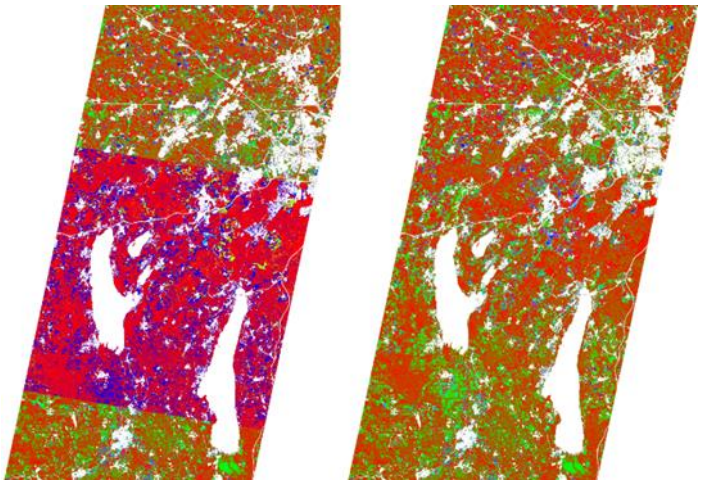

Figure (a) Single scene EM extraction and unmixing(left)and THREB unmixing (right). EnMAP 29.06.2023 south of Munich

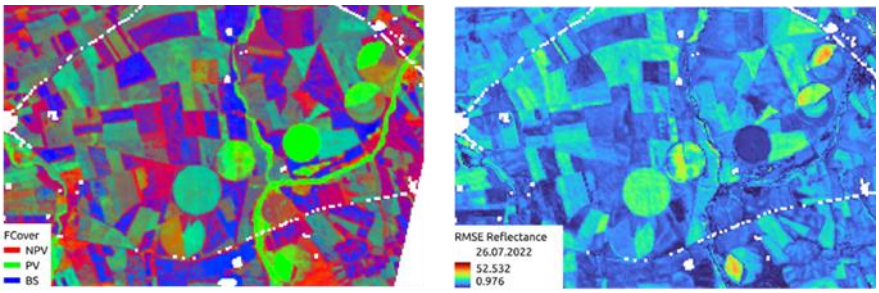

Figure (b) fCover sub-pixel abundance map(left) and corresponding RMSE values in Reflectance (right). Unmixing based on a THREB. EnMAP, Camarena, Spain 26.07.2022.

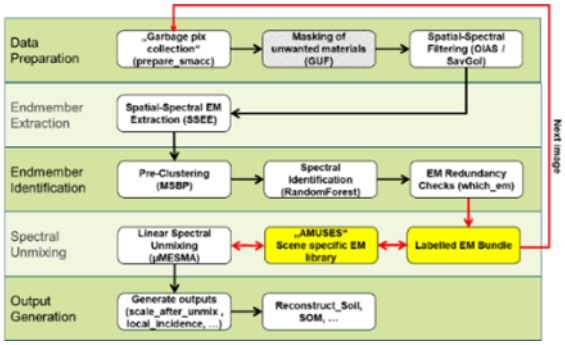

Figure (c) Overview of the adjusted fCover processing chain.