Classification of different plastics on soils based on lab measurement and simulated PRISMA/Hyperion scene

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Plastic products, with the advantages of light weight, waterproof, durable etc., have become increasingly dominant in the marketplace since their development in the 1930s. Along with the rapid developing, the demands for the disposable products rose rapidly. However, as plastic litter is released into the environment, due to their longevity and durability, aggregations are formed in terrestrial and aquatic ecosystems, which severely impacting the habitats. Remote sensing imagery with moderate to high temporal, spectral, and spatial resolution bears the potential to be a powerful tool for qualitative and quantitative mapping of the distribution of plastic litter in the environment.

With the development and improvement of Near Infrared (NIR: 0.8-2.5μm) instrument technology, chemometrics has become one of the most rapidly developing and popular technique for classification (qualification) and regression analysis (quantification) in (imaging) spectroscopy. As petroleum derivatives with the backbone of C-H chains and distinctive functional groups the absorption of plastics in the short-wave infrared (SWIR) is mainly controlled by the stretching vibration overtones and combination modes of C=O, C-C, and hydrogen-containing function groups (X-H) including O-H, N-H, C-H, and others. The SWIR absorption wavelengths and intensities of different groups as well as of the same group as part of a different molecular structure are varying due to anharmonicity and Fermi resonance offering the potential to identify and distinguish different plastic types based on their spectral absorption features. Most studies focus on the differentiation among different plastics by lab measurement and near-realtime algorithms already allow the sorting of plastic waste on automated conveyor belts. Besides, SWIR as one of the most important atmospheric windows that has been investigated operationally in remote sensing, gives a great potential for remote detection of plastics with particular absorption features right at this range.

To investigate this potential, we setup two scenes with samples of 5 widely used consumer plastics (HDPE, PVC, PS, PP, PET) with different optical characteristics (transparent, translucent, opaque and bright, opaque and dark). Samples were placed on two different soils, a bright sandy soil and a dark organic soil. Both scenes were measured with the HySpex SWIR320m-e hyperspectral imager under lab environment and internal measurement protocol. A knowledge-based decision tree classification method based on the distinctive absorption features caused by the molecular structure is developed and applied. The analysis of lab measurements shows that all 5 plastics are well differentiated. Yet, to assess the potential to classify plastic litter from larger scaled remote sensing data, other complex aspects need to be considered, such as noise, and the superposition of absorption bands of atmospheric water as well as of different surface materials. To get a theoretical insight of the capability of space-borne satellites for the detection of plastics, a simple sensor simulation is performed. The simulated scene is generated by spectral resampling of the lab data using the spectral band configurations of PRISMA and Hyperion. The result shows that for EO1-Hyperion sensor, PE, PS (100%), and PET (> 89.1%) can be well classified on both backgrounds, but the performance on identifying PP, PVC is not as good. The classification results of PE and PS for the simulated PRISMA data are as good as for the Hyperion sensor on both backgrounds. However, the differentiation of PP from PVC on sand and of PET from PS on soil is not as good. In conclusion, due to the different spectral band configurations, the classification results from simulated PRISMA and EO1 Hyperion shows disparate performance, even though, it can well separate plastics from the two different backgrounds. These findings play an important role for mapping plastics, because it would enable the exploitation of archive data as well as new acquisitions of the upcoming hyperspectral satellites. There are 165,000 image data sets of EO-1 Hyperion, covering an epoch of more than 15 years (2000-2017), which could provide us with valuable information on the deposition of plastics in the environment in the past and PRISMA which is recently in operational mode can continue the data series to the present.