I spy with my hyperspectral eye
unique reflectance database of plastics and riverbank-harvested litter

Tasseron, P., van Emmerik, T., Peller, J., Schreyers, L., Biermann, L.

Methods
Hyperspectral imaging (400-1700 nm): plastics, water and vegetation

Result 1
Linear discriminant analyses: relevant wavelengths in spectral signatures

Result 2
Validation of spaceborne remote sensing

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Background and objectives

- Airborne and spaceborne remote sensing (RS) collecting hyperspectral imagery provide unprecedented opportunities for detection and monitoring of riverine and marine plastic pollution.

- Several fundamental experiments in controlled environments exploring spectral signatures of virgin and harvested plastics have been conducted.

- **Objective 1:** establishing a high-resolution library of spectral signatures of virgin plastics and riverbank-harvested macrolitter.

- **Objective 2:** identifying which wavelengths are most efficient in discriminating between plastics, vegetation, and water.

- **Objective 3:** validating current satellite remote sensing based on wavelengths measured with the Sentinel-2 and Worldview satellites.
Methods (1): Experimental setup

- The hyperspectral imaging was performed using a double camera setup (Specim FX10 and Specim FX17).

- Together, the two cameras spanned the electromagnetic spectrum from 400 to 1700 nm, covering the visual (VIS) to shortwave infrared (SWIR) range.

- To ensure consistent illumination of the items, two full-spectrum halogen lamps illuminated the samples at roughly 15 degrees off-axis of the cameras.

- The integration time of the cameras was set to a value between 4 and 8 milliseconds depending on the brightness of the items, minimising overexposure, and maximising the signal-to-noise ratio.

Figure 3: Schematic of the experimental setup, emphasising the line-scanning nature of data collection.
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Methods (2): Data preparation

- To further optimise the signal-to-noise ratio, the raw reflectance data were converted into relative reflectance.

\[ R_n = \frac{(R_0 - R_B)}{(R_W - R_B)} \]  \hspace{1cm} (eq. 1)

\[ R_{ni} = \frac{(R_n - \min(R_n))}{(\max(R_n) - \min(R_n))} \]  \hspace{1cm} (eq. 2)

- The next step involves normalising the intensity values of all pixels in the dataset, equalising the darker and lighter pixels belonging to a specific sample item (eq. 2).

Methods (3): Data analysis

- Representative pixels for each item were annotated by hand. Each image was segmented into objects, and each object defined according to an item class, either a type of plastic, vegetation, or water.

- The resulting seven classes were used in a data pipeline to (i) extract the spectral reflectance curves of each item class, and (ii) conduct a Fisher linear discriminant analysis (LDA) to find diagnostic features in the spectral reflectance curves.
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Results

- The reflection spectra of water, vegetation and the five types of plastic each look different.

- Overall, the absorption features of the polymer types, vegetation and water show good agreement with absorption features of similar reflection signatures documented in other studies.

- The reflectance of water in the NIR-SWIR range (950-1700 nm) is consistently close to zero, whereas plastics and vegetation are characterised by higher reflectance values and absorption peaks.

Figure 4: Normalised spectral reflectance curves of the virgin plastic collection, water, and vegetation. The curves were calculated separately for both cameras, explaining the jump in reflectance after the ‘no data’ zone.
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