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Enhancing PRISMA and Sentinel 2 Capabilities for Marine Plastic Litter Detection Using Image Fusion Techniques, Spectral Signature Unmixing and Spectral Indexes

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Introduction

-Marine debris (MD), especially plastics, have been a severe worldwide concern for decades, having adverse environmental, socio-economic, maritime travel safety and marine life impact.

-Recent research efforts have been focus on MD detection and monitoring through remote sensing data (laboratory hyperspectral and satellite multispectral data).

-Classification methodologies as well as spectral indexes are the most common approaches for MD detection.

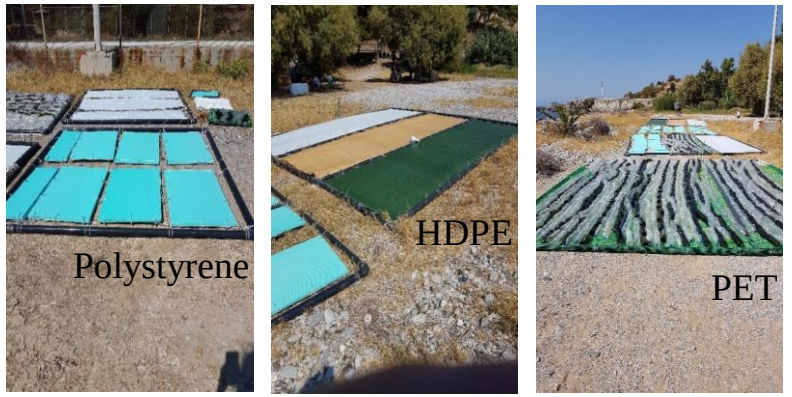
Restrictions on the spectral and spatial resolutions of the available sensors didn't allow for small plastic object detection.

In this study, we exploit pansharpened PRISMA and Sentinel-2 (S2) fused with WV2/3 images for MD detection using spectral indexes and spectral signature unmixing.

Field campaigns and data acquisition

12 floating plastic targets:

- 3 sizes: 5.1 m × 5.1 m, 2.4 m × 2.4 m και 0.6 m × 0.6 m.
- 4 types/compositions of plastic materials: PS, HDPE, PET, mixed.
- 3 10×10 m (PET-1.5 l bottles, LDPE bags, and fishing nets)
- a 28 m circular plastic target
- a 28 m circular wooden target



Algorithm design datasets:

- 2 PRISMA (TOA radiance)
- 1 S2-WV3 (TOA reflectance)

Algorithm validation datasets:

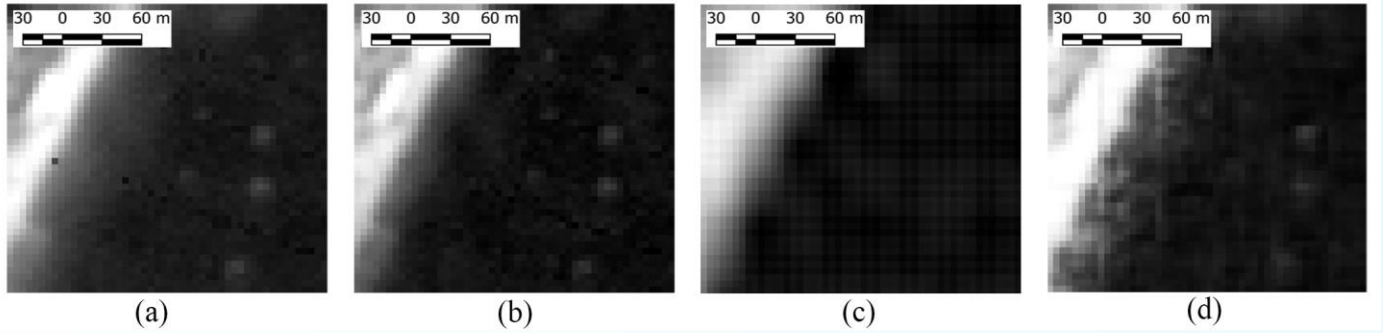
- 2 PRISMA (TOA radiance)
- 1 S2-WV2 (TOA reflectance)

PRISMA Pansharpening

- Component substitution (PCA, GS, GSA)
- multiresolution analysis (SFIM, MTF-GLP, MTF-GLP-HPM, LMM, LMVM)
- Hybrid (GFPCA)
- Bayesian (BayesNaive, HySure)
- Deep learning (PNN, CAE, GDD)

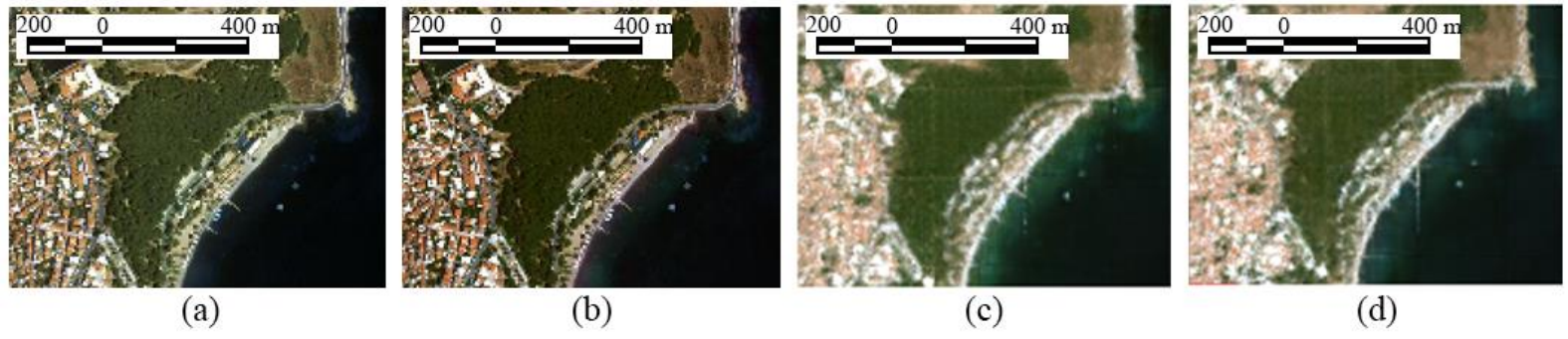
Sentinel 2 and WorldView 2/3 fusion

- Pansharpening based (PCA)
- Spectral unmixing based (CNMF, Lanara's method, HySure, FUSE)
- Deep learning (PNN, PNN-Siamese, ResNet, GAN, SRGAN, RCAN)



Pansharpening results for the PRISMA image acquired on 18/9/2020 (zoomed in view) (670 nm). (a) PCA. (b) SFIM. (c) BayesNaive. (d) PNN – histogram clipping.

Fusion results for the S2 and WV 3 images acquired on 7/6/2018 (zoomed in view) (natural colors). (a) CNMF . (b) HySure. (c) ResNet. (d) GAN.



MD detection through spectral unmixing analysis

The spectral unmixing process can be summarised in the following steps:

i) Estimation of the number of endmembers (Outliers Detection Method (ODM));

ii) Dimensionality reduction (Minimum Noise Fraction (MNF) algorithm);

iii) Endmember extraction and labelling (N-FINDR, Spectral Angle Distance (SAD) algorithms);

v) Inversion of the fully constraint mixture model and calculation of the abundance maps (Network Based Method (NBM)).

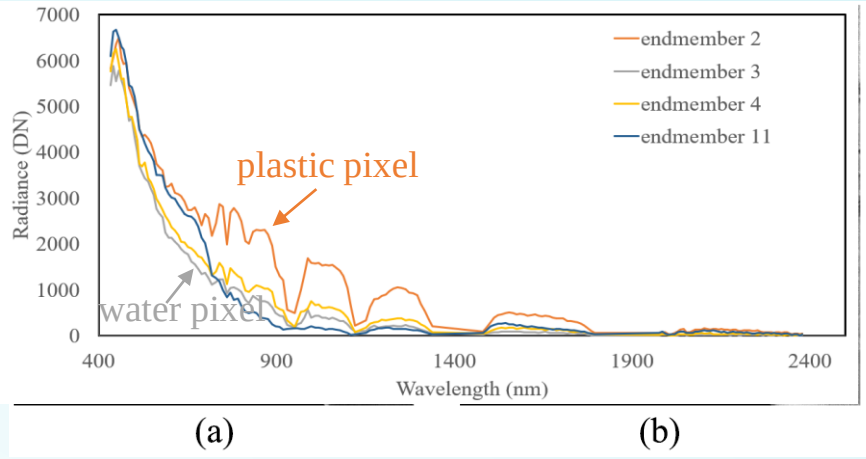
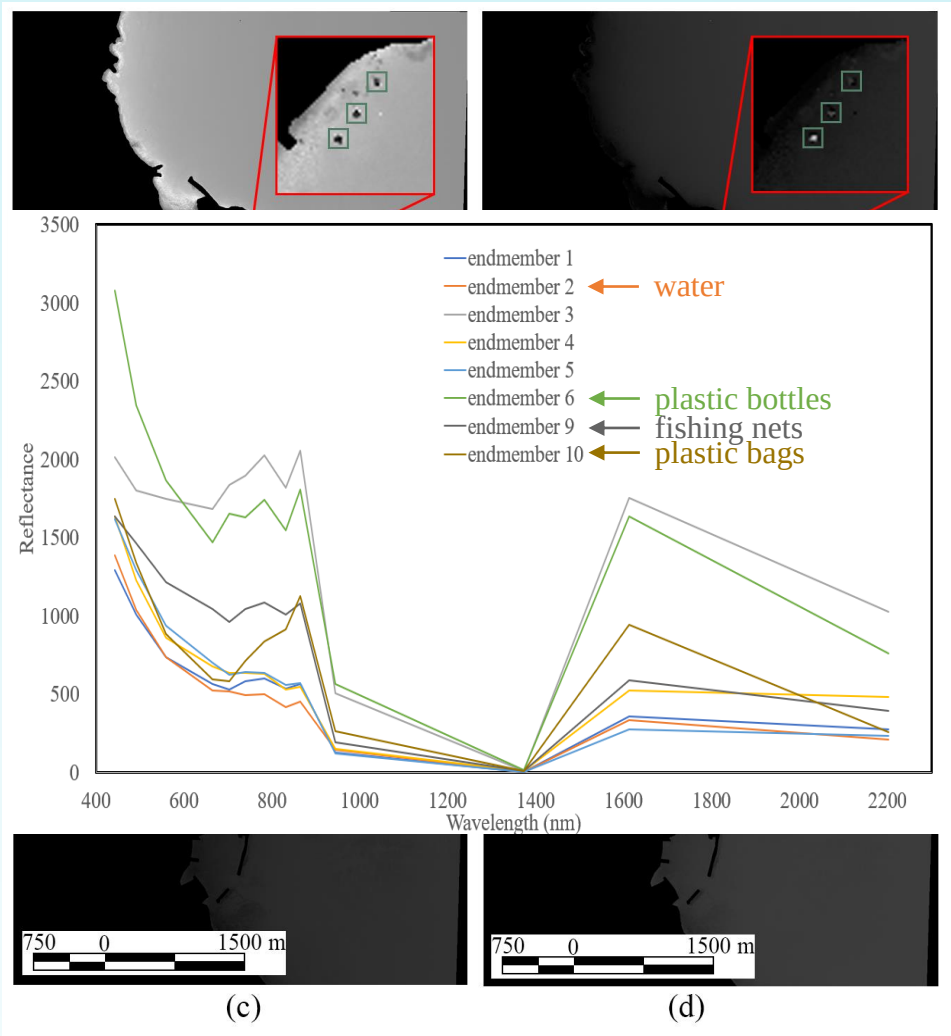


Figure 5. Abundance maps of (a) the plastic and (b) water endmembers for the PCA pan-sharpened PRISMA image acquired on 18/9/2020.

Land and very swallow water (<2 m depth) is masked out for all following processing.



Abundance maps of the (a) water, (b) plastic bottles, (c) fishing nets and (d) plastic bags endmembers for the CNMF fused S2-WV3 image acquired on 7/6/2018.

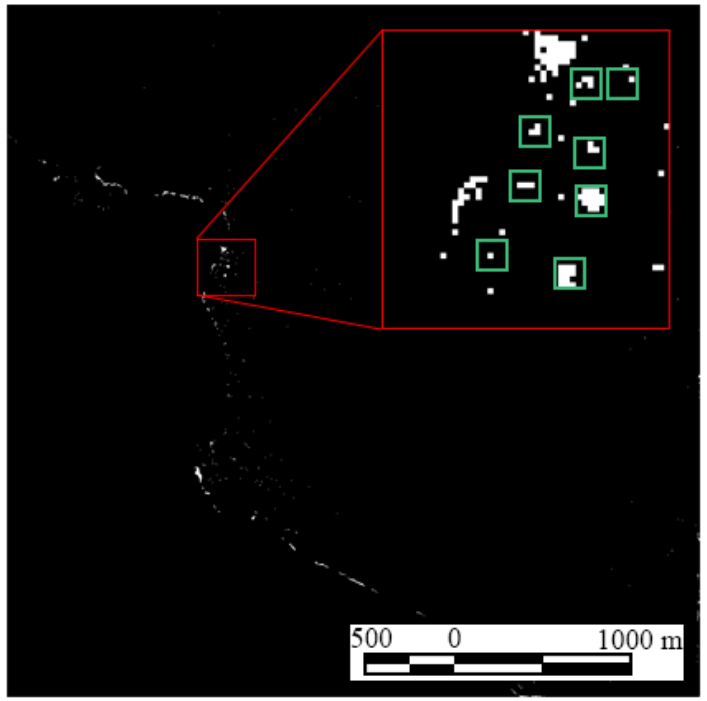
MD detection through spectral indexes application

Pansharpened PRISMA data:

Novel spectral indexes were developed based on radiance differences between spectrum crests and troughs in the VNIR region.

$$Index_1 = \frac{(R_{781}{}^2 - R_{951})}{1000}, \qquad Index_2 = \frac{(R_{596}{}^2 - R_{719}{}^2)}{10000},$$

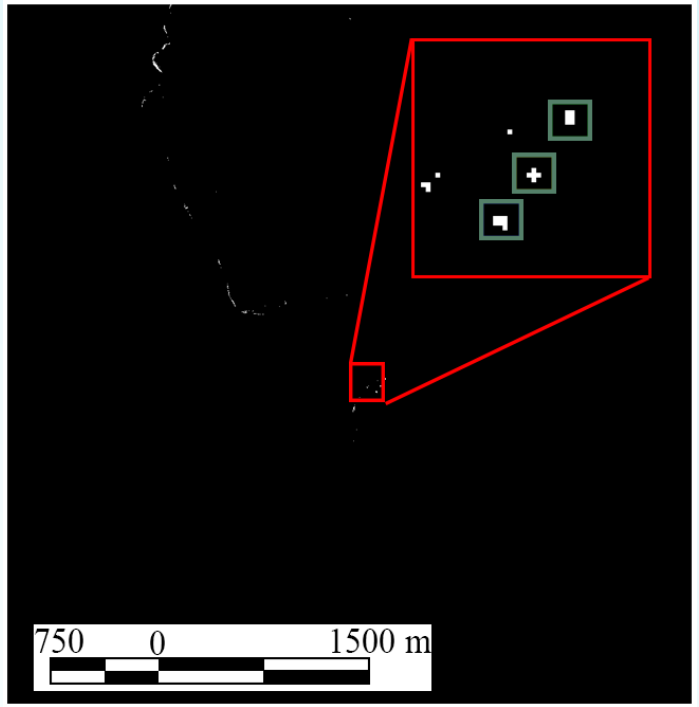
$$Index_3 = R_{492} - R_{719}$$



Mask produced by thresholding the developed spectral indexes on the PCA pan-sharpened PRISMA image on 18/9/2020.

S2 and WV 2/3 fused data:

SOTA spectral indexes (NDVI, Floating Algae Index (FAI), Floating Debris Index (FDI), S2-based index, Hydrocarbon Index (HI)) were applied.



Mask produced by thresholding the FDI spectral indexes on the for the CNMF fused S2-WV3 image acquired on 7/6/2018.

Conclusion

- constraints arose in the unmixing analysis due to the spectral inseparability of the plastic targets and swallow waters in PRISMA data.
- The spectral unmixing analysis properly mapped the plastic and wooden targets. Boats may be a problem for the detection of marine plastic litter as their spectral signature is almost identical with some plastic targets.
- By exploiting image fusion techniques, for a small plastic target to be distinguishable, it should at least occupy 8% of a pixel of the original hyperspectral PRISMA image or 3% of the original S2 multispectral image.
- Overall, the results of this study are very promising for the development of an automated algorithm for the detection of floating anthropogenic objects in marine environments. Though, more datasets are required for the algorithm tuning and adjustment.

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Thank you for your attention!