PRISMA hyperspectral and the application in the UrbanScape domain

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urbisphere
coupling dynamic cities and climate

European Research Council

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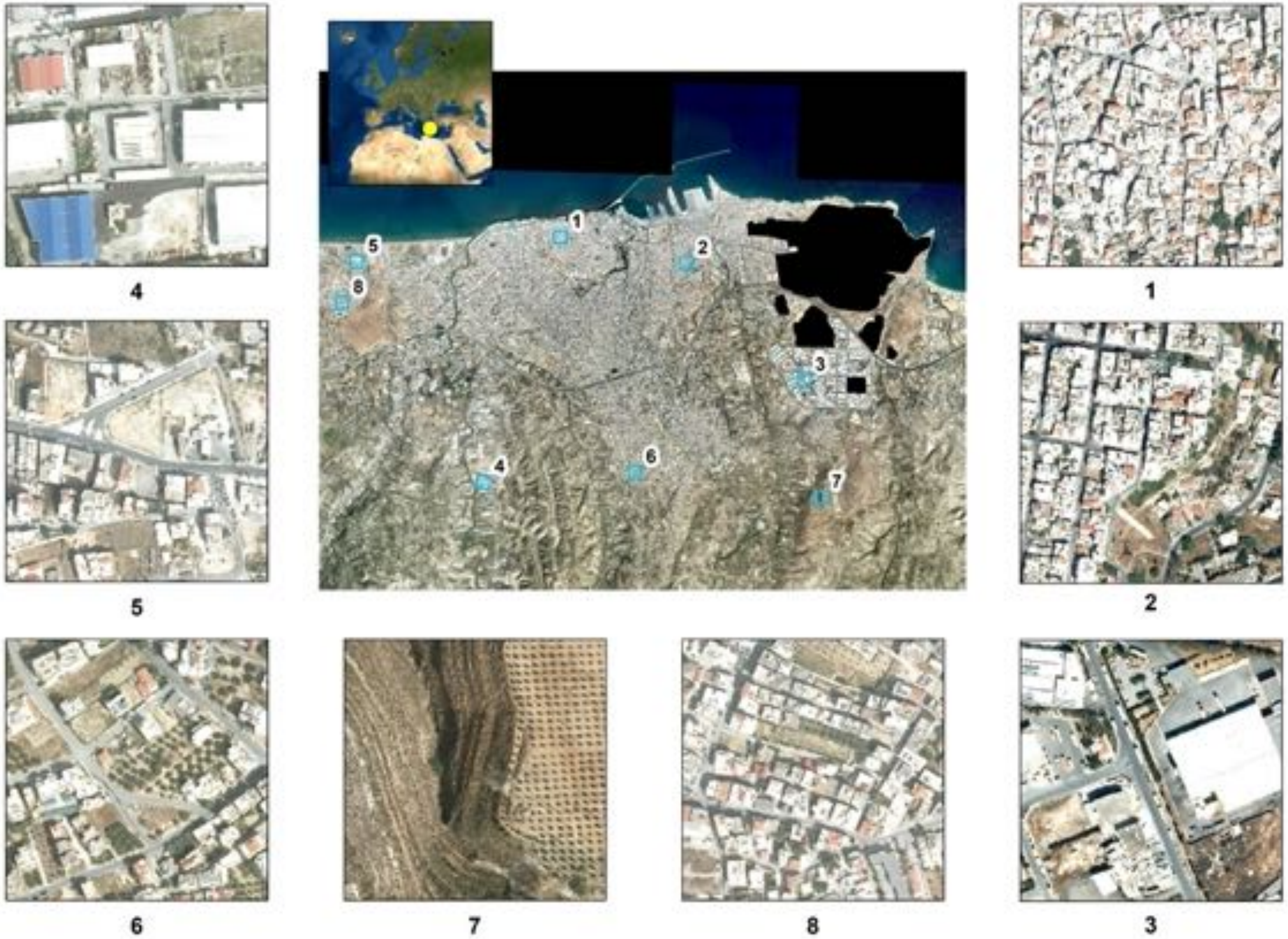
Introduction

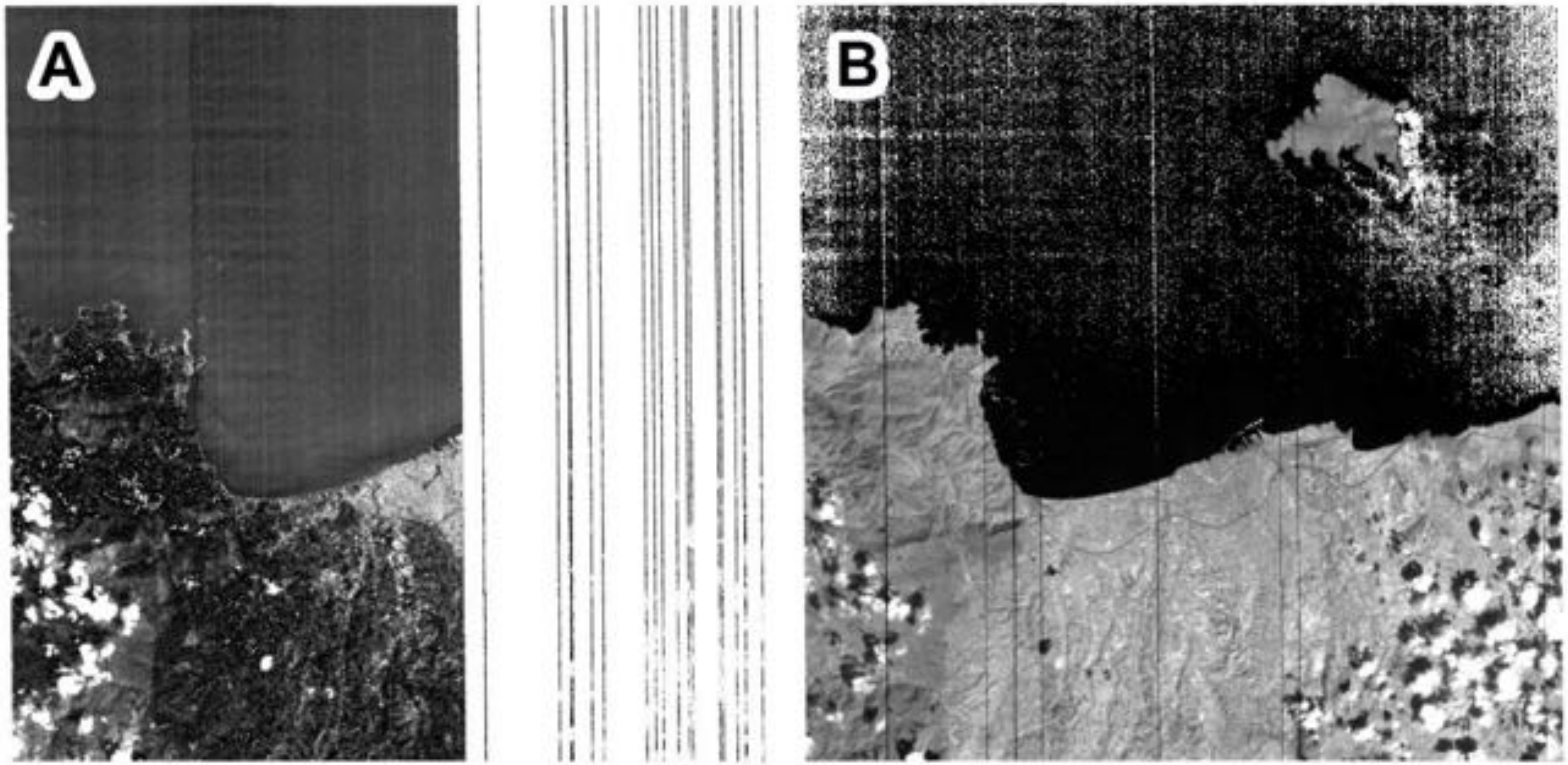
- Urban ecosystems host more than 50% of the global population with an annual increase trend.
- Urban surface materials > urban weather and climate modelling linked with requirements on urban canopy models and urban morphology (spatial and functional).
- Hyperspectral Remote Sensing allow for accurate discrimination of urban materials = Rich in spectral resolution but at a cost (decreased spatial resolution).
- PRISMA hyperspectral sensor, from 2019, collect data in the spectral range from 400 to 2500 nm.
- The current work will utilize the regression-based unmixing using PRISMA L2D imagery aiming at characterizing the UrbanScape of Heraklion city using the V-I-S model framework developed by Ridd 1995.

Study Area

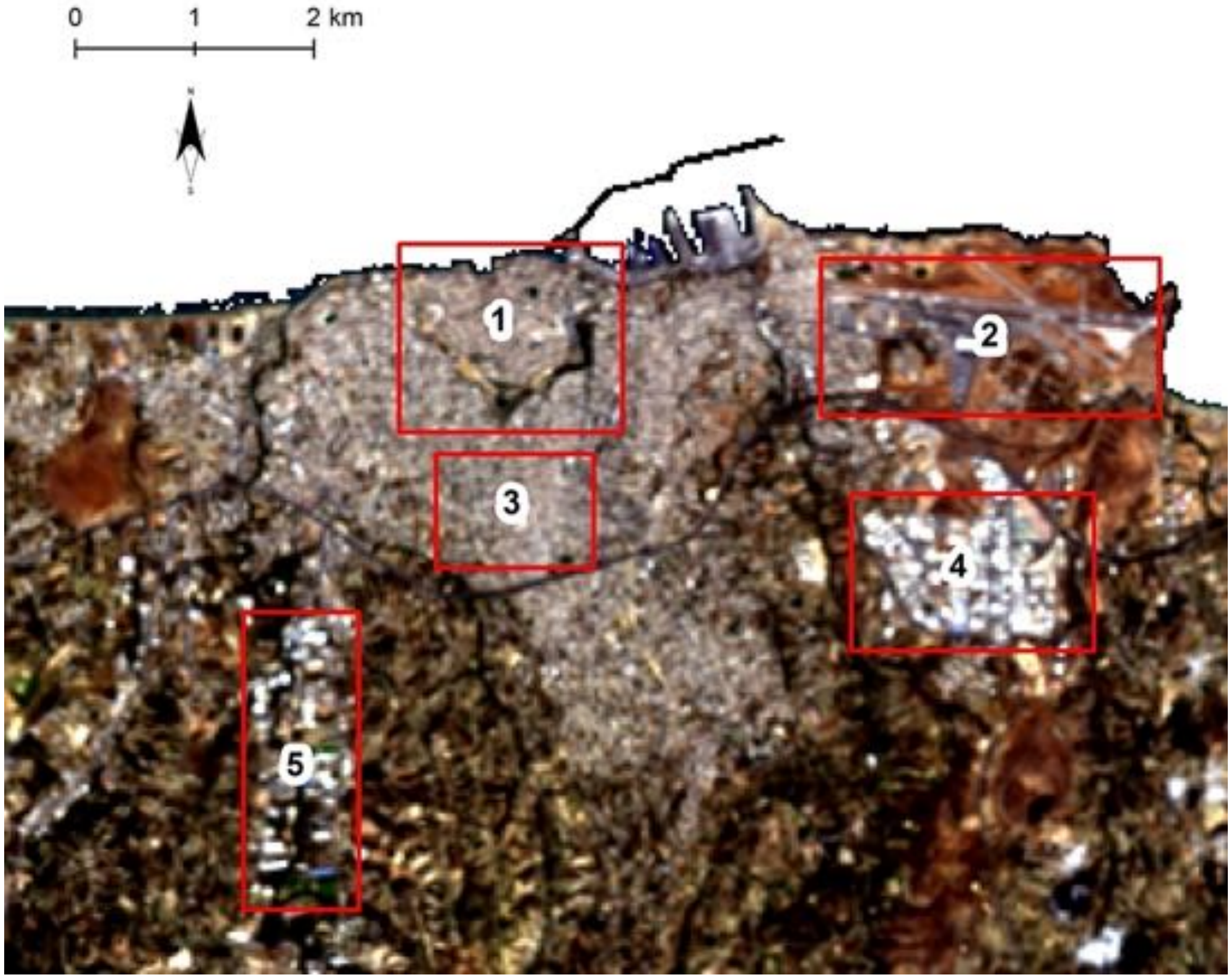
- Heraklion is the largest city of Crete, Greece.
- It has the form of a typical dense Medieval Mediterranean City.
- It is the fourth largest city in Greece with a population of 211,370 (Urban Area) according to the 2021 census. The population of the municipality was 177,064.



PRISMA hyperspectral



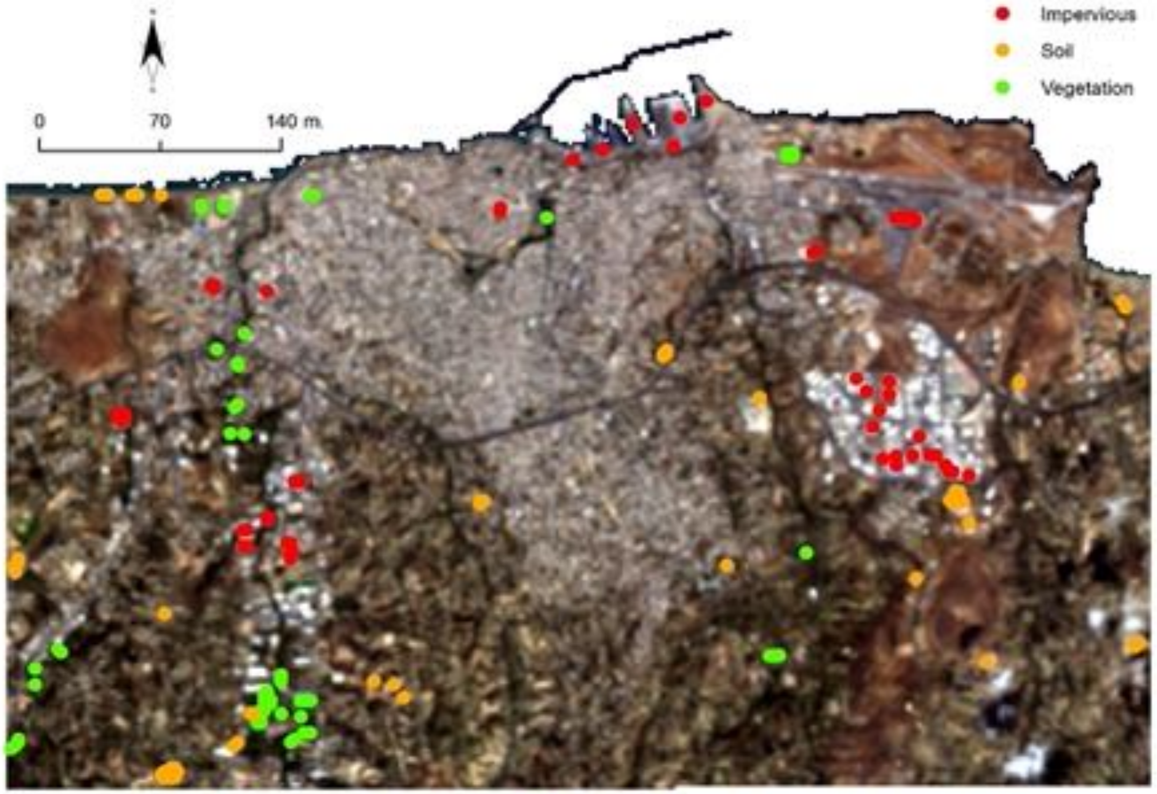
- L2D image, September 2020
- Co-registration with reference aerial true orthoimage using AROSICS
- Wavelength removal at 1340-1440 nm, 1780-1970 nm and 2300-2500 (atmospheric bands)
- Corrupted bands (panel A – band 1, 401.92 nm) or bands with bad lines (panel B – band 60 – 939.72nm) removed manually.

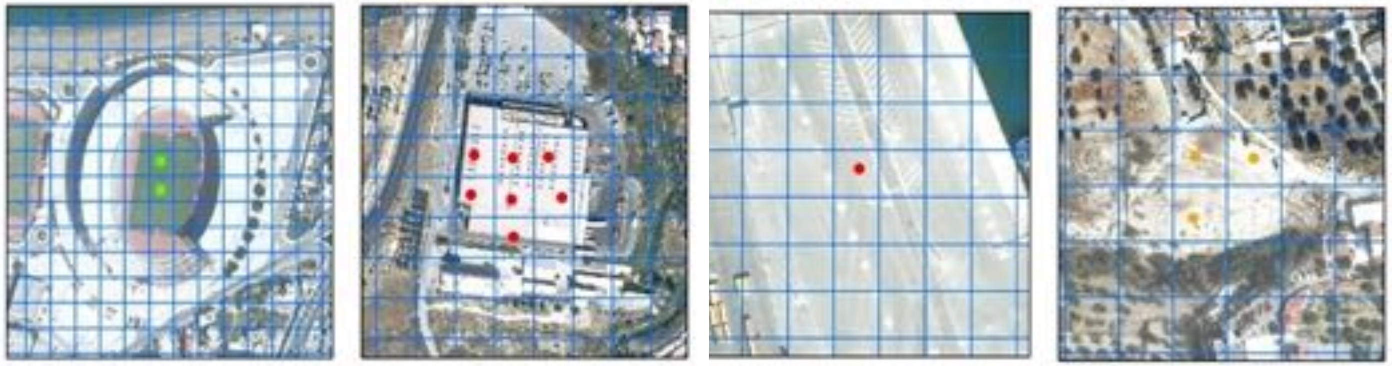


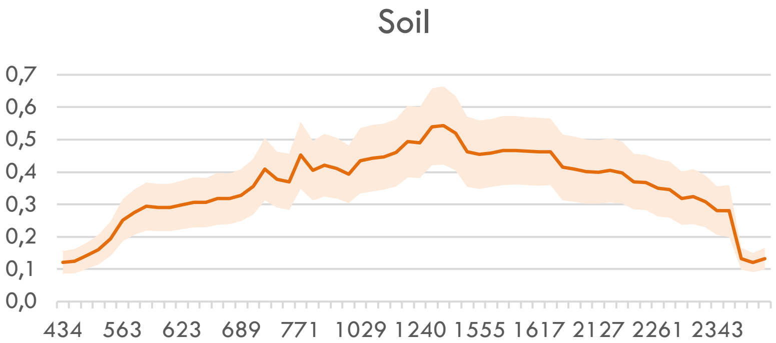
The final PRISMA imagery; in red boxes the heart of the city (box 1), the airport (box 2), the residential area (box 3) the industrial zone (box 4) and the industrial park (box 5).

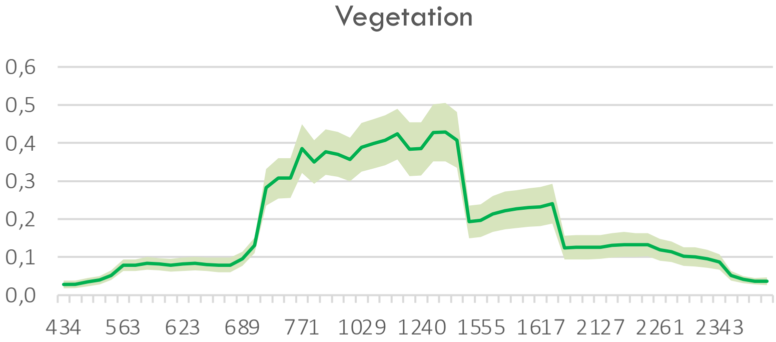
Data

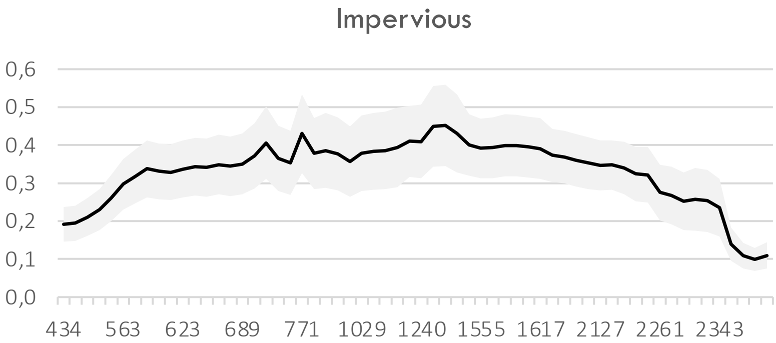
- Image-based endmembers with pure cover type spectra representative of the study area have been created.
- The library is used to create pure spectral by visual inspection of high resolution aerial orthoimage in cross comparison with the corrected coregistered PRISMA imagery.
- The purity of the pixel has been to the greatest degree secured by selecting pixels that correspond in a) Vegetation (low and high), B) Impervious (dark and bright) and C) Soil (mostly bright of limestone origin) in as much as possible homogeneous areas (i.e., an area of 3x3 pixels of PRISMA – 30x30m if that can be secured).
- For each category, 60 points that correspond to the pixel size have been created

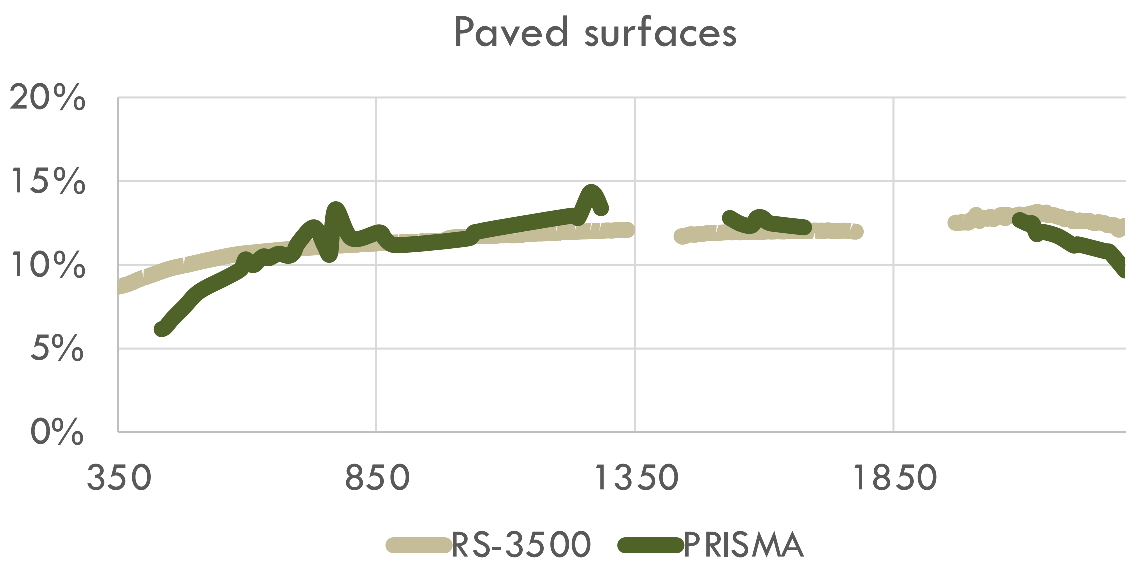

Impervious
Soil
Vegetation
0
70
140 m

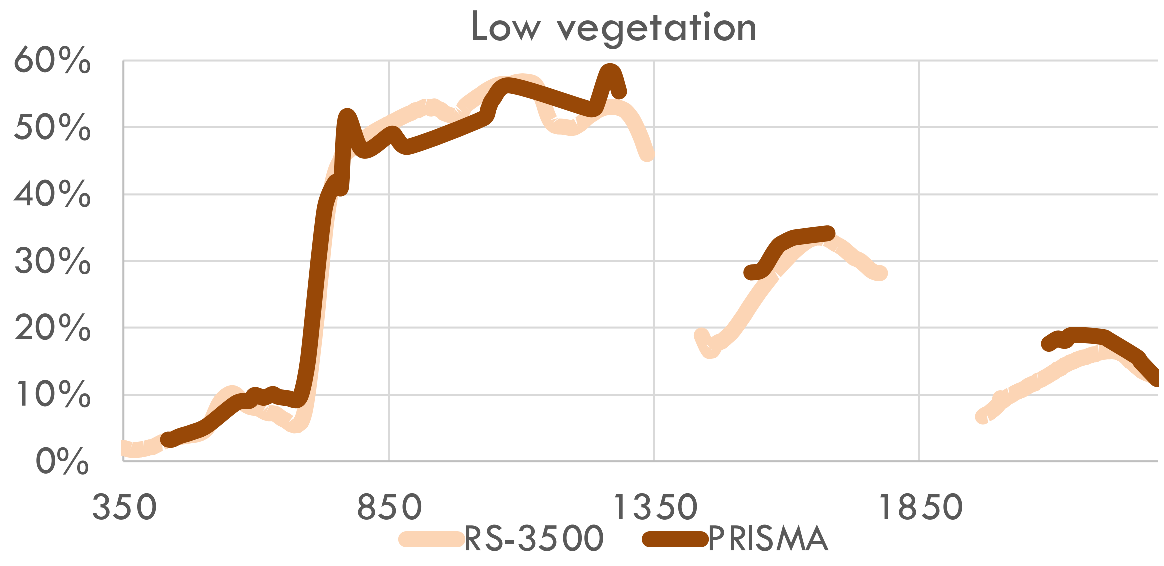


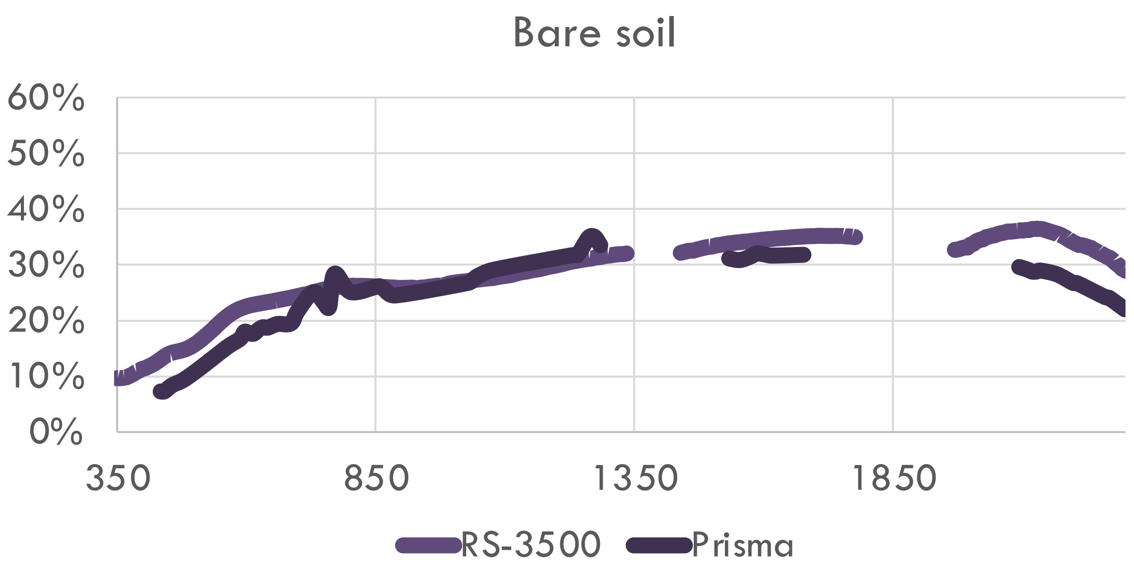

Soil
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
434 563 623 689 771 1029 1240 1555 1617 2127 2261 2343


Vegetation
0,6
0,5
0,4
0,3
0,2
0,1
0,0
434 563 623 689 771 1029 1240 1555 1617 2127 2261 2343


Impervious
0,6
0,5
0,4
0,3
0,2
0,1
0,0
434 563 623 689 771 1029 1240 1555 1617 2127 2261 2343


Paved surfaces
20%
15%
10%
5%
0%
350
850
1350
1850
RS-3500
PRISMA


Low vegetation
60%
50%
40%
30%
20%
10%
0%
350
850
1350
1850
RS-3500
PRISMA


Bare soil
60%
50%
40%
30%
20%
10%
0%
350
850
1350
1850
RS-3500
Prisma

Fraction Mapping

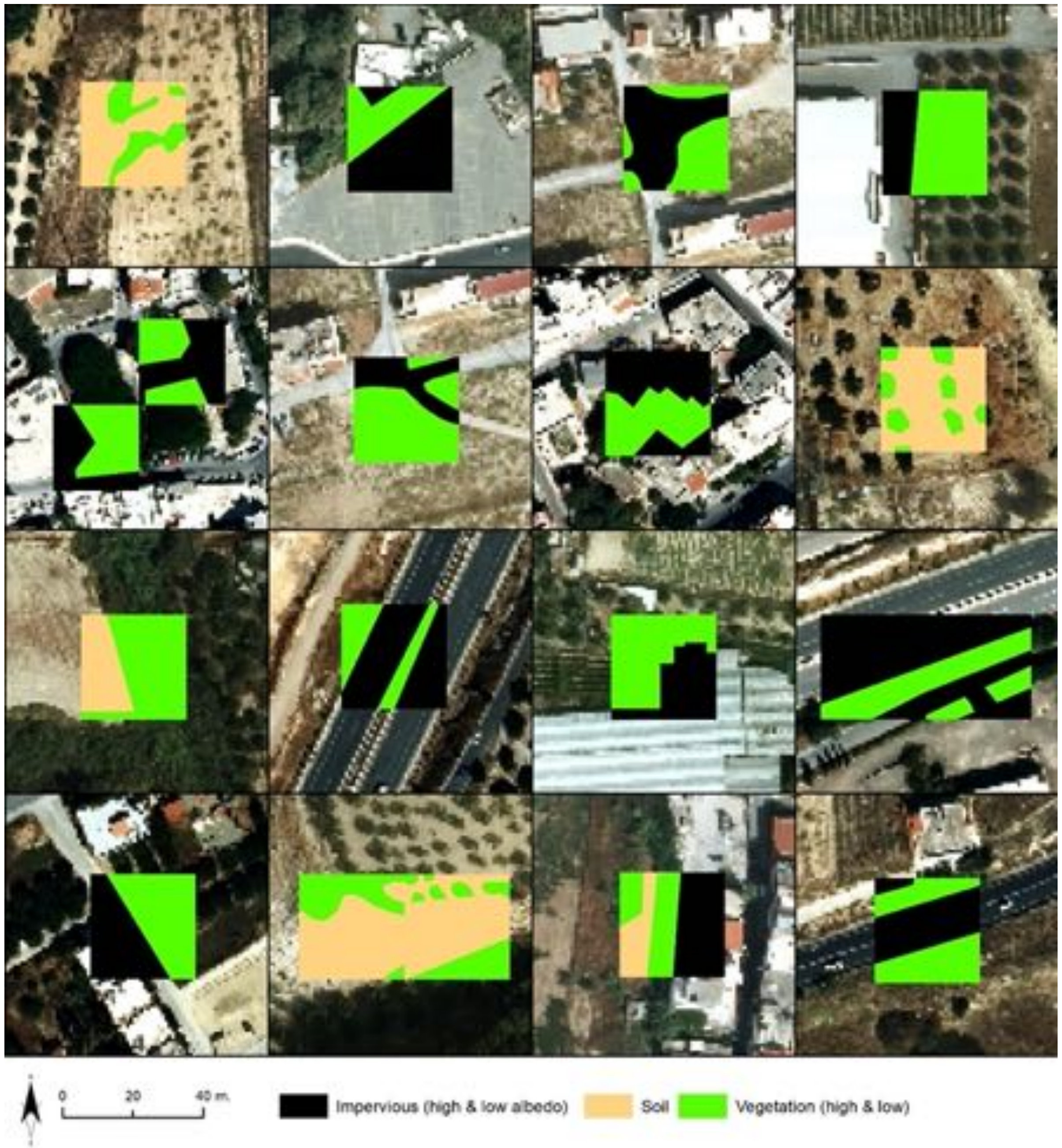
- Random Forest Regression (RFR) to estimate fractional cover using the EnMAP toolbox. RFR is insensitive to parametrize and is recommended to set the number of trees to a large, while computationally feasible, number.
- Num of trees = 1000 while allowing the number of random variables considered at each split (*max_features*), the maximum depth of the tree (*max_depth*), the minimum number of samples required to split an internal (*min_samples_split*) as well as a leaf (*min_samples_leaf*) node to the suggested tunes by EnMAP.
- We create classification datasets assuming a series of fractions (Minimum Pixel Cover - MPC) that occur in each pure pixel, from 70% to 100%. The mixing complexity was binary (two spectra) or ternary (three spectra). We used an ensemble with 1, 3 and 5 folds and 1000 randomly drawn training samples. Iteration results were averaged for the final fraction map of each target. All resulting fraction maps have been restrained to a {0,1} extent.

Validation

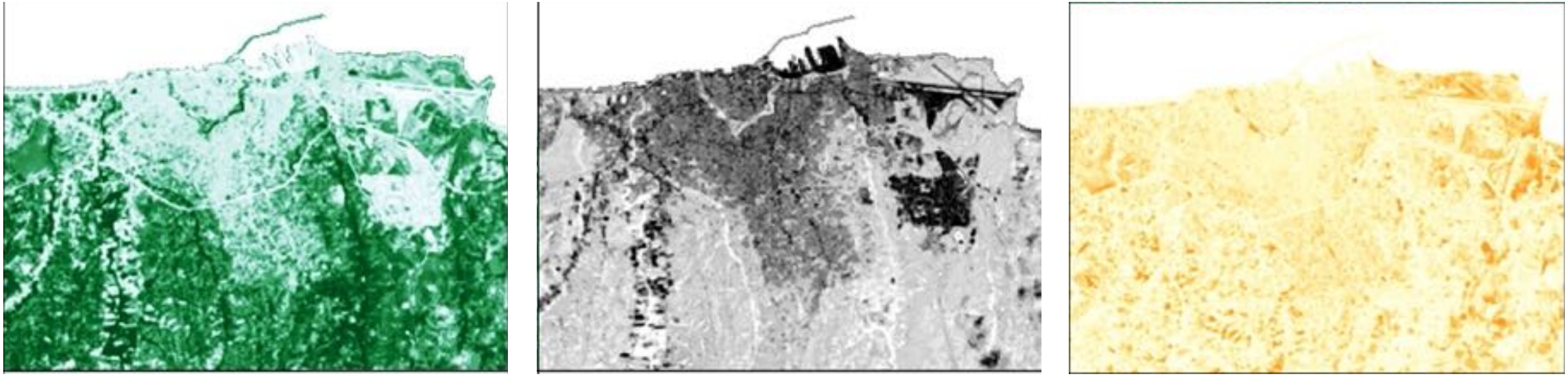
› Reference land cover data where derived from the latest orthorectified aerial imagery of Heraklion city

› 53 plots, each one corresponding to the PRISMA grid, have been created.

› These have been converted into reference fractions and compared to the RFR results of the same area by means of Mean Absolute Error (MAE) values.



Results



- MCF 100%, ensemble = 5, achieve the lowest MAE for the target classes.
- Class *Soil* shows variability in MAE among combinations from 0.3 to 0.23. The other have marginal differences.
- MAE values (0~1) > *Vegetation* = 0.1, *Impervious* = 0.12, *Soil* = 0.17

Discussion

› V-I-S fraction distribution of Heraklion area have been captured by the RFR unmixing method applied in the study area using PRISMA data

› Soil fraction patterns have been overestimated across the scene due to limited wide areas of pure soils (limestones) used in the analysis.

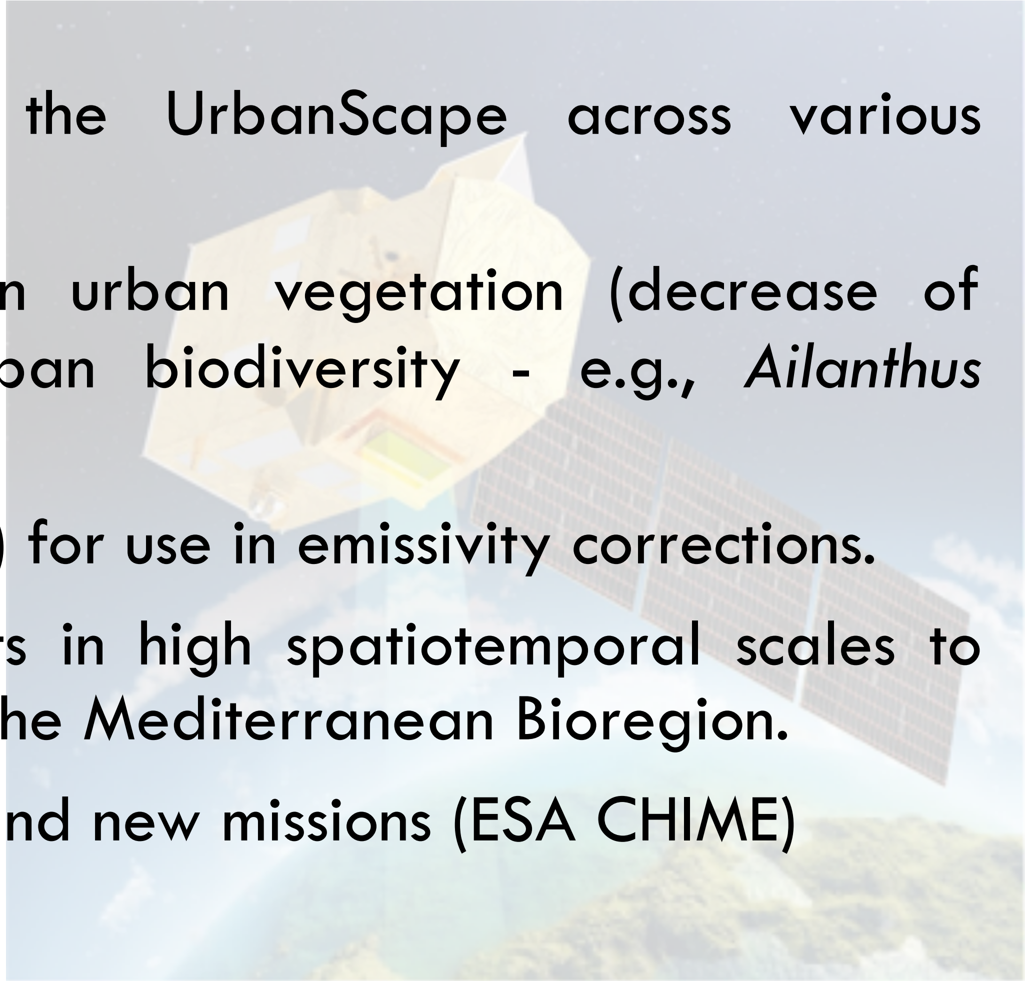
› Vegetation fraction patterns have been delineated with high accuracy as clearly, we observe the vegetative sites in the core city, the olive orchards and vineyards along with the streams that host perennial riparian vegetation.

› Impervious fractions are well mapped with high percentages of fraction cover to exist in the city, airport, industrial zone and park and be captured by the analysis.

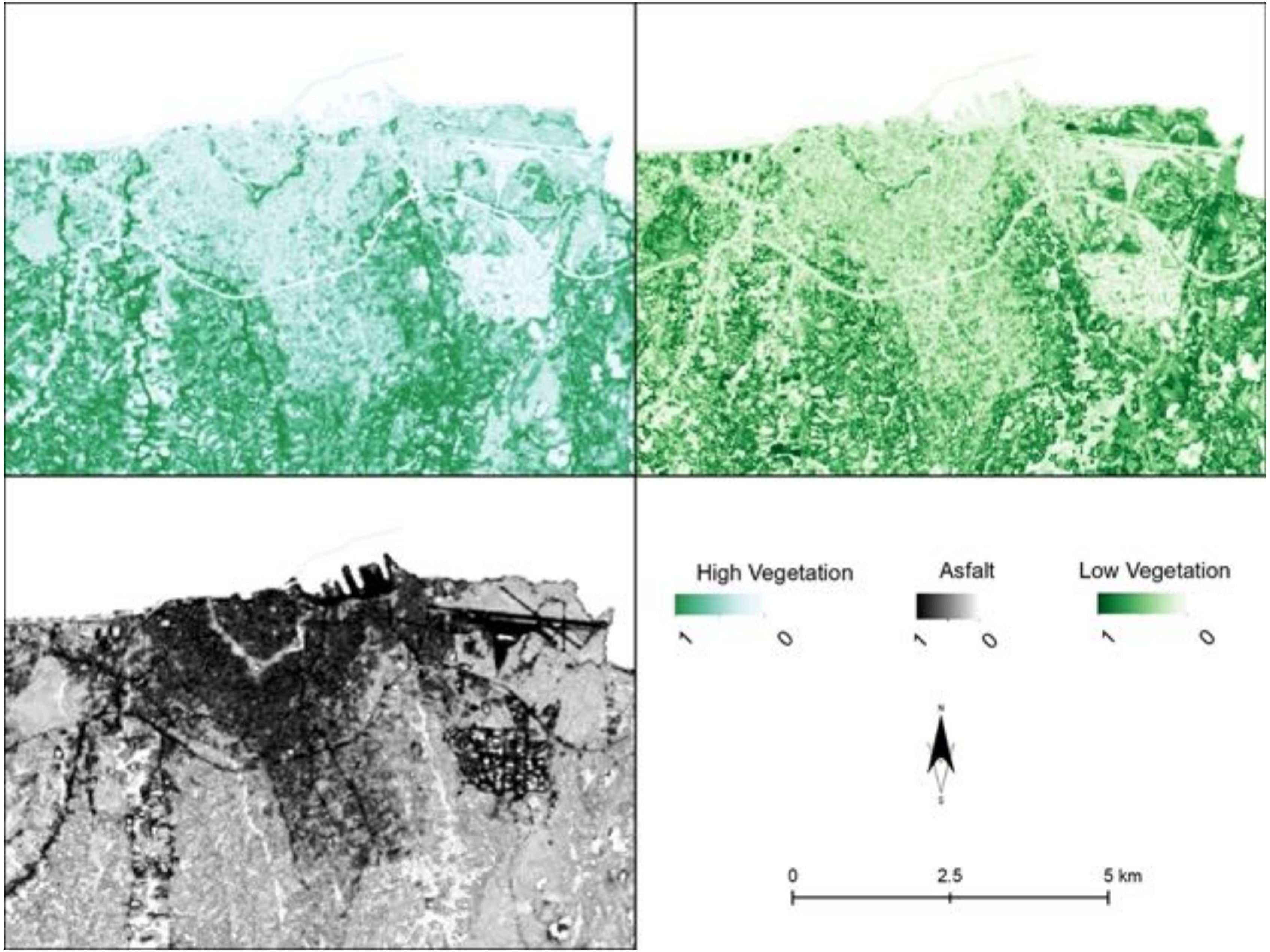
› Our findings are better when comparing with similar approaches using multispectral data, accuracy and spatial patterns wise, and similar when using same sensor type, especially for the soil class.

Outlook

- Multitemporal PRISMA data analysis in the UrbanScape across various Mediterranean Cities.
- Invasive Alien Species fraction mapping in urban vegetation (decrease of functional diversity ~ consequences in urban biodiversity - e.g., *Ailanthus altissima*).
- Material based mapping (hard and fractions) for use in emissivity corrections.
- Need of field based spectral measurements in high spatiotemporal scales to solve the availability of soil spectral data in the Mediterranean Bioregion.
- Fixed targets for reference sites for running and new missions (ESA CHIME)



Example of material-based fractions



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