Sub-pixel Material Fraction Mapping in the UrbanScape using PRISMA Hyperspectral Imagery

Dimitris Poursanidis, Emmanouil Panagiotakis and Nektarios Chrysoulakis

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urbisphere
coupling dynamic cities and climate

European Research Council
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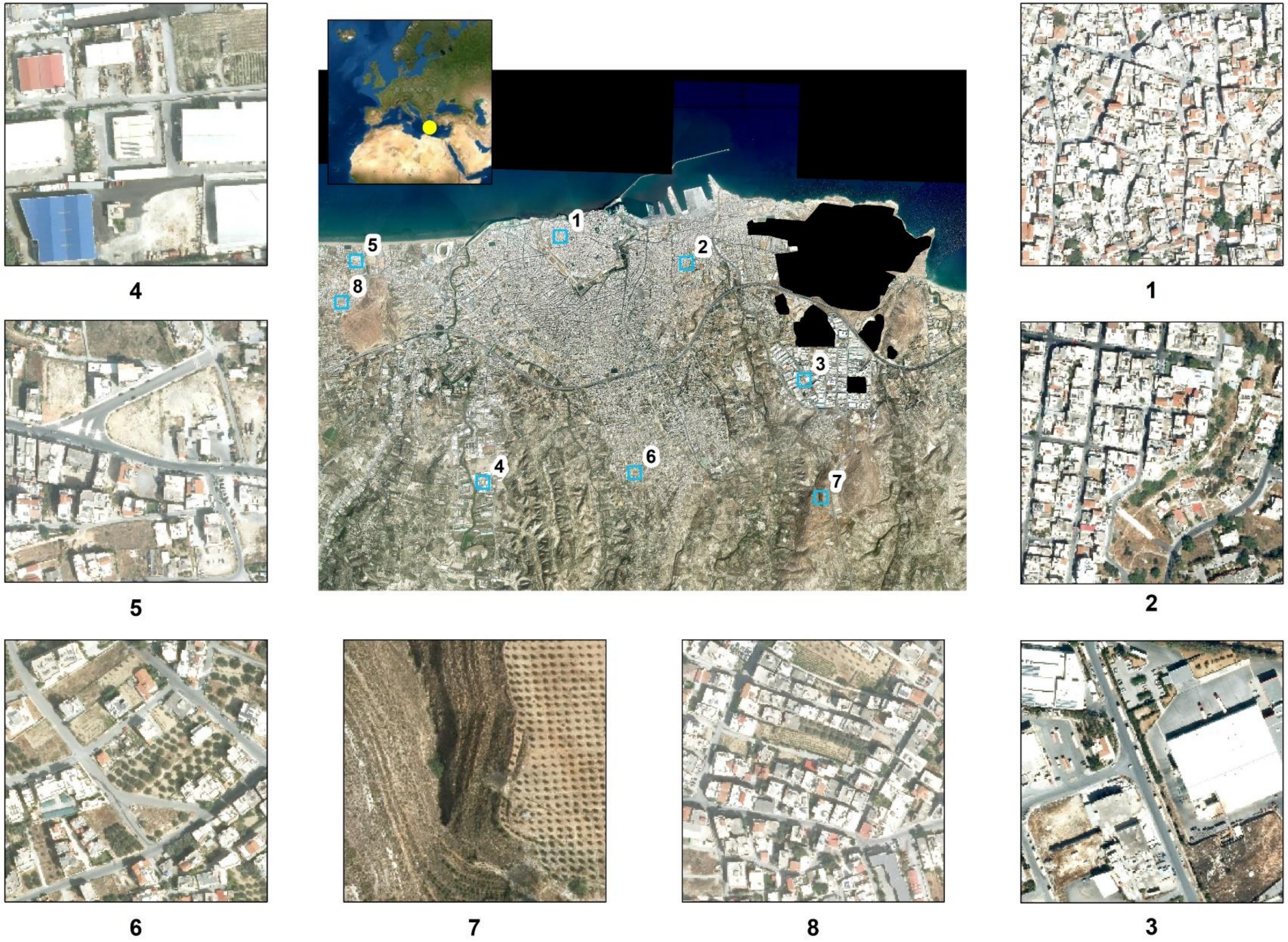
Introduction

- Accurately mapping urban composition is critical for understanding the urban environment
- Distribution of materials across an urban surface directly affects energy and water fluxes
- Which in turn impact urban climate, resource use, and human health

- The current work will utilize the regression-based unmixing using PRISMA L2D imagery aiming at sub-pixel material fraction mapping of spectrally dissimilar materials in Heraklion City

Area of work and methodology


1
2
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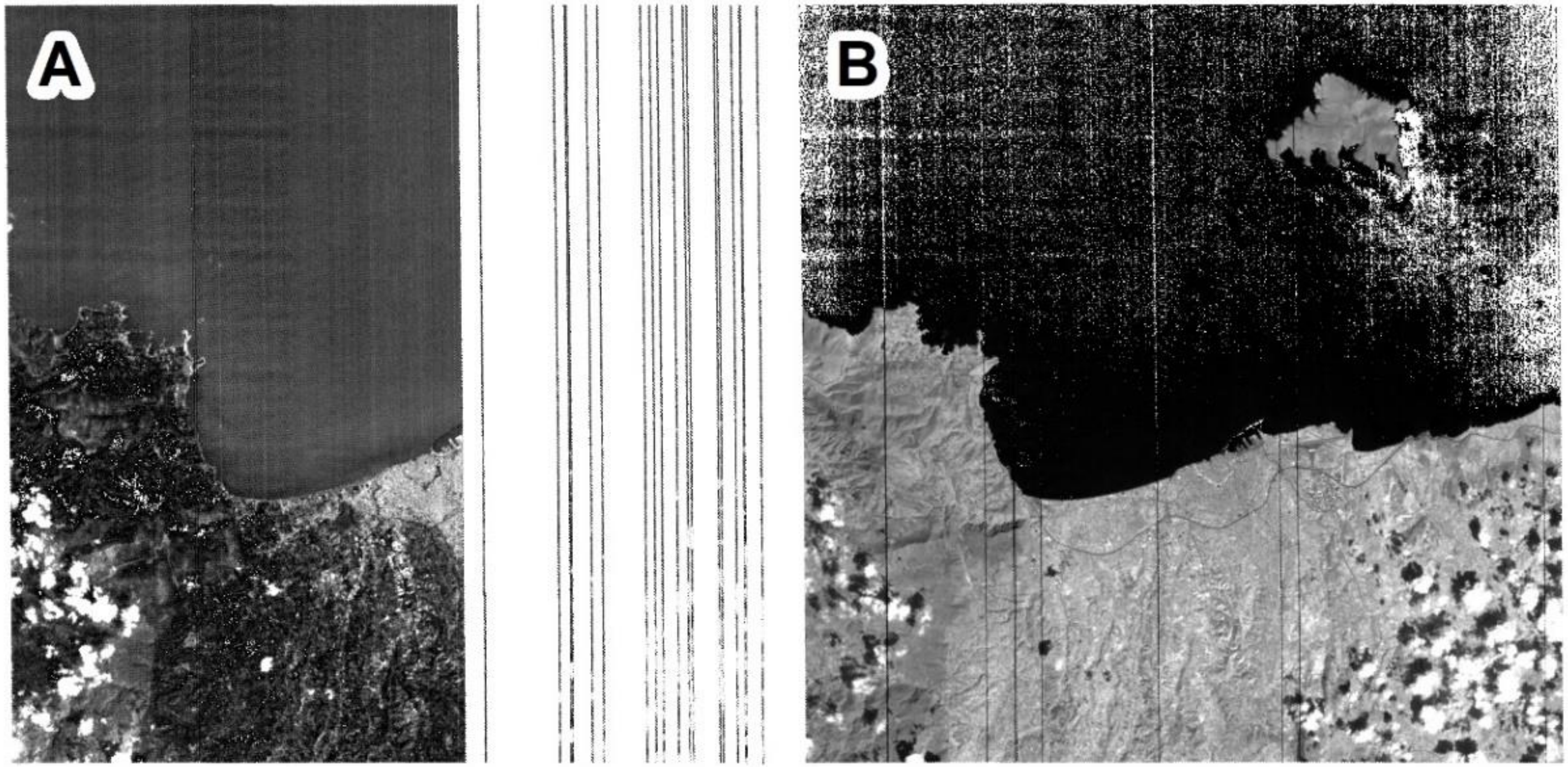
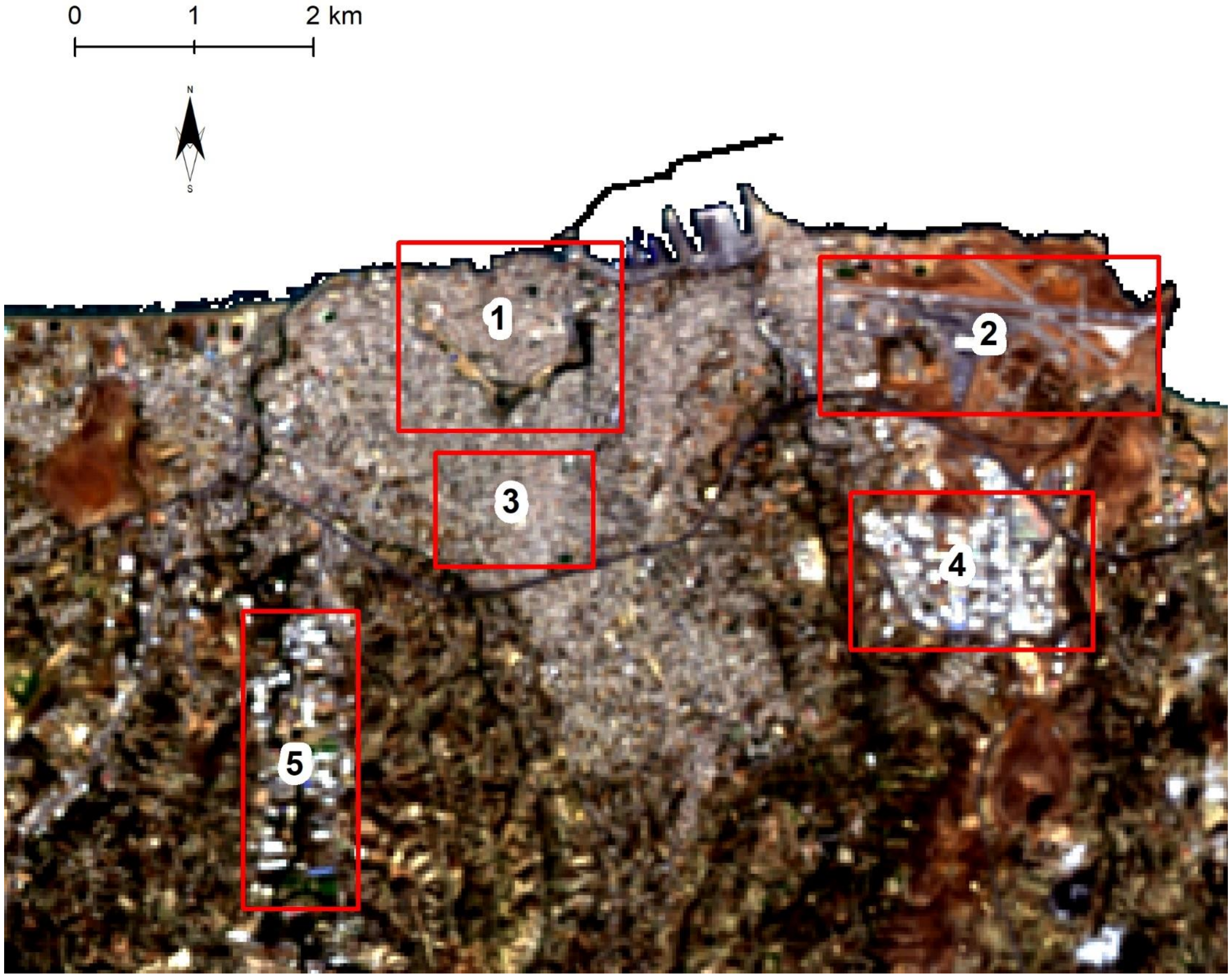
8

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.

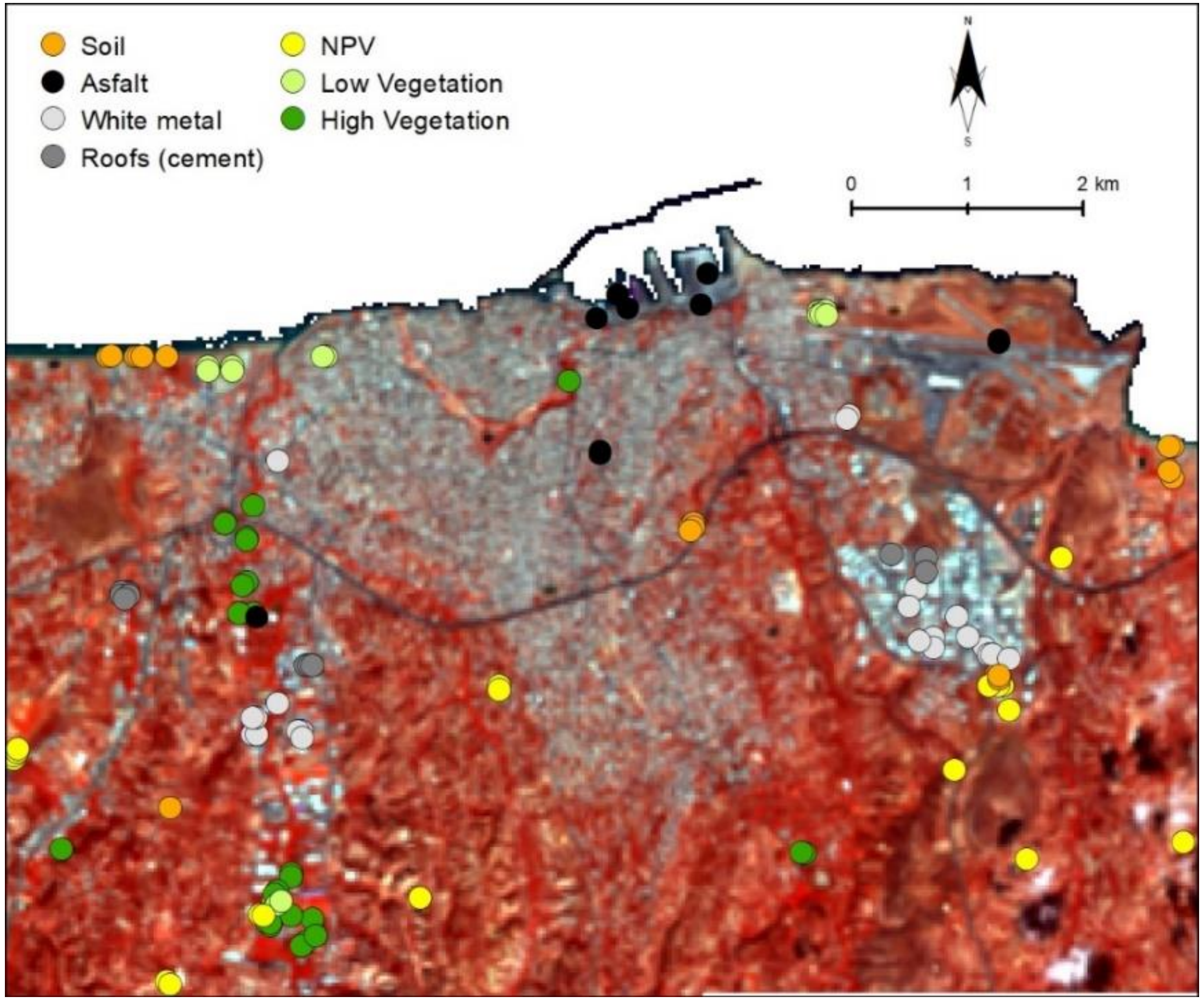


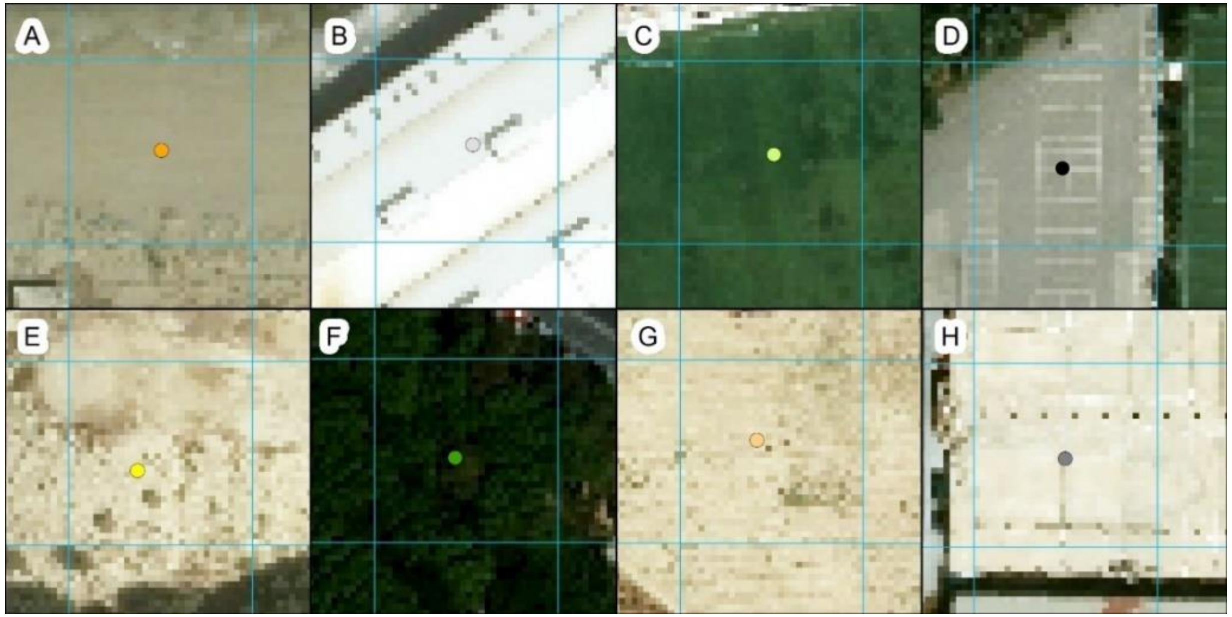
The final PRISMA imagery; in red boxes the heart of the city (box 1), the airport (box 2), the residential area (box 3) the industrial zone (box 4) and the industrial park (box 5).

Data

- Image-based endmembers with “pure” cover type spectra representative of the study area have been created.
- A library was designed to facilitate “pure” spectral by visual inspection of high resolution aerial orthoimage in cross comparison with the corrected coregistered PRISMA imagery.

Level I	Level II	Number of endmembers
Impervious	Asphalt	10
	Cement (roof)	13
	Metal	22
Pervious	Soil	19
	NPV	19
Vegetation	Low Vegetation	18
	High Vegetation	24


Soil
Asfalt
White metal
Roofs (cement)
NPV
Low Vegetation
High Vegetation
N
S
0
1
2 km


A
B
C
D
E
F
G
H

Fraction Mapping

- **RFR** (Random Forests Regression)
- **KRR** (Kernel Ridge Regression)
- **Linear** ENVI (Linear Unmixing @ENVI)

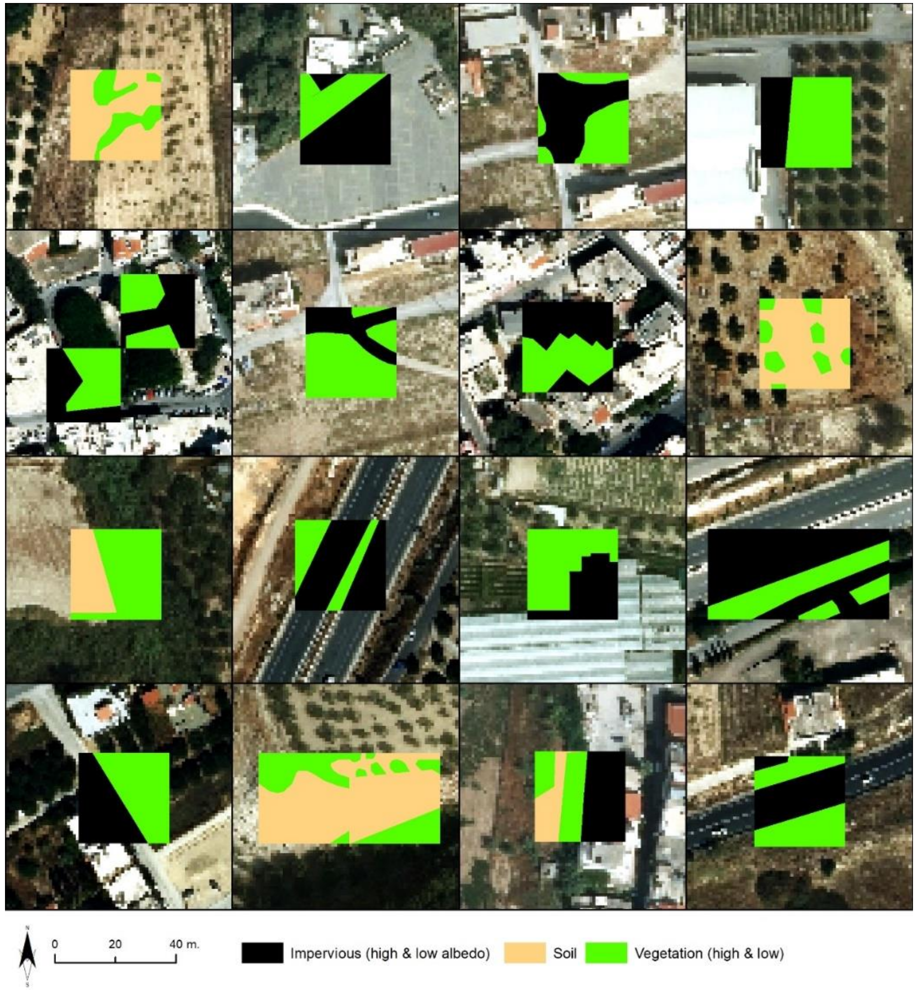
› Constrained unmixing with fraction maps restrained to a {0,1} extent and all sum to one.

Fraction Evaluation

- 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 unmixing results of the same area by means of Mean Absolute Error (MAE) estimation as a measure of accuracy
- MAE is used as it is essentially insensitive to outliers

(2011). Mean Absolute Error. In: Sammut, C., Webb, G.I. (eds) Encyclopedia of Machine Learning. Springer, Boston, MA. https://doi.org/10.1007/978-0-387-30164-8_525

Level I



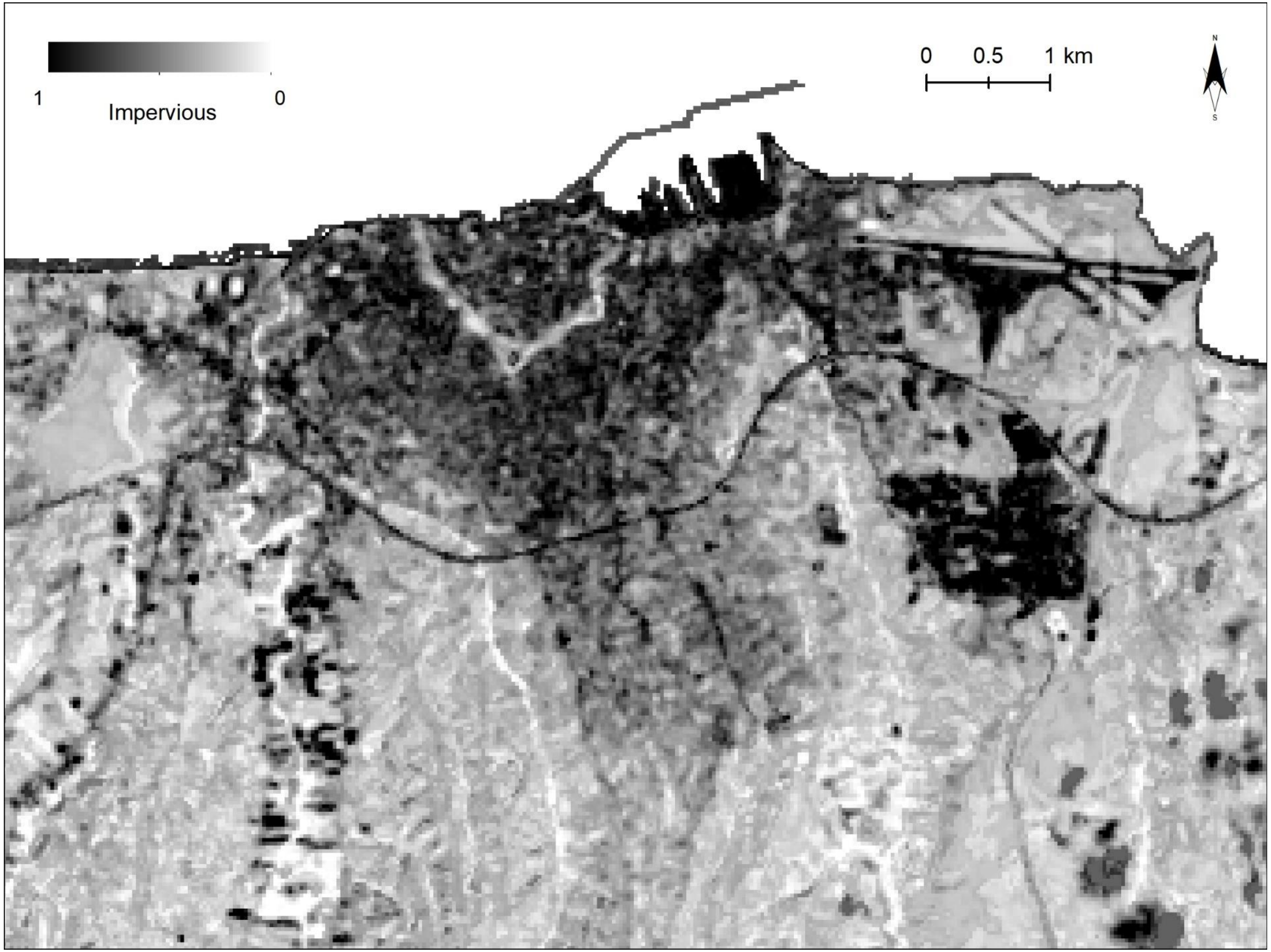
$N_{samples}$: Impervious=43, Soil=31, Vegetation=109

Level II

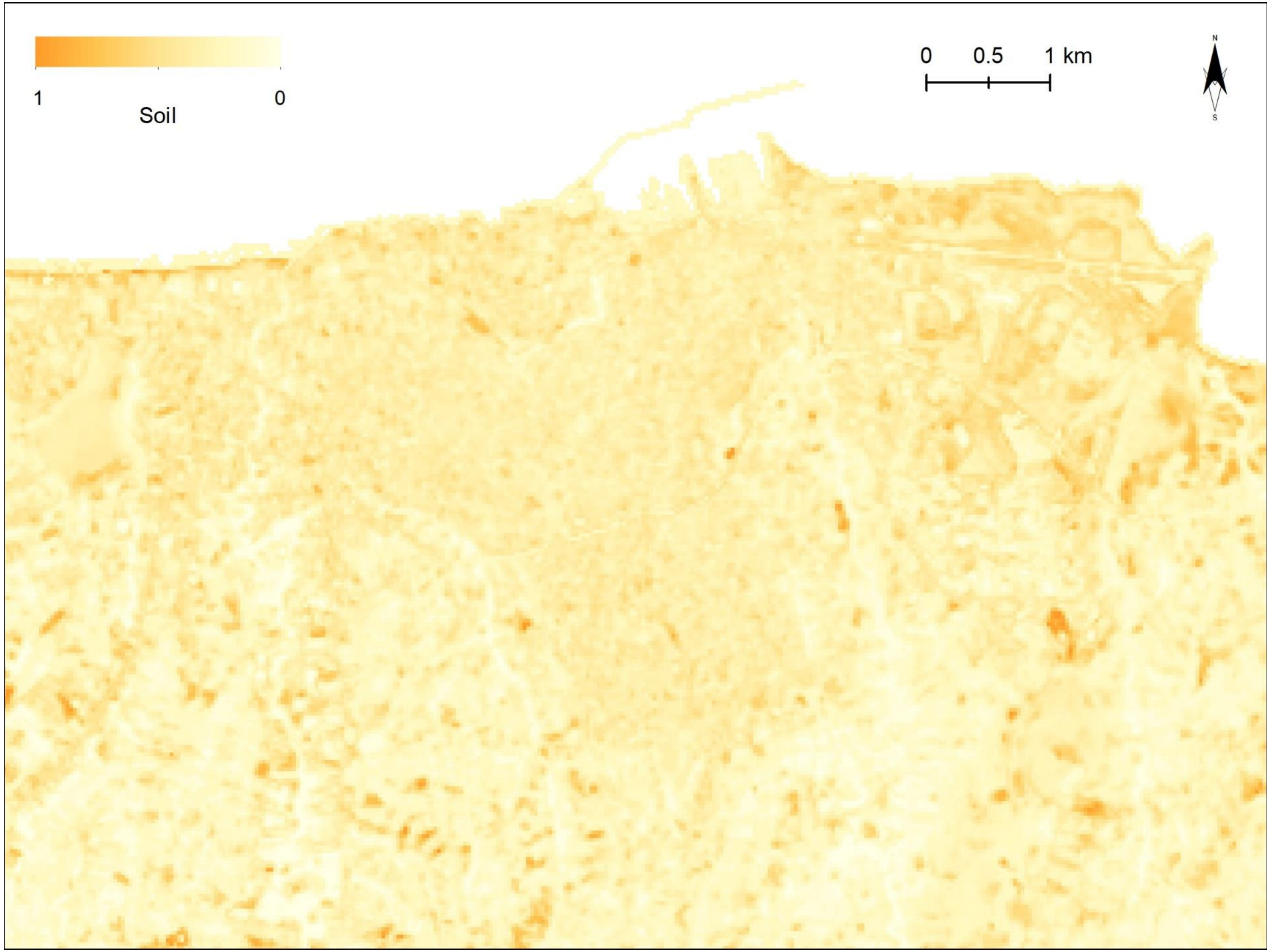
$N_{samples}$: Asphalt=21, Roofs=20, LowV=9, HighV=28, S=21, NPV=16, Metal=15

Findings and why that?

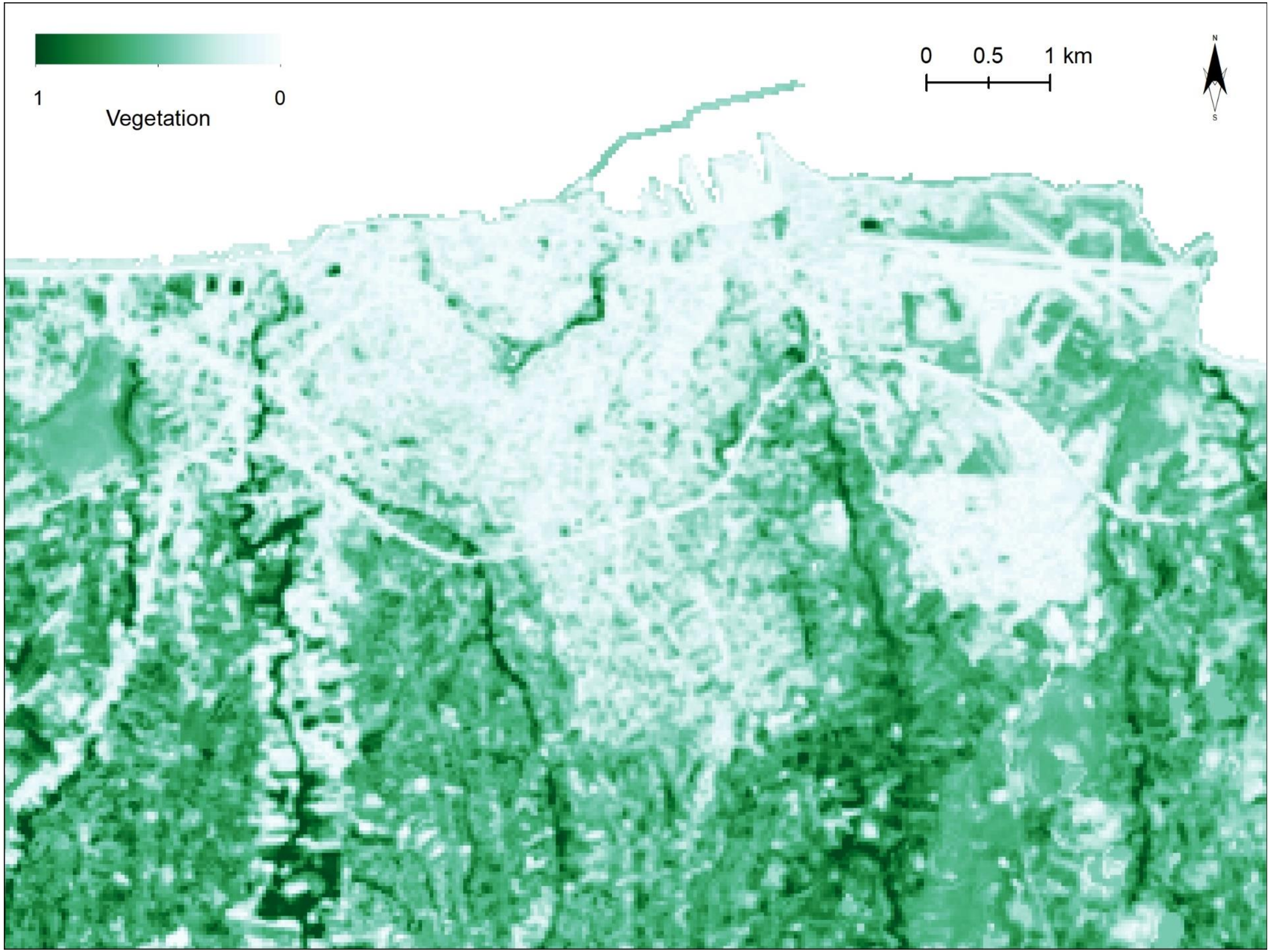
LEVEL I



LEVEL I



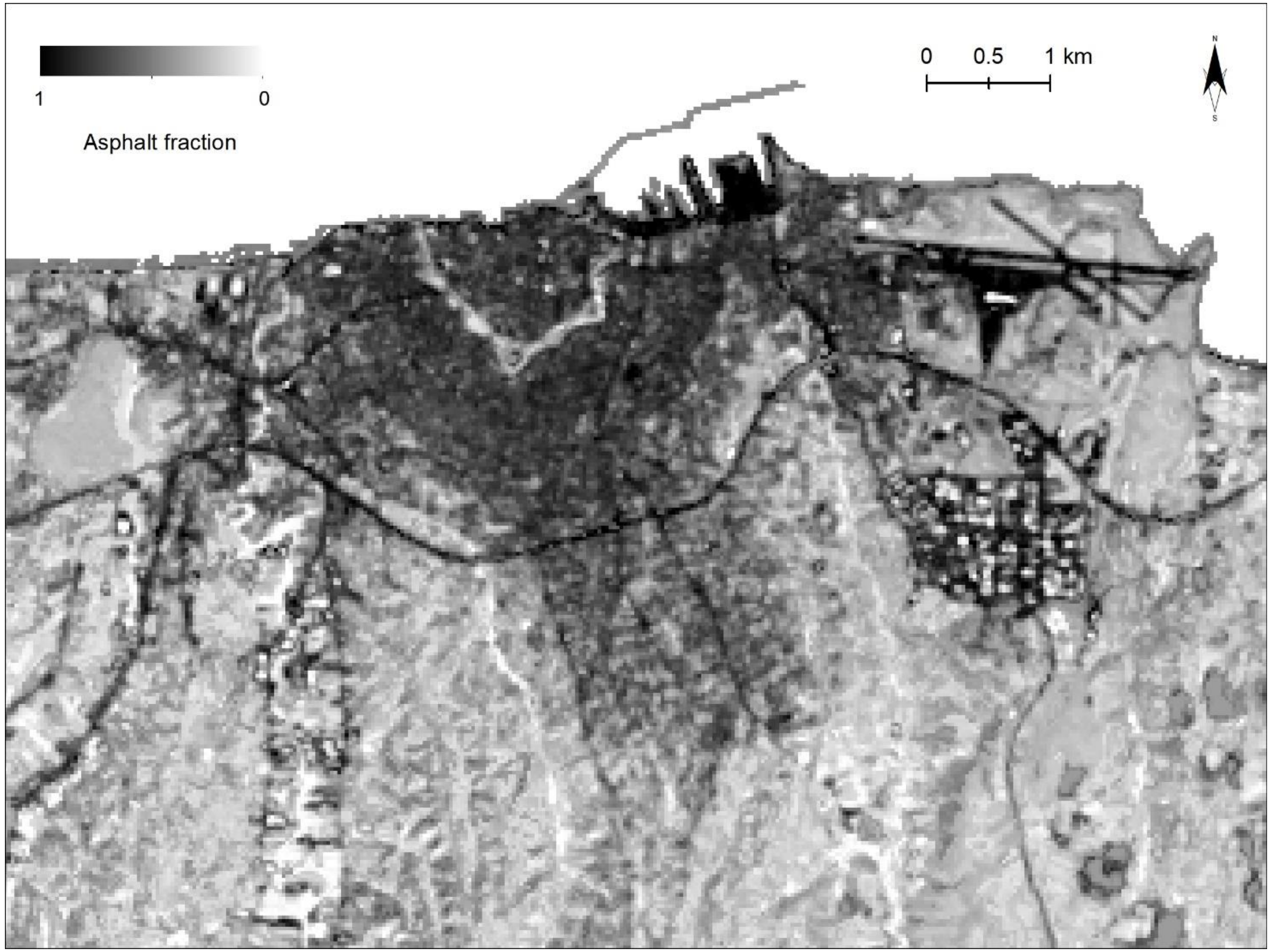
LEVEL I



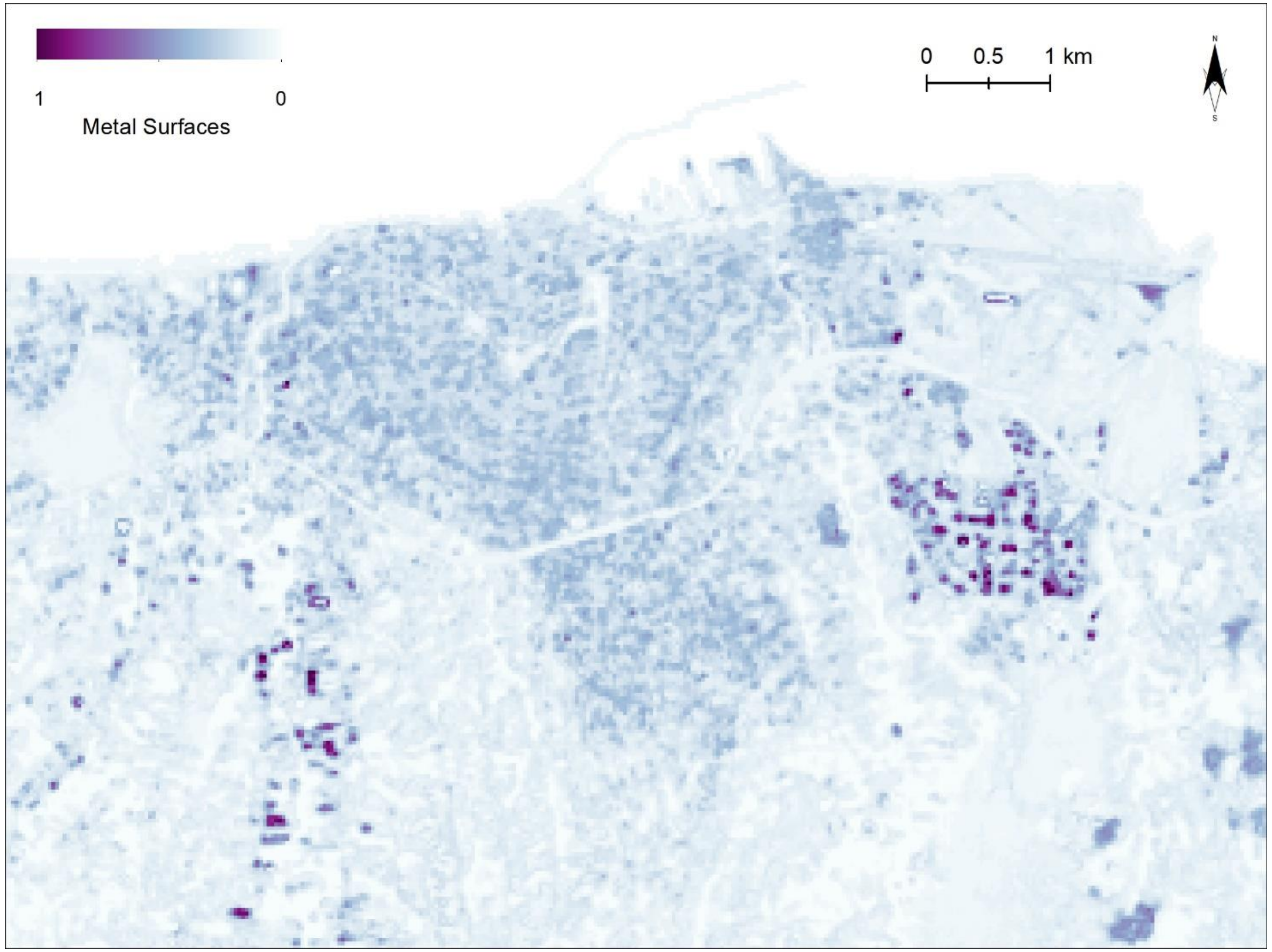
$N_{samples}$: Impervious=43, Soil=31, Vegetation=109

		Soil	Vegetation	Impervious
		n=20	n=23	n=32
RFR	MAE	0.1	0.11	0.09
	RMSE	0.17	0.14	0.17
	r^2	0.91	0.91	0.84
KRR	MAE	0.1	0.12	0.09
	RMSE	0.13	0.18	0.16
	r^2	0.92	0.89	0.86
Linear_ENVI	MAE	0.31	0.34	0.2
	RMSE	0.43	0.44	0.28
	r^2	0.49	0.32	0.63

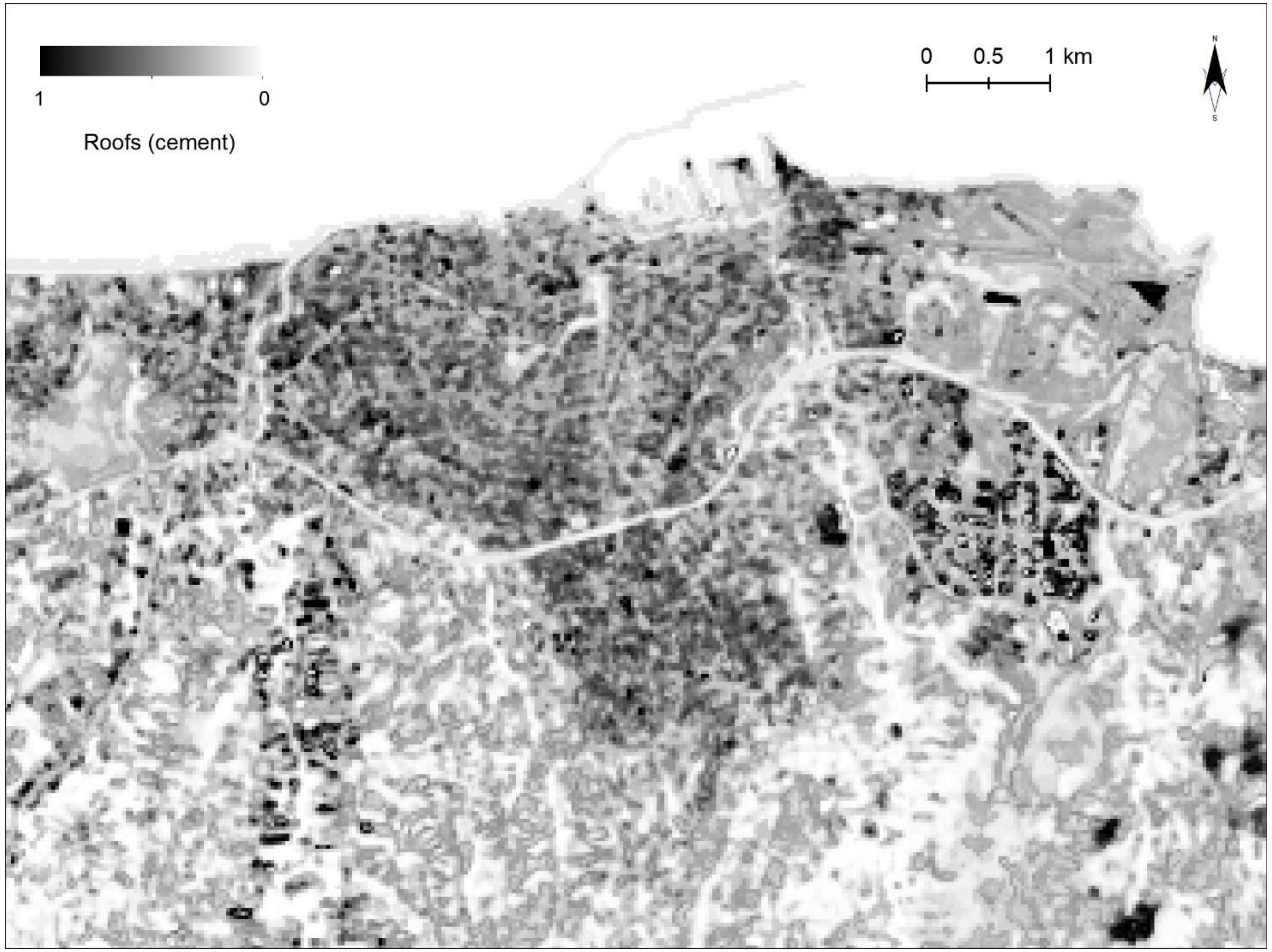
LEVEL II / Impervious classes



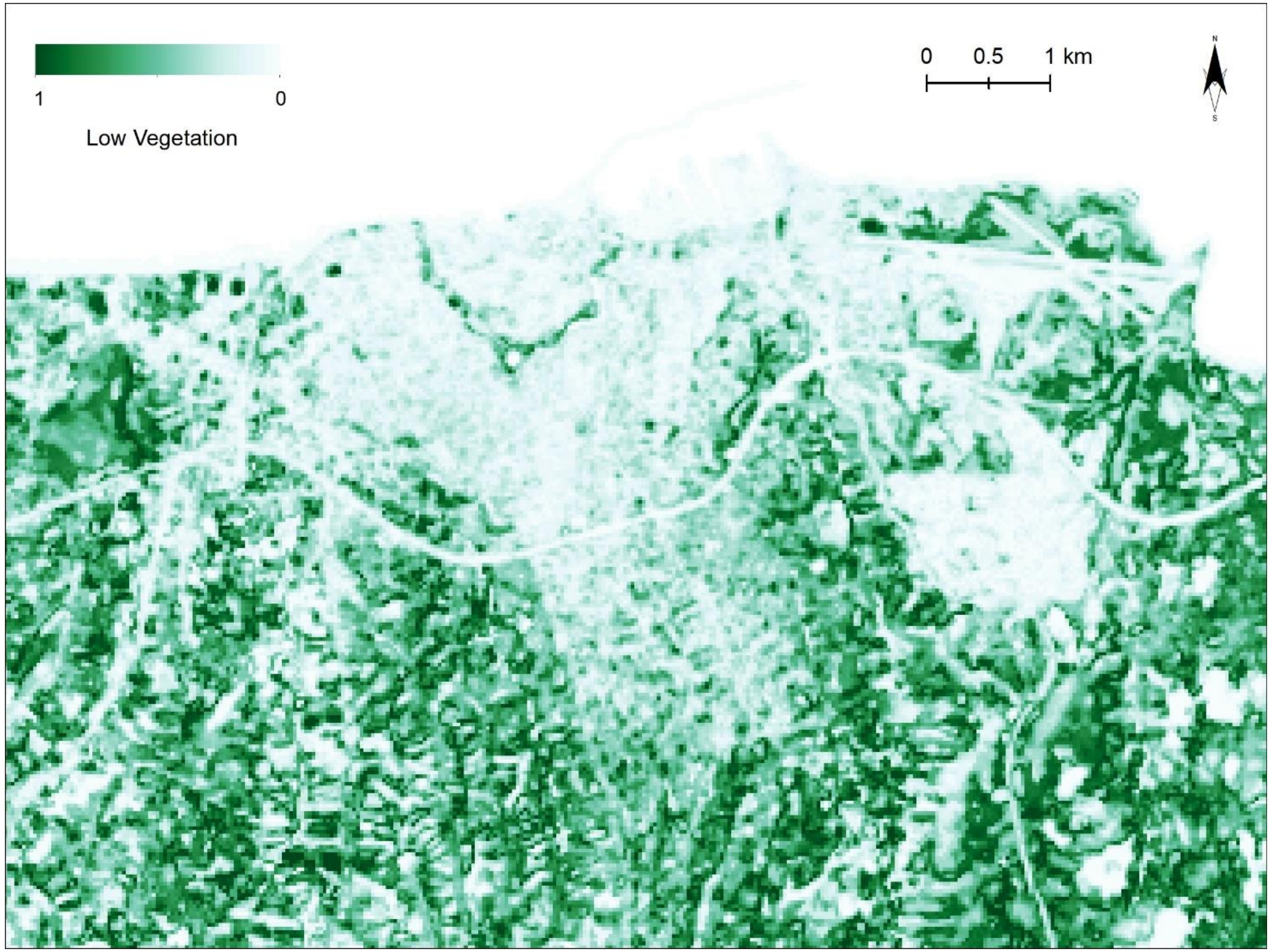
LEVEL II / Impervious classes



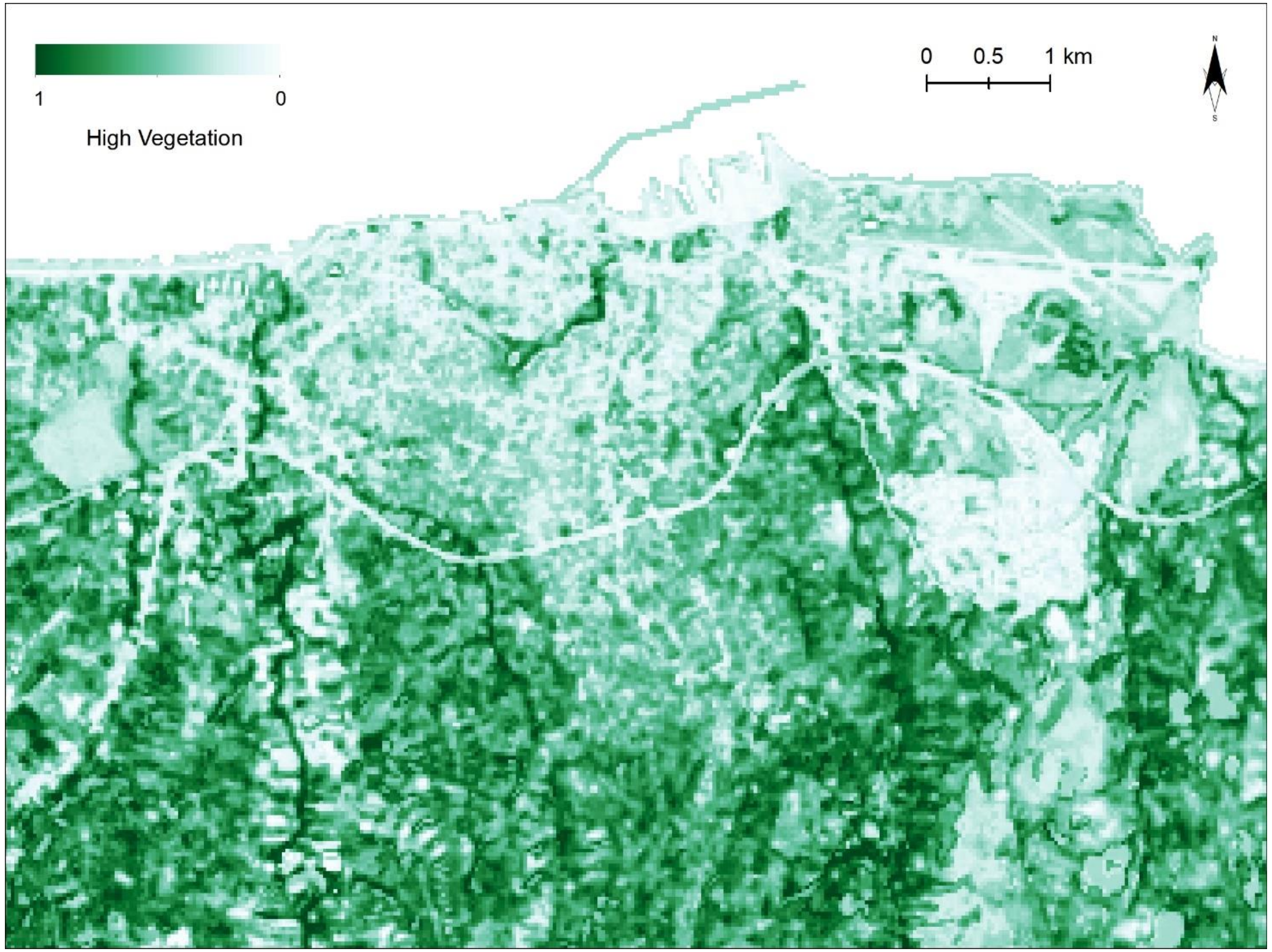
LEVEL II / Impervious classes



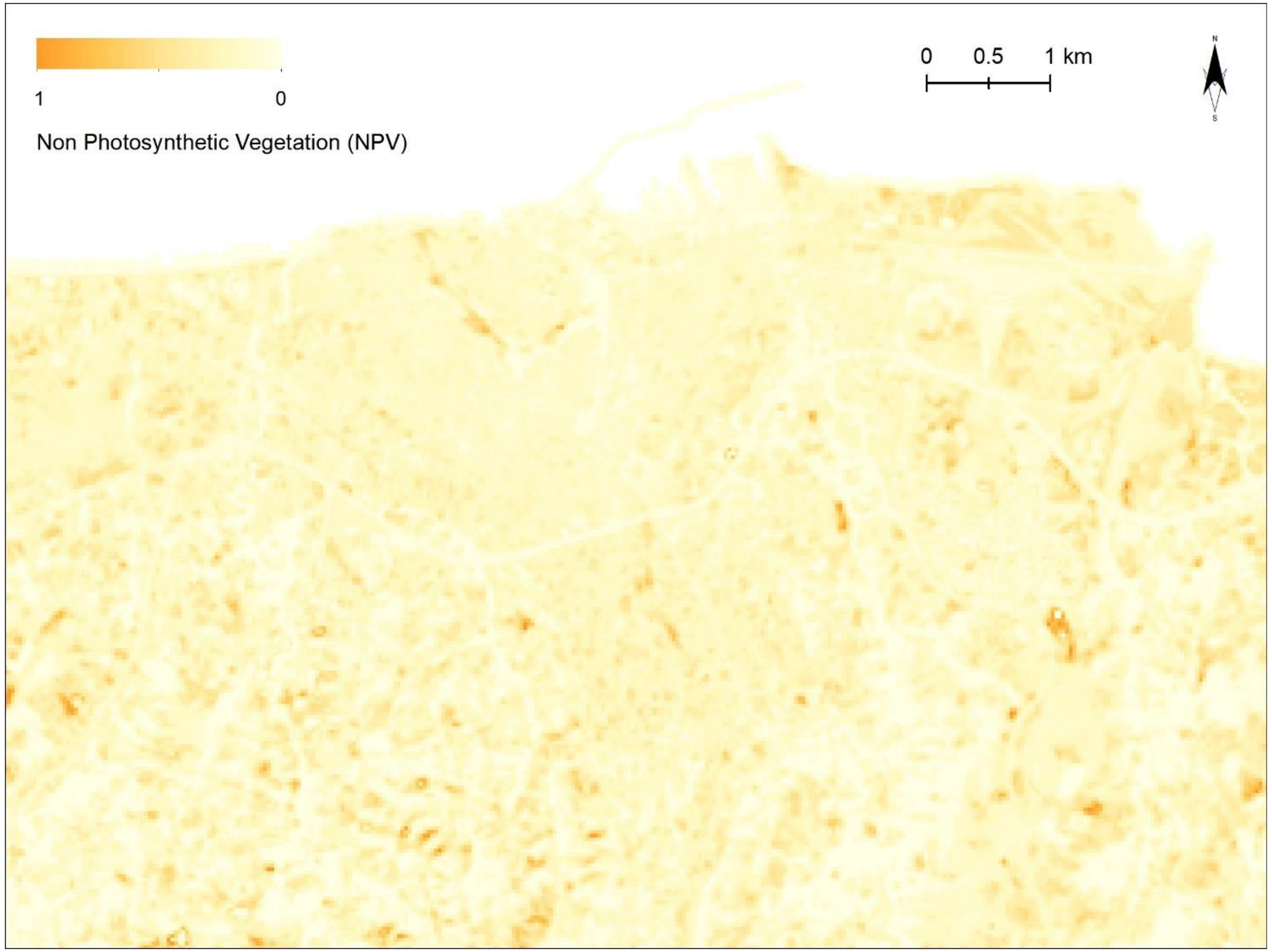
LEVEL II / Vegetation classes



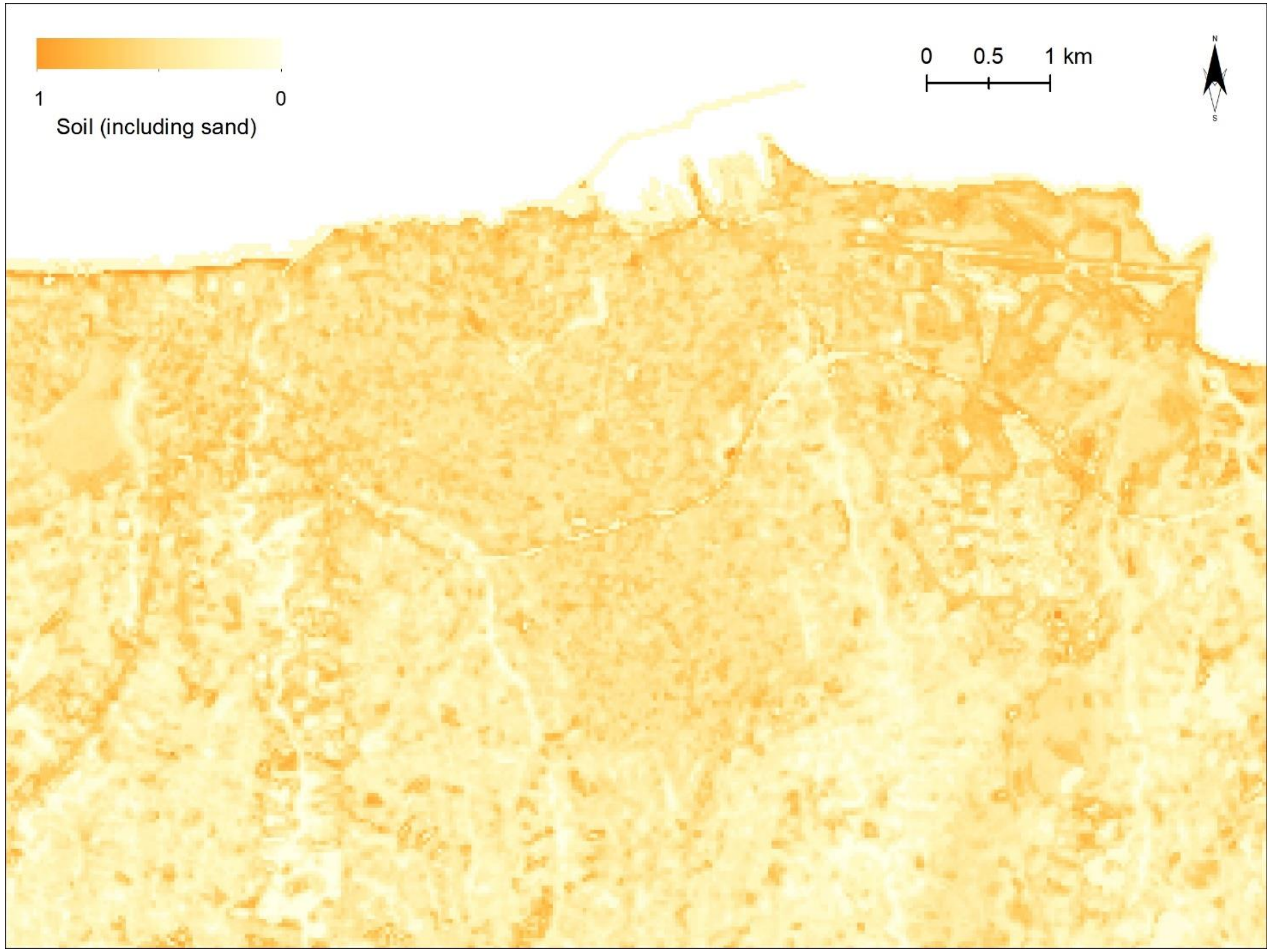
LEVEL II / Vegetation classes



LEVEL II / Pervious classes



LEVEL II / Pervious classes



Regression metrics @ LEVEL II

$N_{samples}$: Asphalt=21, Roofs=20, LowV=9, HighV=28, S=21, NPV=16, Metal=15

		Asphalt	Cement	HighVeg	LowVeg	Metal surf	NPV	Soil
		n=11	n=10	n=13	n=10	n=11	n=11	n=9
RFR	MAE	0.12	0.12	0.12	0.09	0.06	0.07	0.17
	RMSE	0.18	0.2	0.21	0.15	0.1	0.12	0.2
	r^2	0.83	0.72	0.74	0.77	0.92	0.8	0.6
KRR	MAE	0.08	0.1	0.12	0.08	0.06	0.07	0.12
	RMSE	0.12	0.17	0.21	0.16	0.09	0.14	0.18
	r^2	0.89	0.79	0.7	0.66	0.89	0.73	0.74
Linear_ENVI	MAE	0.43	0.25	0.29	0.19	0.2	0.7	0.8
	RMSE	0.62	0.47	0.37	0.25	0.26	0.89	1
	r^2	0.22	0.5	0.67	0.48	0.79	0.31	0.01

Level I & II fraction patterns have been captured well in the study area using PRISMA data

- Soil fraction = overestimated across the scene at both Levels
- Vegetation fraction patterns well delineated = Some mixture between low vegetation (turfs) with vineyards exist
- Impervious fractions patterns are well delineated
- Materials have been identified in high fraction pixels

Sources of errors ‼

1. Mixed pixels occur across the Urbanscape
2. Cars and Metal surfaces (panels, water heaters, etc.) random distributed (space/time wise)
3. Dustness in metal surfaces/asphalt/roofs introduce error (overestimation) across the study area
4. NPV / Soil interplay and is hard to distinguish at large sample number areas for evaluation sites
5. Spatiotemporal mismatch of reference imagery vs PRISMA data

Next Steps towards operational fraction mapping?

- **Space-based** hyperspectral data to provide **frequent** data (aka Landsat/Sentinel) – **NOT PER REQUEST**
- **Urban** material spectral **libraries** from **field** campaigns to become **open** and well **documented.**
- These to include the **temporal** dimension (spectrum) of the target **materials.**
- Joined campaigns at multiscales using handhelds, UAV-based, airborne and space platforms (PRISMA/EnMap).

Contact info

Dimitris Poursanidis

dpoursanidis@iacm.forth.gr

tel. +30 2810 391774

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http://rslab.gr

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