The use of neural networks for non-linear spectral unmixing over urban areas

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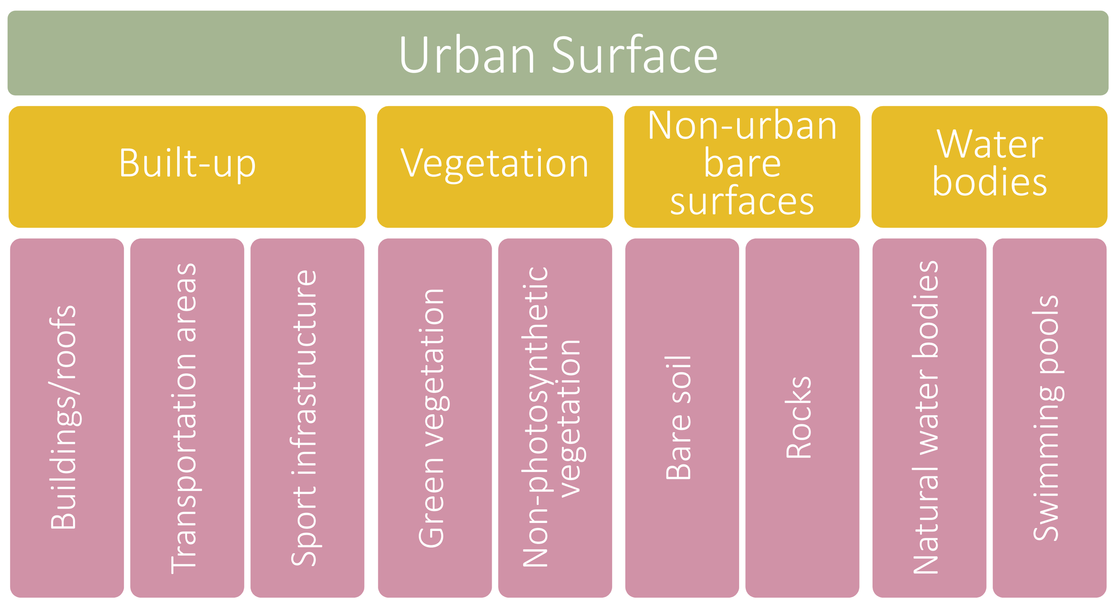
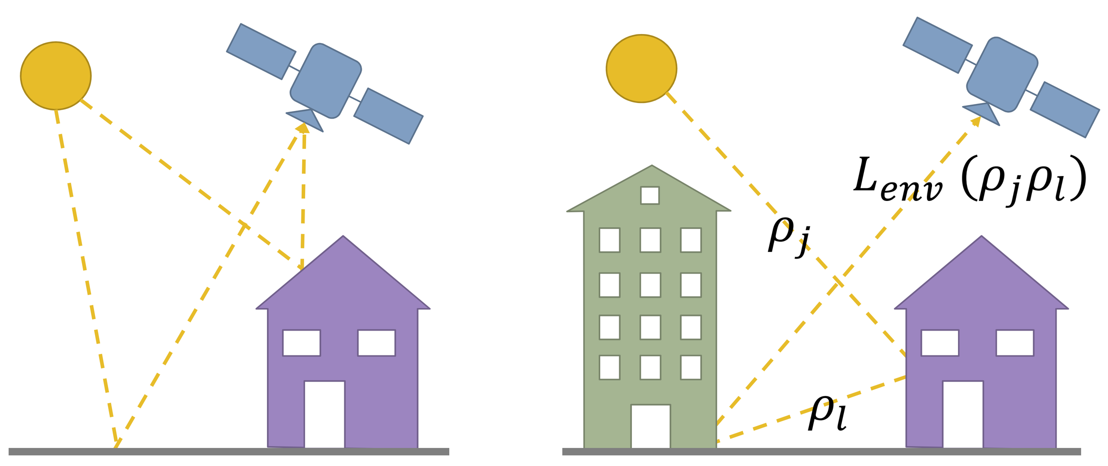
Abstract

The high spatial and spectral diversity of man-made structures and the 3D structure of the cities makes the mapping of urban surfaces using Earth Observation data one of the most challenging tasks of remote sensing field. Spectral unmixing techniques, although designed for and mainly used with hyperspectral data, they can be proven useful for use with medium spectral resolution data. The large spectral variability of urban structures imposes the use of multiple endmember spectral mixture analysis techniques, which are very demanding in terms of computation time. Moreover, the commonly used linear spectral mixture analysis approaches do not account for the multiple scattering of light between surfaces, which contributes significantly to the measured by the satellites reflectances in the urban canyons. In this study, a method is proposed to overcome these limitations, using an artificial neural network trained with endmember and non-linearly mixed synthetic spectra to inverse the pixel spectral mixture in Landsat imagery.

Urban Spectral Mixture





Linear Mixing Model

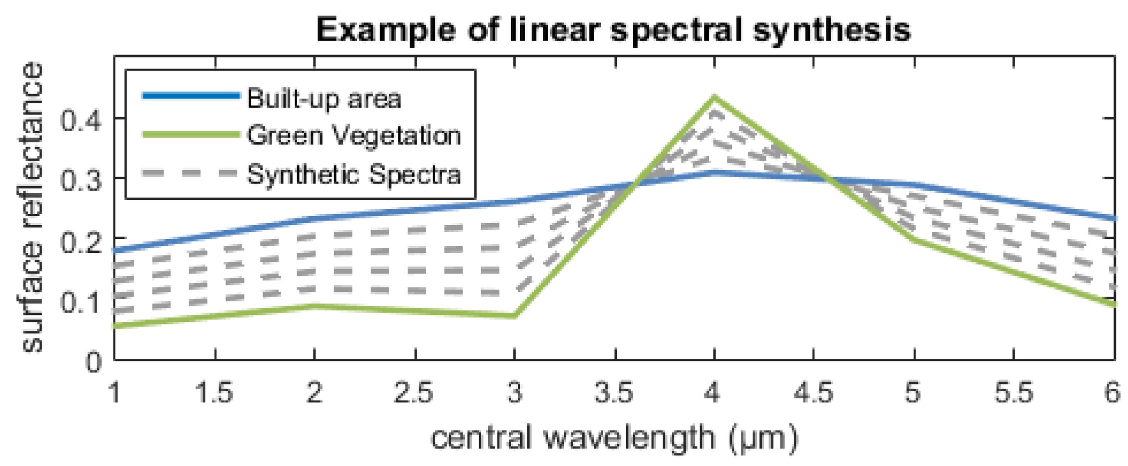
$$\rho_i = \sum_{j=1}^{M} a_j(i) \cdot \rho_j$$

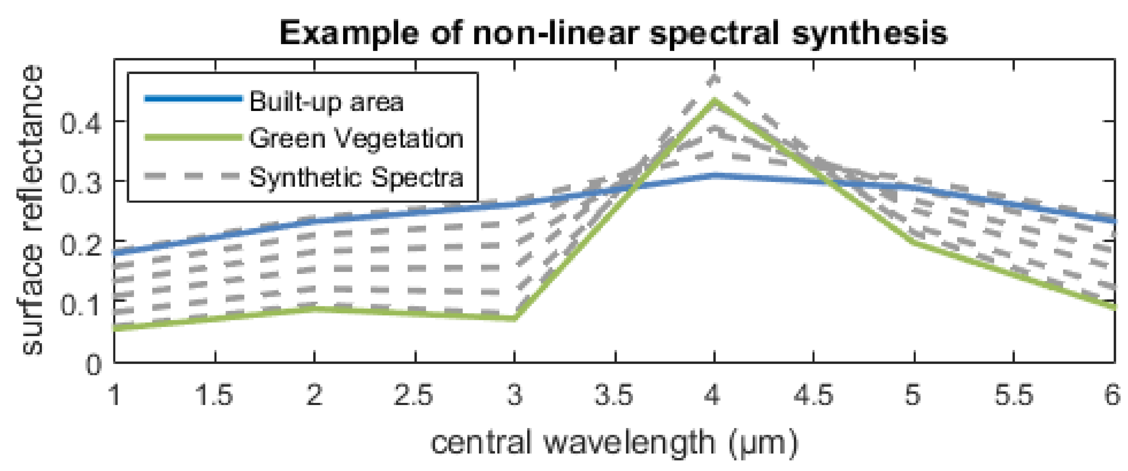
where ρ_i is the observed spectrum of pixel i, ρ_j is the representative spectrum of endmember j, M is the number of endmembers and $a_j(i)$ is the contribution of endmember j to the observed spectrum.

Quadratic Mixing Model

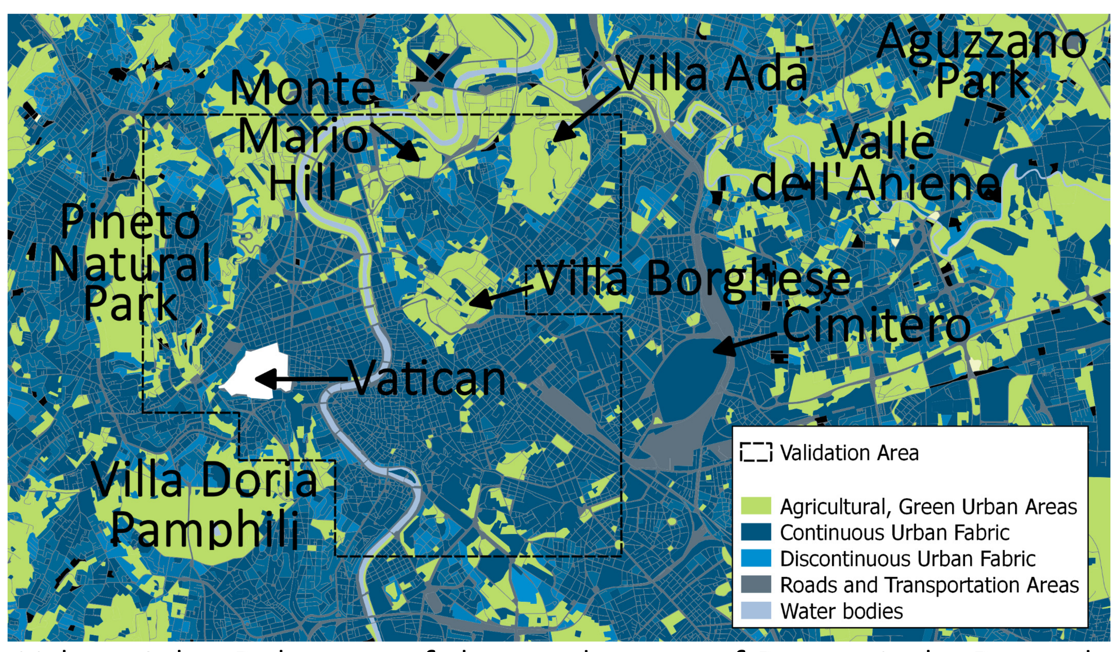
$$\rho_i = \sum_{j=1}^{M} a_j(i) \cdot \rho_j + \sum_{j=1}^{M} \sum_{l=j}^{M} a_{j,l}(i) \cdot \rho_j \rho_l$$

The first term accounts for linear mixing, while the second one accounts for multiple reflections of light between urban surfaces (Meganem et al., 2014).





Study Area and Data

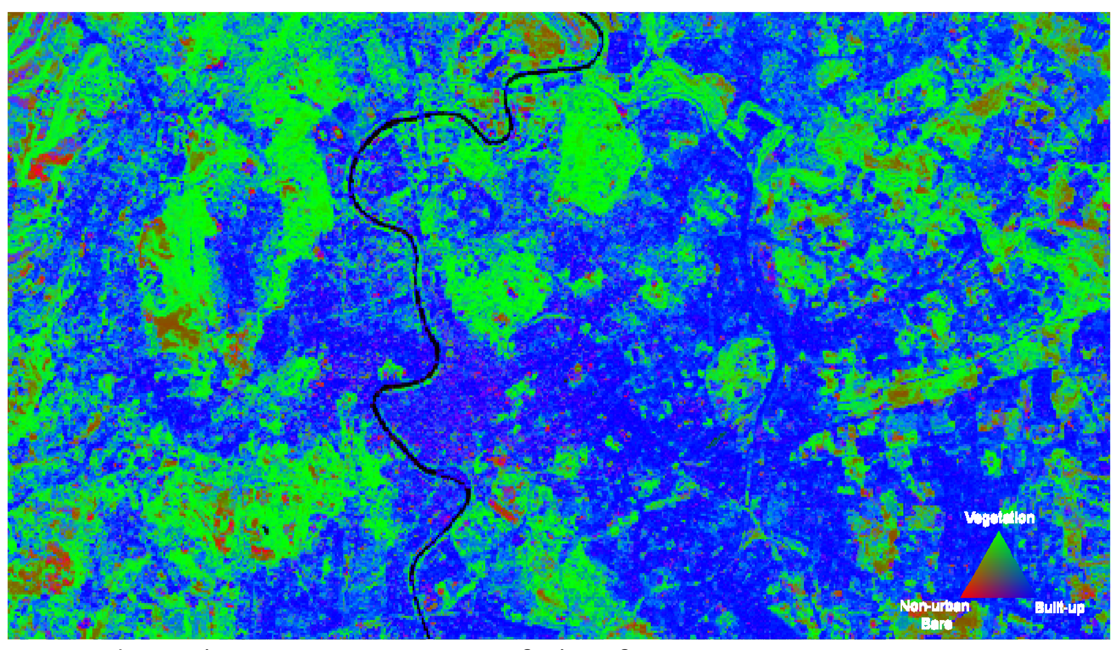


Urban Atlas Polygons of the study area of Rome, Italy. Dotted lined represent the validation area.

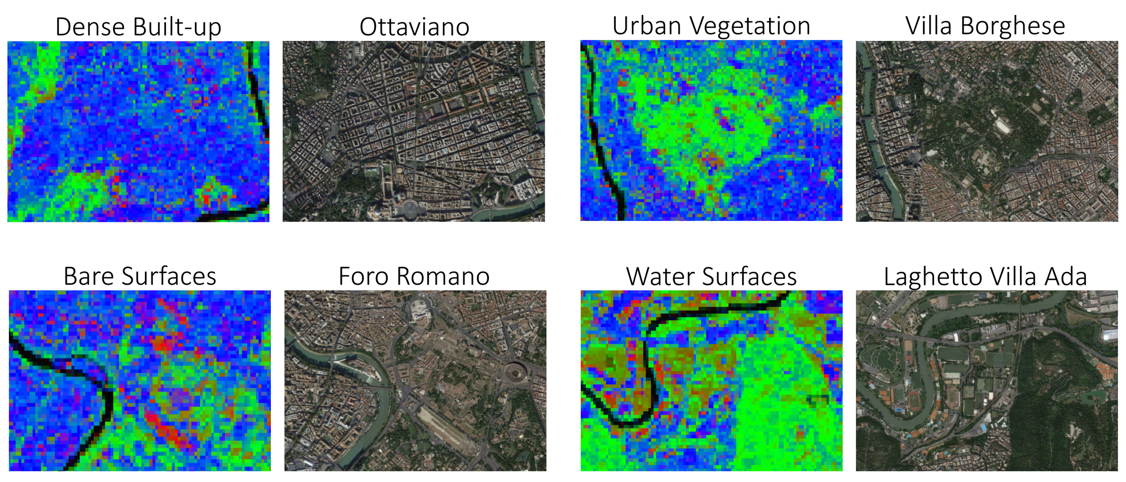
Data

- Six cloud-free Landsat 7 Surface Reflectance Climate Data Record for 2011
- High resolution (0.3 m) Land Cover information for 2011

Results

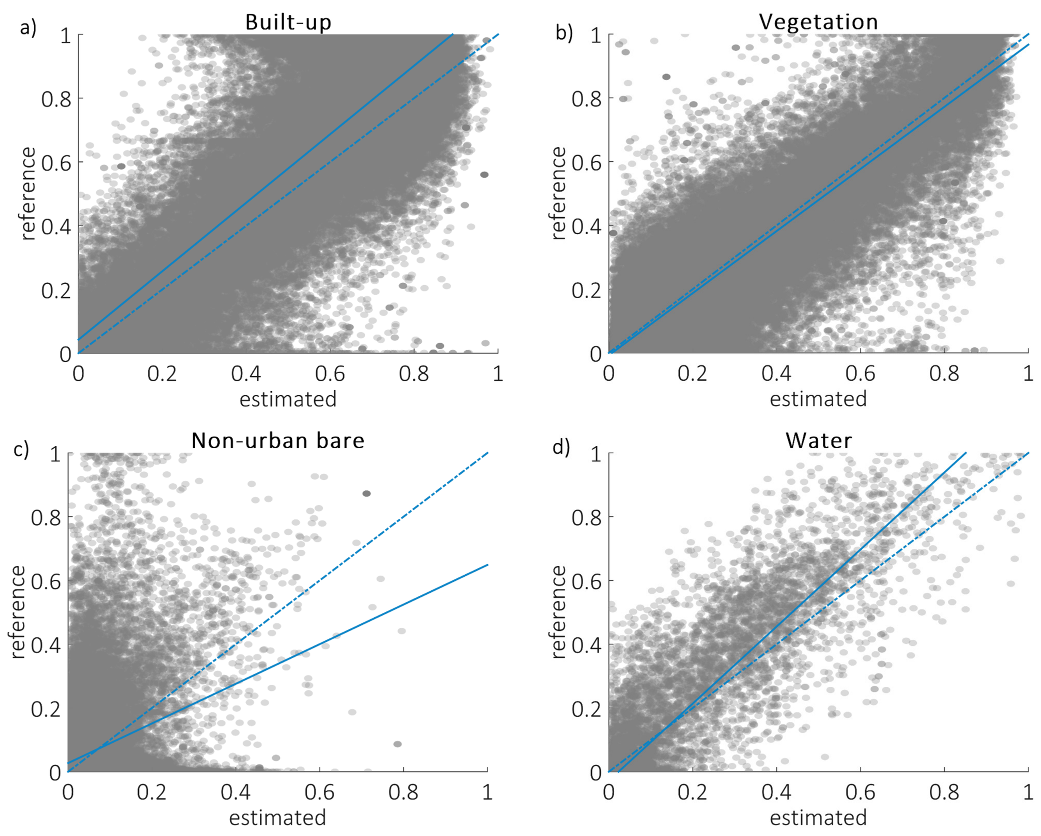


Pseudo color composition of the fraction images, RGB: Non-urban bare, vegetation, built-up; water is background.



Validation

Derived fraction image were compared to fractions from higher resolution land cover info



	Built-up	Vegetation	Non-urban bare	Water
slope	1.074	0.974	0.622	1.208
intersect	0.043	-0.007	0.027	-0.028
R^2	0.686	0.777	0.105	0.812
MAE	0.152	0.097	0.073	0.053
RMSE	0.192	0.130	0.122	0.081

Conclusions

- This study presents a spectral unmixing approach using **endmember** and **non-linearly mixed synthetic spectra** to estimate urban surface cover fraction from Landsat imagery;
- The 3D structure of cities imposes the use of non-linear spectral mixture models to account for **multiple reflections** in the **urban canyons**;
- The estimated fractions were **compared to higher resolution land cover** information and a good agreement was observed, especially for the built-up surface cover fraction;
- Neural networks' quick and accurate performance makes them ideal to use for **operational applications with the Copernicus Sentinels**.

References

Carbone, F. et al. (2015). A Citizen Science approach for the classification of VHR images in urban areas. In *IGARSS 2015*. Milano, Italy.

Meganem, I. et al. (2014). Linear-quadratic mixing model for reflectances in urban environments. *IEEE Transactions on Geoscience and Remote Sensing*, *52*(1), 544–558.

Okujeni, A. et al. (2013). Support vector regression and synthetically mixed training data for quantifying urban land cover. *Remote Sensing of Environment*, *137*, 184–197.