Quantification of urban green areas: An innovative remote sensing approach for official statistics

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Urban Environmental data survey in Istat

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Process description

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Report

[S] - Urban environmental data

Description	The "Urban Environmental data", carried out annually by Istat, collects environmental statistical information relating to the 109 municipalities of provincial capitals / the metropolitan city and from the 2020 edition the Municipality of Cesena participates on a voluntary basis. The data collected are aimed at providing an information framework to support the monitoring of state of the urban environment, and the policies to be adopted by the local administration to ensure good quality of environment in the cities. The survey is divided into seven dedicated questionnaires - Air, Eco management (which includes water ration measures for civil use, previously collected by a specific Water module), Energy, Mobility, Waste, Noise and Urban Green - which gather information on: level of air pollutants and measures to contain them; production of energy from renewable sources, efficient use of energy, certification and energy upgrading of buildings; policies to prevent production, facilitate the correct supply and collection of urban waste; noise measurements, exceeding limits and temporary activities with significant noise impact; supply and demand for local public transport, sustainable mobility and info mobility; public urban green areas, actions for the development of green areas, protected natural areas and urban forestation; planning tools related to the main urban environmental issues. In addition to the data collection related, the survey also allows the possibility of revising the statistical information collected for Air, Energy, Noise and public urban green areas questionnaires. Since the edition 2018 the Water module has been incorporated in the "Census of waters for civil use" (biennial), that will be carried out in the current year. The Urban Environmental survey is part of the National Statistical Program, which includes all the statistical surveys of public interest. Therefore Istat is required by law to carry out this survey and the provincial capitals are required to participate in it, as, as required by the law, the obligation to reply is mandatory.
Eurostat type of process classification	Multiple data sources statistic
First production year	2000
Questionnaire	Questionnaire environmental data collection in the city in 2018 since 31/12/2017 Questionnaire environmental data collection in the city in 2021 since 31/12/2017 Questionnaire environmental data collection in the city in 2017 since 31/12/2016

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Automatic estimate of vegetation by remote sensing

- The point of reference are the very high spatial resolution ortho-images released by AGEA (Agency for the Agricultural Supply) characterized by a 20 cm pixel on the ground (urban areas) and 50 cm for the extra-urban areas.

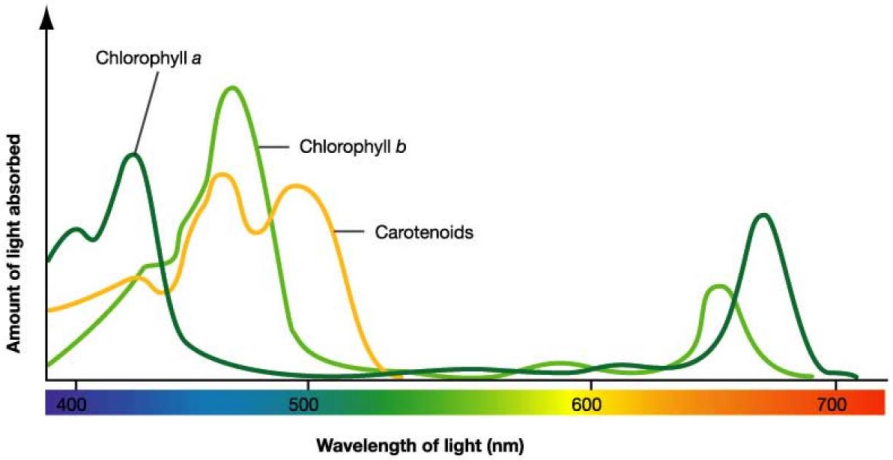
- These images cover, over a three years period, the entire Italian territory and starting from 2012, have been released to ISTAT at four spectral bands

- Detect Vegetation: Normalized Difference Vegetation Index (NDVI)

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$

The NDVI values range from -1.0 to 1.0:

Values Close to 1.0: Indicate high levels of vegetation, suggesting dense green leaves.
Negative Values: Usually represent water.



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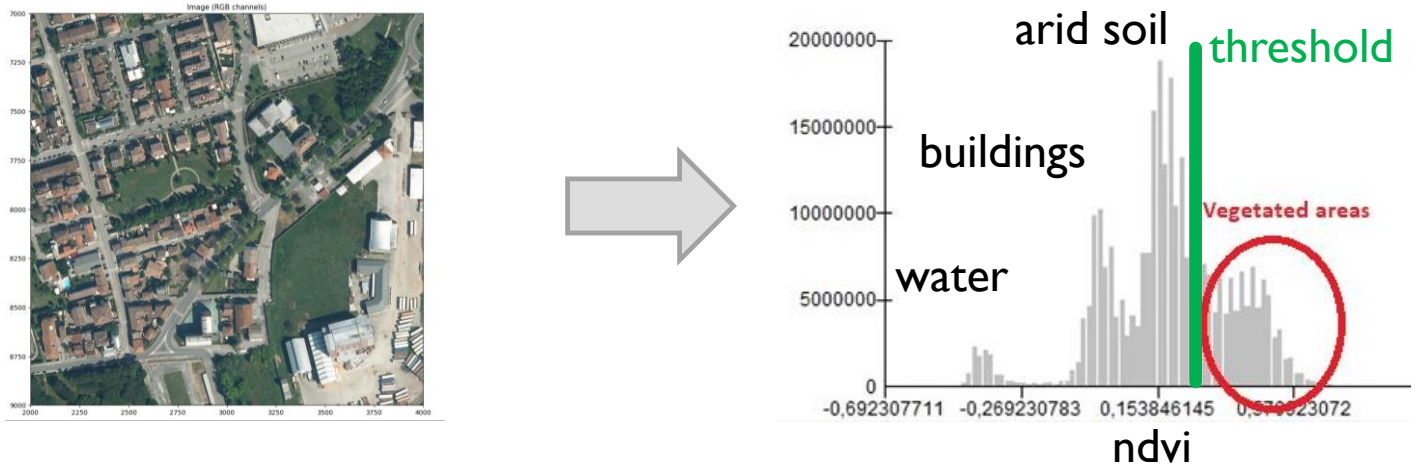
Methodological support

The identification of vegetation with NDVI has been a consolidated technique.



Our study aims to find a robust procedure to identify the threshold that best identifies the vegetation separation zone:

- Variability: Each ortho-image has its own threshold
- Class separation: can be unclear with overlapping classes
- Number of classes: do not always have the same number of k classes

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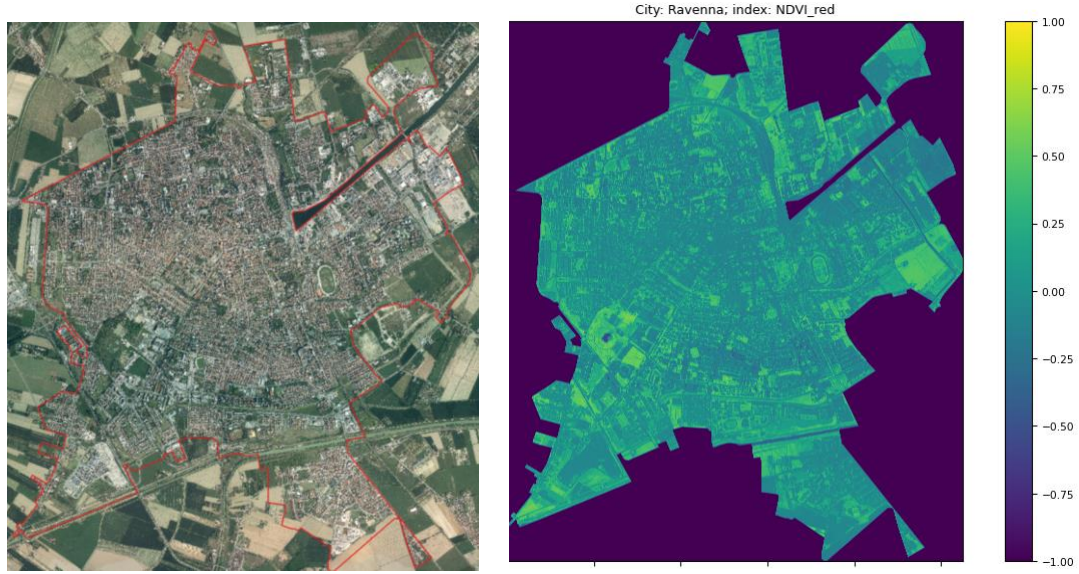
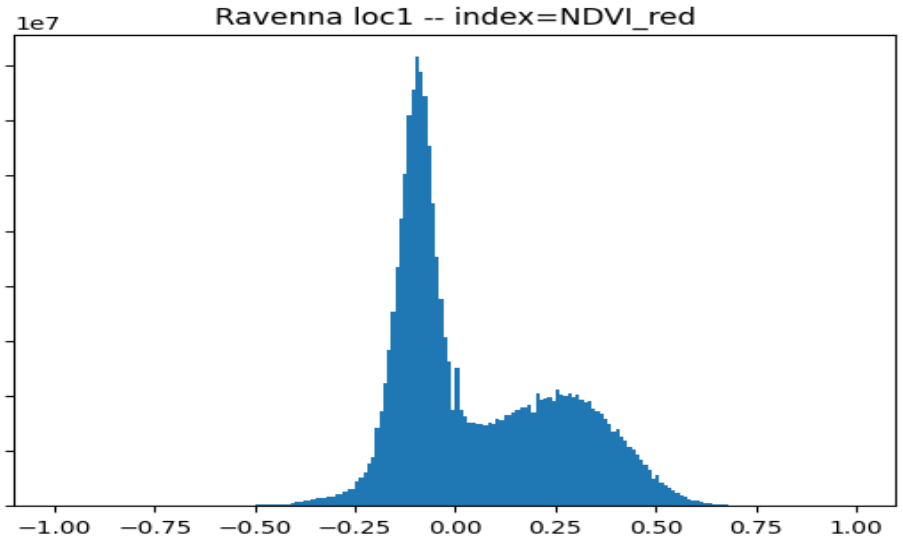
Preprocessing

For **each municipality**:

- Ecw ortho-images are converted to tiff.
- Multiple tiff images for each city are merged (**mosaic**) averaged along the overlap zones.
- To identify the **urban areas** within the municipality, the analysis is carried out only on the **"inhabited area" type census sections** (Istat basi territoriali).
- The **NDVI** is calculated on the inhabited area
- The **histogram** is producted





Find the vegetation threshold

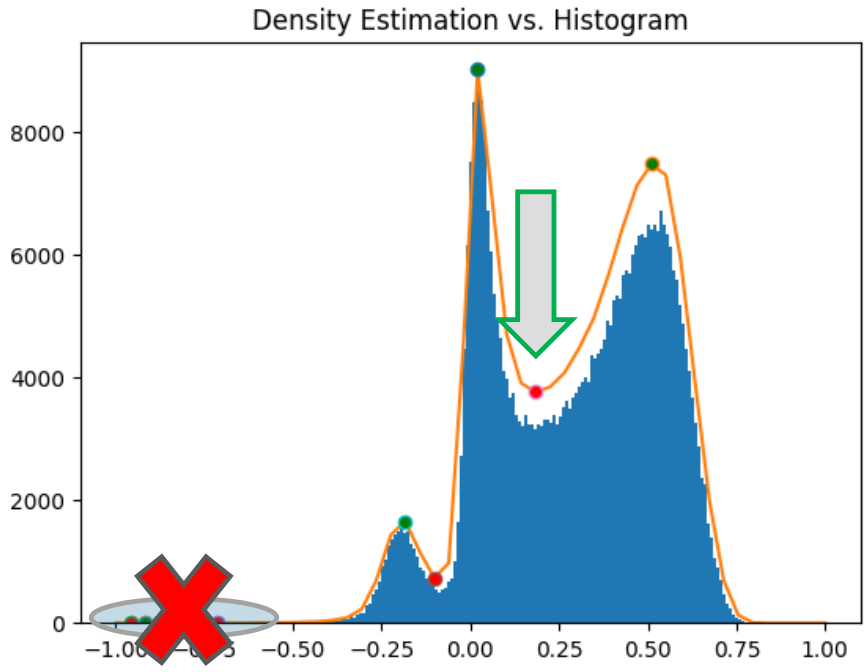
1) Method: Kernel Density Estimation KDE

Is a non-parametric method used to estimate the probability density function of a random variable. (NDVI values)

In the density function local maximum and minimum points are calculated

Small maximum and minimum points below a density value are not considered

The vegetation threshold is identified by the last minimum



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Find the vegetation threshold

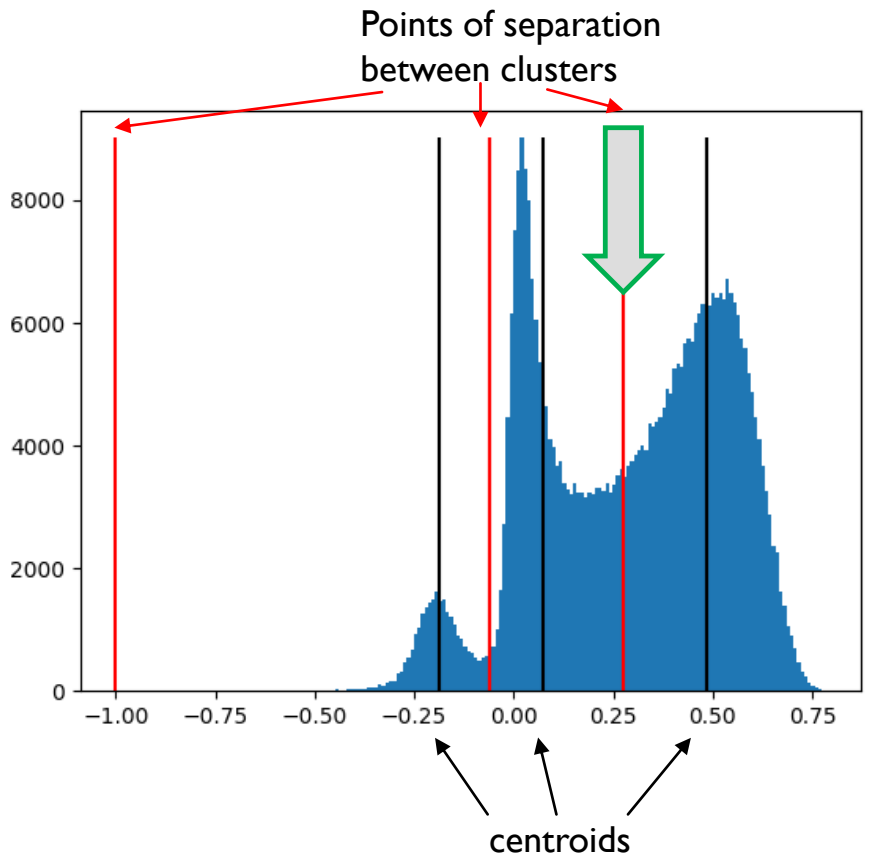
2) Method: Cluster Analysis (k-means k-medians)

Unidimensional cluster analysis problem.

We used the results from the previous KDE to:

- Set the parameter k the number of clusters: max(2,Number_of_maximum_KDE)
- Initialize the position of the centroids

The last point of separation between classes is the vegetation threshold

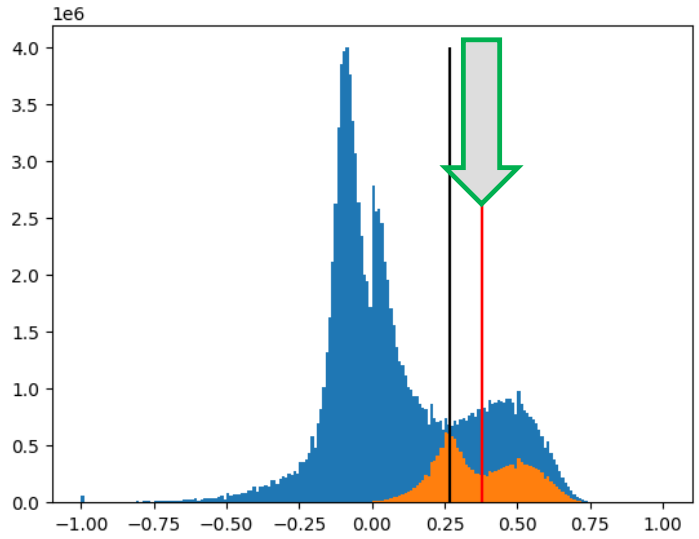


Find the vegetation threshold

3) Method: Advanced pipeline

This approach has a slightly different purpose, that of finding the specific vegetation threshold along vegetation boundary zones

- Create a vegetation mask using the vegetation threshold calculated in KDE method
- Apply the mask over NDVI image and then apply edges detection filter (canny-edge) to the to detect the separation zone of vegetation.
- Dilate the edges by a buffer
- Calculate a new NDVI histogram only on the buffered areas
- Apply Otsu algorithm to detect the vegetation threshold



Results city of Ravenna

		index	tot pix	tot m^2	tot Ha	threshold	green pix	green m^2	green Ha	perc green
Totale Ravenna	KDE	NDVI_red	457.439.517	18.297.580,68	1.829,76	0,06	182.322.979	7.292.919,16	729,29	39,86
	KMEANS (2 clusters)	NDVI_red	457.439.517	18.297.580,68	1.829,76	0,11	165.830.738	6.633.229,52	663,32	36,25
	KMEDIANS (2 clusters)	NDVI_red	457.439.517	18.297.580,68	1.829,76	0,08	174.698.659	6.987.946,36	698,79	38,19
	Advanced pipeline	NDVI_red	457.439.517	18.297.580,68	1.829,76	0,18	136.061.208	5.442.448,32	544,24	29,74

The results with the first three methods are similar in terms of percentage of vegetation in the urban area, this suggesting a certain degree of stability of the results respect to the approaches.
Between 36.25% and 39.86%

The Advanced pipeline, refining the identification of a more intense vegetation threshold, shows a lower percentage (29.74%)

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Sentinel-2 with Google Earth Engine

- Collaboration with Google Italia and GEE researcher
- Use of the Cloud platform (free account) for the creation of an Advanced Pipeline
- Data source: Sentinel2 MSI: 10 m resolution 5 days equatorial period, temporal averages on the images, cloud correction.
- The only input to provide is the contours of the (inhabited center) of the municipality that we want to analyze
- Period March 2022 – July 2022 Emilia Romagna
- Quick implementation and execution (statistics production output, no map export)

Sentinel-2 with Google Earth Engine (Results)

With Sentinel2 satellite data.

We ran the Advanced pipeline in 30 municipalities in Emilia Romagna (small, large and medium-sized).

Ravenna 39014 shows a green percentage of 0.33%

For large municipalities the vegetation share aligns with the results of the orto-images

For small municipalities we have an overestimate of the percentage of urban vegetation due to the 10m resolution of satellite images

procom	thr	greenShare	area
37006	0.290006	0.423936	7,66E+13
35033	0.306024	0.425843	5,47E+13
38008	0.286047	0.428978	5,24E+13
34027	0.277958	0.381284	4,70E+13
39014	0.289999	0.334010	4,61E+13
36023	0.286011	0.339625	4,61E+13
40012	0.298035	0.374773	3,70E+13
40007	0.298018	0.375632	3,37E+13
99014	0.278030	0.252345	3,30E+13
33032	0.250000	0.293729	3,07E+13
36013	0.273994	0.216691	1,01E+13
39002	0.293971	0.406677	6,92E+12
37047	0.274090	0.502048	6,48E+12
40045	0.289979	0.350246	6,24E+12
36019	0.290040	0.334865	6,03E+12
37037	0.321932	0.377919	4,72E+12
99002	0.297998	0.245689	4,63E+12
36027	0.285965	0.355421	4,44E+12
37021	0.302047	0.296329	3,96E+12
36030	0.270069	0.396701	3,93E+12
34005	0.289957	0.623265	6,12E+11
36035	0.274975	0.632966	5,31E+11
33030	0.293978	0.597969	4,92E+11
40033	0.294972	0.602242	4,84E+11
33017	0.254950	0.481444	3,72E+11
33034	0.296960	0.578133	2,73E+11
33047	0.292967	0.638616	2,58E+11
33015	0.294929	0.636292	1,92E+11
34044	0.285101	0.549220	1,13E+11
99021	0.311015	0.713694	6,63E+10

Conclusions

- Determination of urban vegetation through radiometric approach (S.Mugnoli, A.Sabbi)
- Data source: ortho-images, 4 Bands, 20 cm Resolution, Total coverage every 3 years
- Output type: for the urban center of each city of interest (provincial capitals) production of statistics and maps of urban vegetation.

- Study on the automatic identification of the vegetation threshold
- Three methods KDE, Clustering, Advanced pipeline
- KDE, Clustering return comparable results
- Advanced pipeline returns lower vegetation estimates

Next Steps

- Perform the process across many municipalities and evaluate which of the tested methods is a candidate for the final estimate.
- Provide estimates after the removal of areas below 100m^2.
- A more refined classification. Classify types of urban greenery (sports fields, parks, avenues).
- Evaluate the use of Sentinel-2 in large cities to have a proxy for the urban greenery estimate, performed with ortho-images to have more timely estimates of urban green.

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THANKS

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