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8.2 Annual trend in vegetation cover in urban green infrastructure

Project Name: MAvES (Mapping, Assessment and Valuation of Ecosystems and their Services) (JRC-D3- Institutional project)

Author/s and affiliations: Grazia Zulian[1], Joachim Maes[1], Guido Ceccherini[2]

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Greenest urban green infrastructure and long-term trend in green spaces pattern	Green Space Management
Description and justification	This indicator examines how and in which direction vegetation cover changes within the Urban Green Infrastructure. Trend detection in Normalized Difference Vegetation Index (NDVI) time series can help to identify and quantify recent changes in ecosystem properties.
Definition	Urban green spaces make an important contribution to the liveability of cities. This indicator examinehow green are urban green infrastructure using remote sensing data. 1- The greenest value per UGI is derived

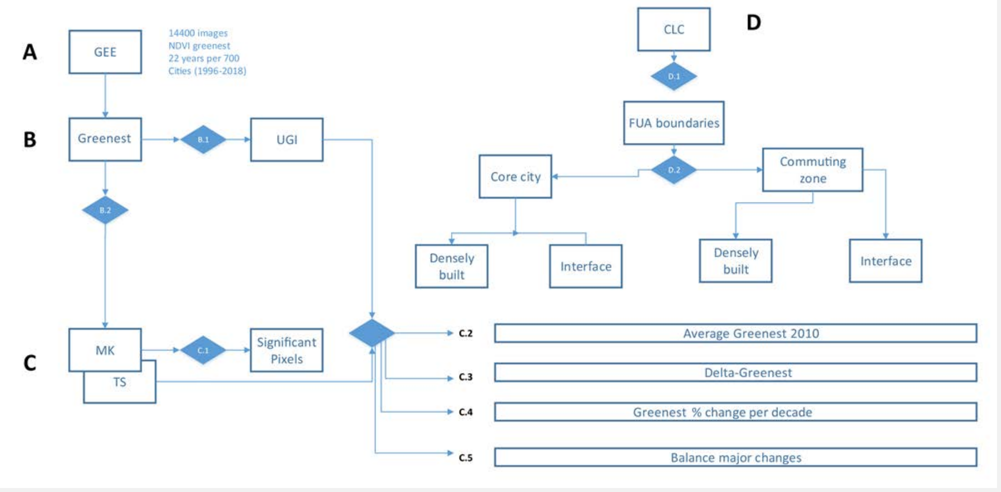
<table>
<tr><td></td><td>2- patterns of changes in the long-term. are reported as:
a. % of change per decade
b. Balance between greening and browning areas
Greenness and temporal trends were measured within core cities and within their commuting zones focusing on:
-Densely built-up areas where artificial areas cover > than the 60% of a 2.25 km2 neighborhood
-not densely built up areas where artificial areas are mixed with urban forest, seminatural vegetation or urban fringes</td></tr>
<tr><td>Strengths and weaknesses</td><td>-spatially explicit -> provides a detailed analysis of change in urban green infrastructure
-relatively complex</td></tr>
<tr><td>Measurement procedure and tool</td><td>Trend analysis employed non-parametric approaches, namely Theil–Sen regressions. The slopes of the regression approach were tested for their statistical significance using the p-value of the Mann–Kendall test for slopes (Forkel et al. 2013; Corbane et al. 2018; Novillo et al. 2019). Pixels for which the p-value (Mann–Kendall) was less than 0.1 (90% confidence interval) were extracted and considered to have a significant medium-term trend. We then applied the Theil–Shen regression to obtain the Theil–Sen positive or negative slopes of all significant NDVI trend pixels from 1996 to 2018.
From the Theil–Sen positive or negative slope we extracted the pixels that overlap areas where (at least once between 1996 and 2018) the highest-NDVI was greater than 0.4. In this way we could focus on changes which affected the urban green infrastructure, minimizing the impact of mixed pixels on the analysis (Dobbs et al. 2018).
Changes were reported for densely and not densely built up areas.

- Medium-term trend summary statistics
o Average value - Coefficient of variation - Minimum - Maximum
- Medium-term trend classes share (%)

Slope was reclassified in 5 classes representing key change thresholds:
<table>
<tr><td>≤-0.015 → hard browning</td><td rowspan="2">Downward trends (Browning) due to housing policies, development of industrial and commercial areas, new grey infrastructures</td></tr>
<tr><td>-0.015 < x ≤ -0.0001 → light browning</td></tr>
</table></td></tr>
</table>

-0.0001 < x ≤ 0.0001 → no changes	No changes
≤ 0.007 → light greening	Upward trend (Greening) due to green infrastructure management; vegetation growth; climate change

Percentage of pixels with significant positive and significant negative trends were used as accuracy indicator.



Scale of measurement	Functional Urban Areas (Core cities and Commuting Zone)
Data source	
Required data	- Landsat annual Top-of- INTERNATIONAL JOURNAL OF DIGITAL EARTH 3 Atmosphere (TOA) reflectance composites available as collections in the Google Earth Engine (GEE) platform for the period 1996–2018 - the model can be implemented using NDVI trend data Measurement Unit: - % [change in NDVI (greenest value) per decade] - Greening-Browning balance (difference between share of UGI where there has been a major upward and downward trend in vegetation cover)
Data input type	-raster (vector data will be rasterised)
Precision	30 m
Data collection frequency	Year or time-series range (for available data at EU scale): 1996–2018 (http://data.jrc.ec.europa.eu/collection/GHSL)
Level of expertise required	-GIS programmer (advanced)

Synergies with other indicators	- With structure of Urban green and Urban Forest - With recreation opportunities - With land suitability for pollinators
Connection with SDGs	//
Opportunities for participatory data collection	No
Additional information	
References	Corbane C, Pesaresi M, Politis P, Florczyk J. A, Melchiorri M, Freire S, Schiavina M, Ehrlich D, Naumann G, Kemper T (2018) The grey-green divide: multi-temporal analysis of greenness across 10,000 urban centres derived from the Global Human Settlement Layer (GHSL). Int J Digit Earth 0(0): 1–18. doi: 10.1080/17538947.2018.1530311 Dobbs C, Hernández-Moreno Á, Reyes-Paecke S, Miranda MD (2018) Exploring temporal dynamics of urban ecosystem services in Latin America: The case of Bogota (Colombia) and Santiago (Chile). Ecol Indic 85(November 2017): 1068–1080. doi: 10.1016/j.ecolind.2017.11.062 Forkel M, Carvalhais N, Verbesselt J, Mahecha MD, Neigh CSR, Reichstein M (2013) Trend Change detection in NDVI time series: Effects of inter-annual variability and methodology. Remote Sens 5(5): 2113–2144. doi: 10.3390/rs5052113 Jin J, Gergel SE, Lu Y, Coops NC, Wang C (2019) Asian Cities are Greening While Some North American Cities are Browning: Long-Term Greenspace Patterns in 16 Cities of the Pan-Pacific Region. Ecosystems. doi: 10.1007/s10021-019-00409-2 Maes, J., Teller, A., Erhard, M., Condé, S., Vallecillo, S., Barredo, J., Paracchini, M.L., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A.I., Ivits, E., Mauri, A., Rega, C., Czúcz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J.V., Spinoni, J., Cammalleri, C., Bastrup-Birk, A., San Miguel, J., San Román, S., Petersen, J., Kristensen, P., Christiansen, T., Zal, N., de Roo, A., Cardoso, A.C., Pistocchi, A., Del Barrio Alvarellos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Robert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O., Santos-Martín, F., Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment, EUR (where available), Pulications Office of the European Union, Ispra, 2020, ISBN 978- 92-79-XXXXX-X (where available), doi:10.2760/XXXXX (where available), JRC120383.

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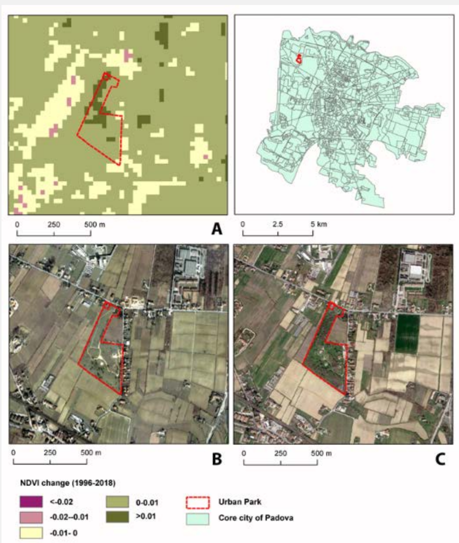
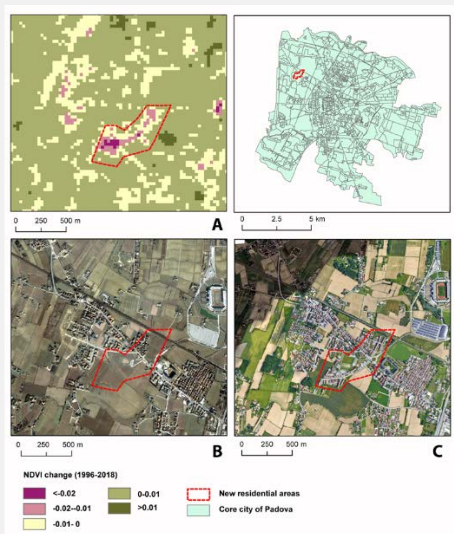
Yu Z, Wang Y, Deng J, Shen Z, Wang K, Zhu J, Gan M (2017) Dynamics of Hierarchical Urban Green Space Patches and Implications for Management Policy.

Zhu Z, Fu Y, Woodcock CE, Olofsson P, Vogelmann JE, Holden C, Wang M, Dai S, Yu Y (2016) Including land cover change in analysis of greenness trends using all available Landsat 5, 7, and 8 images: A case study from Guangzhou, China (2000–2014). Remote Sens Environ 185: 243–257. doi: 10.1016/j.rse.2016.03.036

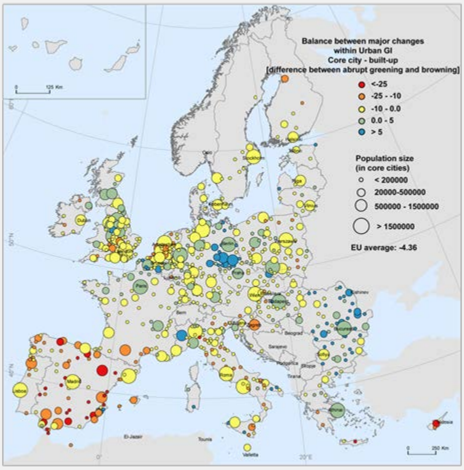
Below, left: Example of abrupt greening (upward trend) due to due to green infrastructure management in Padova core city - not densely built zone (Italy). A. represents the NDVI change between 1996-2018; B represents the park in 2001 and C represents the park in 2018.

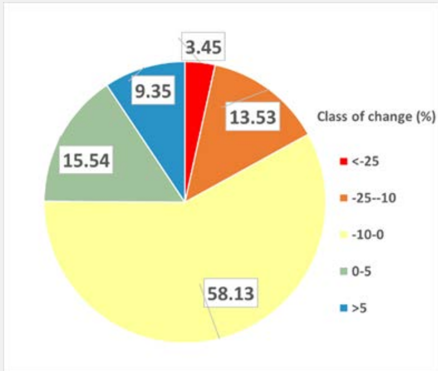


Below, right: Example of abrupt browning (downward trend) due to housing policies in Padova core city - not densely built zone (Italy). A. represents the NDVI change between 1996-2018; B represents the area in 2001 and C represents the area with a new residential zone in 2018.



Balance between abrupt greening and browning changes within densely built areas in core cities and commuting zones. Pie charts show the proportion of reporting units per class of change (%).





8.3 Edge density

Project Name: Indicators for urban green infrastructure (EEA)

Author/s and affiliations: EEA, ETC/ULS

Edge density	**Green Space Management**
Description and justification	Within cities, green areas may not be equally distributed. An uneven distribution of GUAs prevents equal accessibility for all city dwellers, focuses benefits from exposure on fewer city elements (neighbourhoods, streets, buildings or houses) and prevents connectivity of all the available green spaces in the ecological network. The edge density provides an indication of the distribution of GUAs. A high edge density in a city indicates a relatively high number of green areas that border residential, commercial, and industrial or other public buildings. Consequently, a higher value for the indicator may be due to a long boundary length, i.e., more small patches. This measure provides a proxy for the equal or non-equal distribution of green urban areas in the city. Increasing the green area and distributing it more evenly is an effective measure in reducing the undesired effects of clustered urban green areas.