# Indicator 2.3.3: Level of Urban Greenness

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**Methods**

The urban center spatial extents were defined by the Global Human Settlement (GHS) program of the European commission.(1) The GHS uses a blend of demographic and remote sensing data to define more than 10,000 urban centers worldwide. We computed the greenness indicator for global urban centers with populations larger than 500,000. For countries that lacked urban centers meeting this threshold, we selected the most populated city where possible, giving a final count of 1,041 urban centers across 174 countries. Due to missing data in the GHS data, 22 countries (mostly small island states) were not represented in the analysis.

Data on population size for all years came from the Joint Research Commission’s Global Human Settlement Layer, which models the distribution of human population at the 100m x 100m resolution.(2)

Green spaces were estimated using the normalized difference vegetation index (NDVI). The NDVI is the most commonly used satellite-based vegetation index and it calculates the ratio of the differences between near infrared radiation and visible radiation to the sum of these two measures. NDVI values range from -1.0 to 1.0 with values less than 0 indicate bodies of water and values close to 1 indicating high levels of vegetation density or greenness.(3) For this process, we utilized publicly available data from the Landsat satellite, a joint program of the USGS and NASA.(4) Landsat images the Earth’s surface at 30-meter resolution approximately every two weeks (~16 days). We first masked water pixels using the Joint Research Commission’s Global Surface Water dataset. (5) Next, to account for seasonal fluctuations, we computed NDVI for each of the following time periods (with season labels based on the northern hemisphere):

* Winter—December 1 of previous year through February 28
* Spring—March 1 through May 31
* Summer—June 1 through August 31
* Fall—September 1 through November 30

We did this for ten different years: 2015-2024. Landsat 8 was used to estimate values for the included years. For each year and city, a total of four exposure metrics were calculated: peak NDVI (maximum NDVI across the four seasons); annual mean NDVI based on the four-season average NDVI; population-weighted peak NDVI; and population-weighted mean NDVI. The population weighted NDVI was computed for each city by multiplying each NDVI value (peak and four-season average) by the population size within the same 100m x 100m raster. Population data from 2015 were used for years 2015-2019 and population data from 2020 were used for years 2020-2024. We then summed the weighted values within the urban extent, and dividing by the sum of the weights, as shown by the equation below:

Additional analyses include subsetting the data by levels of the Human Development Index (HDI, see Figure 1), climate regions as defined by the Köppen Climate Classification System (see Figure 2), Lancet Countdown regional country groupings, and WHO region (see Figure 3).(5) Google Earth Engine was used to generate the raw data for analysis. The R Statistical Software was used for data analysis and management and to compute the four metrics described above. We defined ‘Level of Greenness’ according to the table below (Table 1):

Table 1: Categorization of Greenness Levels

|  |  |
| --- | --- |
| Level of Greenness | Population-Weighted Peak NDVI |
| Exceptionally Low | <0.20 |
| Very low | 0.20-0.29 |
| Low | 0.30-0.39 |
| Moderate | 0.40-0.49 |
| High | 0.50-0.59 |
| Very High | 0.60-0.69 |
| Exceptionally High | ≥0.70 |

**2024 Updates**

We made several methodological changes this year. First, we updated the population data source to a higher resolution data set (from 1km to 100m pixels). Additionally, rather than set all negative NDVI values (typically representative of water) to zero, we used JRC’s global surface water dataset to mask these pixels, after finding that many pixels representing urban areas were had very small negative values. Finally, we calculated each of the four measures of urban greenspace for ten years (2015-2024). We found substantial inter-annual variation in NDVI that is likely the result of climate change, annual weather patterns, and city efforts to expand greenspaces. In several analyses, we compare 2024 levels of NDVI to a baseline period of 2015-2020. In future years it may make sense to compare multiple recent years to this baseline period to highlight urban greenspace trends from climate change and urban interventions.

In addition to these methodological updates, we added a 2020 indicator of urban blue space. We derived blue space from the MODIS landcover dataset, available at a 500m resolution (6). Blue spaces include all permanent surface water, including rivers, lakes, and coastlines. While the evidence supporting a relationship between urban blue space and improved population health is less robust than that of greenspace, many studies have reported positive associations (7-9).

**Data**

1. Global Human Settlement Programme of the European Commission (GHS) used to identify urban centers.(1)
2. Population size identified from JRC GHSL.(2)
3. Satellite data were downloaded from the publicly available Landsat satellite, a joint program of the US Geological Survey and NASA.(4)
4. MODIS landcover data set. (6)
5. Global climate regions from the Köppen Climate Classification System.(10)
6. Human Development Index. (11)

**Caveats**

This approach has some limitations. First, while satellite-based vegetation measures are used extensively to measure greenness, NDVI cannot decipher the quality of greenness (e.g., curated park vs vacant lot), the type of green space (e.g., park vs. forest), the type of vegetation (e.g., shrubs vs. trees) or social characteristics (e.g., level of security). However, studies have demonstrated that NDVI performs adequately when compared with environmental psychologists’ evaluations of green spaces.(12) In addition, reviews of the literature on greenness and health have been undertaken and found consistent and strong evidence of associations of higher greenness measured by NDVI, with improvements in birthweights, physical activity, lower mortality rates, and lower levels of depression.(13, 14)

**Additional analysis**

The findings below represent multiple measures of urban greenness and allow for examination of trends over time.

**A map of the world

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**Figure 1. Köppen Climate Regions.** Designated climate regions of the world using the Koppen Climate Zones system.

**Map

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**Figure 2. Country Development Level.** Development level as denoted by the Human Development Index (HDI).

A map of the world

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Figure 3. World Health Organization (WHO) regions.

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Figure 4. Lancet countdown regions and urban greenness.



Figure 5: Trends in population-weighted peak-season Normalized Difference Vegetation Index (NDVI) over time (2015-2024), by Lancet Countdown region. Each thin line represents an individual city within the Lancet Countdown region, coloured by Human Development Index level.

Table 1: Annual population-weighted peak-season NDVI (2015-2024) by LCD region.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Population-weighted peak-season NDVI** | | | | | | | | | | | | | | | | | | |
|  | **2015** | | **2016** | **2017** | | **2018** | | **2019** | | **2020** | | **2021** | | **2022** | | **2023** | | **2024** | |
| **Global average** | 0.28 | 0.28 | | | 0.28 | | 0.28 | | 0.28 | | 0.28 | | 0.28 | | 0.28 | | 0.28 | | 0.28 |
| **LCD Region** |  |  | | |  | |  | |  | |  | |  | |  | |  | |  |
| **Africa** | 0.26 | 0.25 | | | 0.25 | | 0.25 | | 0.25 | | 0.25 | | 0.24 | | 0.24 | | 0.24 | | 0.24 |
| **Asia** | 0.27 | 0.27 | | | 0.27 | | 0.26 | | 0.27 | | 0.27 | | 0.27 | | 0.27 | | 0.27 | | 0.27 |
| **Europe** | 0.33 | 0.33 | | | 0.33 | | 0.33 | | 0.33 | | 0.33 | | 0.33 | | 0.33 | | 0.33 | | 0.34 |
| **Northern America** | 0.39 | 0.39 | | | 0.39 | | 0.39 | | 0.39 | | 0.39 | | 0.38 | | 0.38 | | 0.37 | | 0.39 |
| **Oceania** | 0.33 | 0.34 | | | 0.34 | | 0.33 | | 0.32 | | 0.32 | | 0.35 | | 0.34 | | 0.34 | | 0.34 |
| **SIDS** | 0.33 | 0.34 | | | 0.33 | | 0.33 | | 0.32 | | 0.34 | | 0.33 | | 0.34 | | 0.33 | | 0.34 |
| **South & Central America** | 0.24 | 0.24 | | | 0.24 | | 0.24 | | 0.24 | | 0.24 | | 0.24 | | 0.24 | | 0.23 | | 0.24 |



Table 2: Estimates of Urban Green Space by HDI (2024)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **HDI-level** | **Peak NDVI** | **Four-season NDVI** | **Pop. weighted Peak NDVI** | **Pop. weighted Four-season NDVI** |
| **Low** | 0.31 | 0.26 | 0.30 | 0.25 |
| **Medium** | 0.38 | 0.31 | 0.37 | 0.31 |
| **High** | 0.34 | 0.28 | 0.32 | 0.26 |
| **Very High** | 0.36 | 0.28 | 0.35 | 0.28 |
| **Global Mean** | 0.35 | 0.29 | 0.34 | 0.28 |

Table 3: Estimates of Urban Green Space by Climate Region (2024)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate Region** | **Peak NDVI** | **Four-season NDVI** | **Pop. weighted Peak NDVI** | **Pop. weighted Four-season NDVI** |
| **Arid** | 0.25 | 0.21 | 0.24 | 0.20 |
| **Continental** | 0.39 | 0.27 | 0.38 | 0.26 |
| **Polar** | 0.17 | 0.13 | 0.14 | 0.11 |
| **Temperate** | 0.36 | 0.30 | 0.35 | 0.28 |
| **Tropical** | 0.40 | 0.34 | 0.38 | 0.33 |

Table 4: Estimates of Urban Green Space by WHO region (2024)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **WHO Region** | **Peak NDVI** | **Four-season NDVI** | **Pop. weighted Peak NDVI** | **Pop. weighted Four-season NDVI** |
| **African** | 0.35 | 0.28 | 0.33 | 0.26 |
| **Americas** | 0.36 | 0.31 | 0.34 | 0.29 |
| **E Mediterranean** | 0.23 | 0.20 | 0.22 | 0.19 |
| **European** | 0.38 | 0.29 | 0.37 | 0.28 |
| **SE Asian** | 0.41 | 0.34 | 0.41 | 0.34 |
| **W Pacific** | 0.33 | 0.25 | 0.30 | 0.23 |

Table 5: Estimates of Urban Green Space by LCD region (2024)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **LCD Region** | **Peak**  **NDVI** | **Four-season NDVI** | **Pop. weighted Peak NDVI** | **Pop. weighted Four-season NDVI** |
| **Africa** | 0.32 | 0.27 | 0.30 | 0.25 |
| **Asia** | 0.35 | 0.29 | 0.34 | 0.28 |
| **Europe** | 0.42 | 0.32 | 0.40 | 0.32 |
| **Northern America** | 0.38 | 0.26 | 0.37 | 0.25 |
| **Oceania** | 0.35 | 0.33 | 0.35 | 0.33 |
| **SIDS** | 0.39 | 0.34 | 0.38 | 0.34 |
| **South & Central America** | 0.35 | 0.29 | 0.30 | 0.26 |

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