Sandyford Business District

Surface Urban Heat Island and Tree Cover Density Analysis

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1 Executive summary

Latitudo 40 is a leading company in the field of Earth Observation. We harness the power of artificial intelligence with satellite imagery to provide smart cities and urban planners with a Data-Driven Urban Regeneration model. Our motto is: learning from the past, monitoring the present and designing the future.

We proposed the following information layers, derived from Earth Observation products using AI, to the Sandyford Business District:

- Surface Urban Heat Island: The SUHI layer assesses the UHI effect, highlighting areas that become warmer than surrounding rural areas due to human activities like urbanization and transportation. By analysing ground temperature data, an index from 0 to 100 is generated, where higher values indicate greater UHI exposure, pinpointing critical zones
- Tree Cover Density: The Tree Cover Density (TCD) layer depicts the percentage of tree canopy cover across a range of 0-100%. It can be used to identify regions exhibiting varying levels of tree canopy cover and thus aid in evaluating deforestation or reforestation patterns in rural areas. The product has a spatial resolution of 10 meters, and it's generated via Machine Learning and Sentinel-2 MSI.

2 Urban Heat Islands

Urban Heat Islands, Product Specifications	
Input Data	L40 LST 10m | Landsat-8/9 | MODIS
Algorithm	Operational Procedure
Metrics	Not Applicable
Spatial Resolution	10 m | 30m | 1km
Temporal Resolution	5-7 days | 2-3 days | Daily (in absence of clouds)
Possible Aggregations	Monthly, Seasonal, Annual
Format	GeoTiff
Units	Percentage
Automation	Fully Automated | Possibility to specify custom rural area
Scalability	Global
Production Time	20 min / 100 Sqkm

2.1 Overview

The Urban Heat Islands (UHI) product allows monitoring of the heat island phenomenon by highlighting areas that become hotter than surrounding rural areas due to human activities such as urbanization. By analyzing ground temperature data, a percentage index is generated, from 0 to 100, where higher values indicate greater exposure to the phenomenon, thus locating critical areas.

2.2 Methodology

To calculate Urban Heat Islands, the Area of Interest (AoI) and rural reference areas must be defined. The developed pipeline allows for manual input of rural areas, if already available, via shapefiles (or similar formats). However, an automatic methodology was developed to identify rural areas that considers Land Cover Classification (LC) as a mask and Tree Cover Density (TCD). Having defined the rural areas within the AOI, it is necessary to define the temporal range in which to calculate the UHI. The most frequent aggregation periods are monthly, seasonal, or annual. Depending on the period identified, we proceed by calculating the median value, pixel by pixel, of the Land Surface Temperature thus obtaining a median value representative of the time range. Finally, the UHI, ranging from 0 to 100, is derived by applying the simple formula:

$$UHI\ Intensitypixel = LSTpixel - LSTrural$$

where LSTrural is the median temperature of the rural area.
Next, a normalization process is carried out:

$$UHI\ pixel = UHI\ Intensitypixel - min(UHI\ Intensity)\ max(UHI\ Intensity) - min(UHI\ Intensity)\ 100$$

2.3 Metrics and Results

This product is the result of a procedural algorithm so for validation reference must be made to the LST layer produced and the goodness of the identified rural area.

2.4 Areas of Application

The Urban Heat Islands product is derived from the Land Surface Temperature and allows for information on heat islands, thus not just temperature. The main application areas identified are:

- Urban planning: Analysis of urban areas that suffer most from the heat island phenomenon to identify efficient and effective mitigation strategies.
- Health: Using the index to predict areas of potential heat-related health risk to guide medical preparedness and public health campaigns.
- Energy efficiency: Predict peak energy demand in heat-affected areas, ensuring grid stability and efficient distribution.

2.5 References

Fabrizi, Roberto, Stefania Bonafoni, and Riccardo Biondi. "Satellite and ground-based sensors for the urban heat island analysis in the city of Rome." Remote sensing 2.5 (2010): 1400-1415.

Ryu, Young-Hee, and Jong-Jin Baik. "Quantitative analysis of factors contributing to urban heat island intensity." Journal of Applied Meteorology and Climatology 51.5 (2012): 842-854.

Zhang, Yang, et al. "Study on urban heat island intensity level identification based on an improved restricted Boltzmann machine." International journal of environmental research and public health 15.2 (2018): 186.

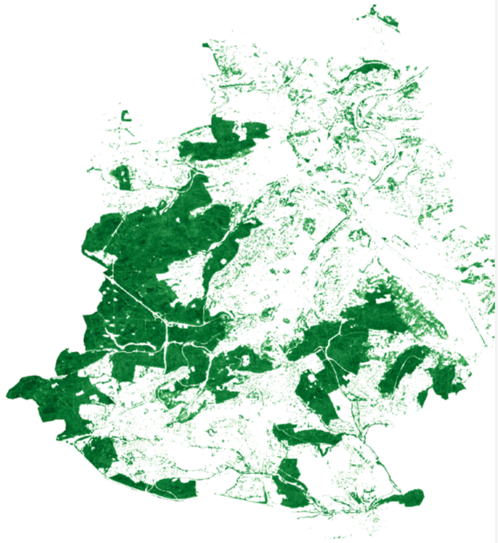
Wu, Xiangli, Lin Zhang, and Shuying Zang. "Examining seasonal effect of urban heat island in a coastal city." PLoS One 14.6 (2019): e0217850.

3 Tree Cover Density

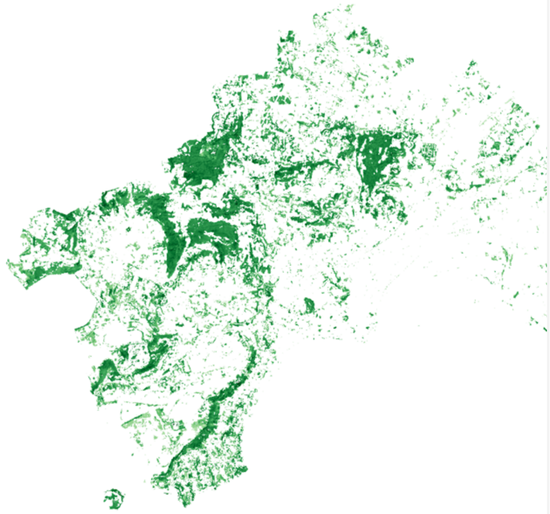
Tree Cover Density, Product Specifications	
Input Data	Sentinel-2
Algorithm	Catboost
Metrics	MAE: 9.97 | RMSE: 14.86
Spatial Resolution	10 m
Temporal Resolution	Annual
Possible Aggregations	Not Applicable
Format	GeoTiff
Units	Percentage
Automation	Fully Automated
Scalability	Global
Production Time	25 min / 100 Sqkm

3.1 Overview

Tree Cover Density, or TCD, represents the percentage of tree cover in a range from 0 to 100. It can be used to map tree cover levels and to assess patterns of deforestation or reforestation in rural areas. The product has a spatial resolution of 10 metres and is generated using Machine Learning and Sentinel-2 multispectral imagery. Below you can see the Arboreal Cover Density map for the cities of Stuttgart and Naples for the year 2022. As can also be seen from the detail, the Arboreal Cover Density map makes it possible to highlight features not discernible to the human eye.

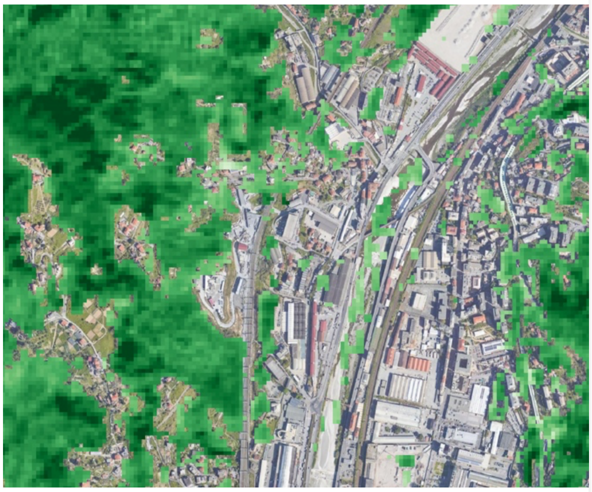


Arboreal Cover Density, Stuttgart 2022



Density Coverage Arborea, Naples 2022

Satellite image ESRI Imagery over an area of the city of Genoa



Arboreal Cover Density, Genoa Area 2022

3.2 Methodology

The methodology employs the CatBoost Regressor for efficient regression modelling. The model is configured to operate on a zonal basis, analysing specific areas and adapting to various local characteristics of the tree cover. This zonal mode of the model allows for fast and targeted processing, further reducing the computational load and processing time. Model training uses stratified cross-validation and a split train-test (70-30) to maximise the accuracy and generalisability of the estimates.

3.3 Results

The model was tested on several cities and the metrics are reported below:

City	Year	RMSE	MAE
Napoli	2018	10.18	9.24
Milano	2018	11.12	11.76
Genova	2018	25.67	17.87
Stoccarda	2018	8.76	7.66
Saragozza	2018	8.23	7.31
Aix-En-Provence	2018	21.23	11.25
Washington D.C.	2018	9.96	9.88

The CatBoost model shows promising results in predicting Tree Cover Density using Sentinel-2 images, achieving an average R2 of 0.87

3.4 Areas of Application

The Tree Cover Density product, besides being fundamental for the calculation of other layers such as the Park Cool Islands or the Microclimatic Performance Index (see next sections), can be used in the following areas

- Urban planning: Assessing tree canopy density and distribution to guide city development and monitoring green infrastructure.
- Real estate: Analysing areas with significant tree cover to assess land value and development potential of valuable properties.
- Agriculture: Monitor tree density in agricultural areas to understand the balance between open farmland and areas covered by trees.
- Climate: Understand tree distribution patterns in relation to local climate variations and adaptations.

3.5 References

Nasiri, Vahid, et al. "Modeling forest canopy cover: a synergistic use of Sentinel-2, aerial photogrammetry data, and machine learning." Remote Sensing 14.6 (2022): 1453.

Cilek, Ahmet, et al. "The use of regression tree method for Sentinel-2 satellite data to mapping percent tree cover in different forest types." Environmental Science and Pollution Research (2022): 1-12.

Eskandari, Saeedeh, and Sajjad Ali Mahmoudi Sarab. "Mapping land cover and forest density in Zagros forests of Khuzestan province in Iran: A study based on Sentinel-2, Google Earth and field data." Ecological Informatics 70 (2022): 101727.

Rondeaux, G., Steven, M., & Baret, F. (1996). Optimisation of soil-adjusted vegetation indices. Remote Sensing of Environment, 55(2), 95-107.

European Space Agency. (2018). Tree Cover Density 2018 10m. [Online Database].

4 The Area of Interest

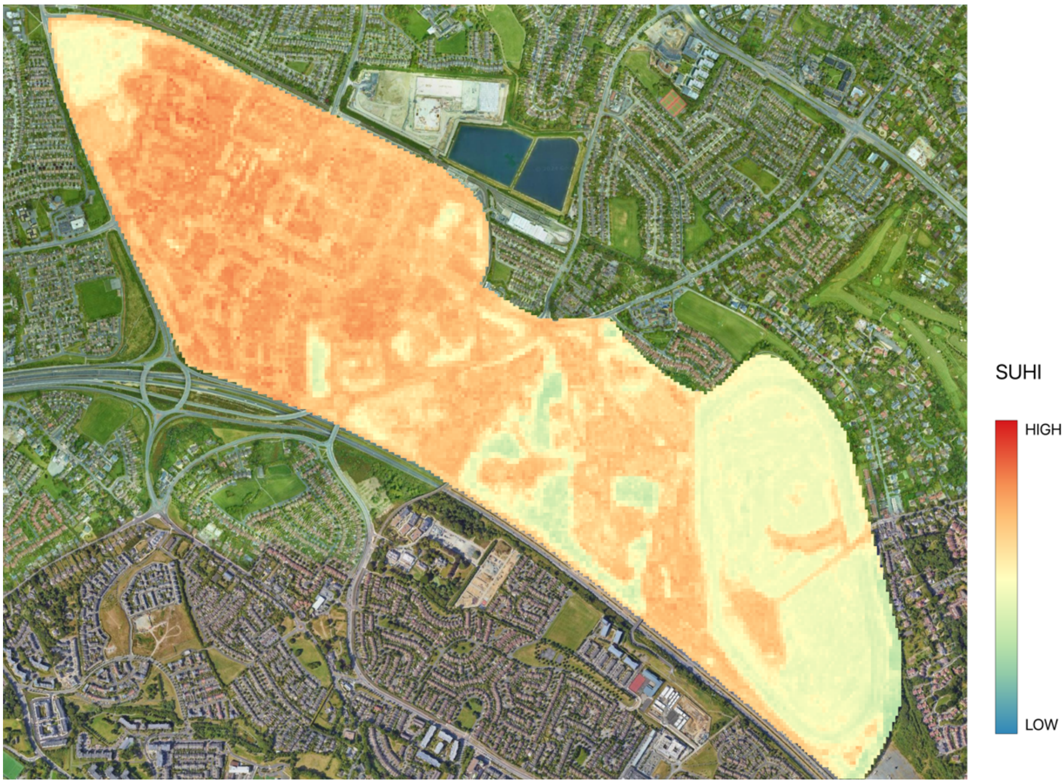
The area of interest is shown in the following figure.

The total area is 2.5 SqKM.

5 Surface Urban Heat Island map

The following figure shows the Surface Urban Heat Island map.
Each pixel of the map represents two values:

- An index between 0 and 1 where 0 means a low LST difference (lower UHI intensity) and 1 the highest difference (maximum intensity)
- A difference expressed in °C between each map location and the average temperature value of the reference rural area

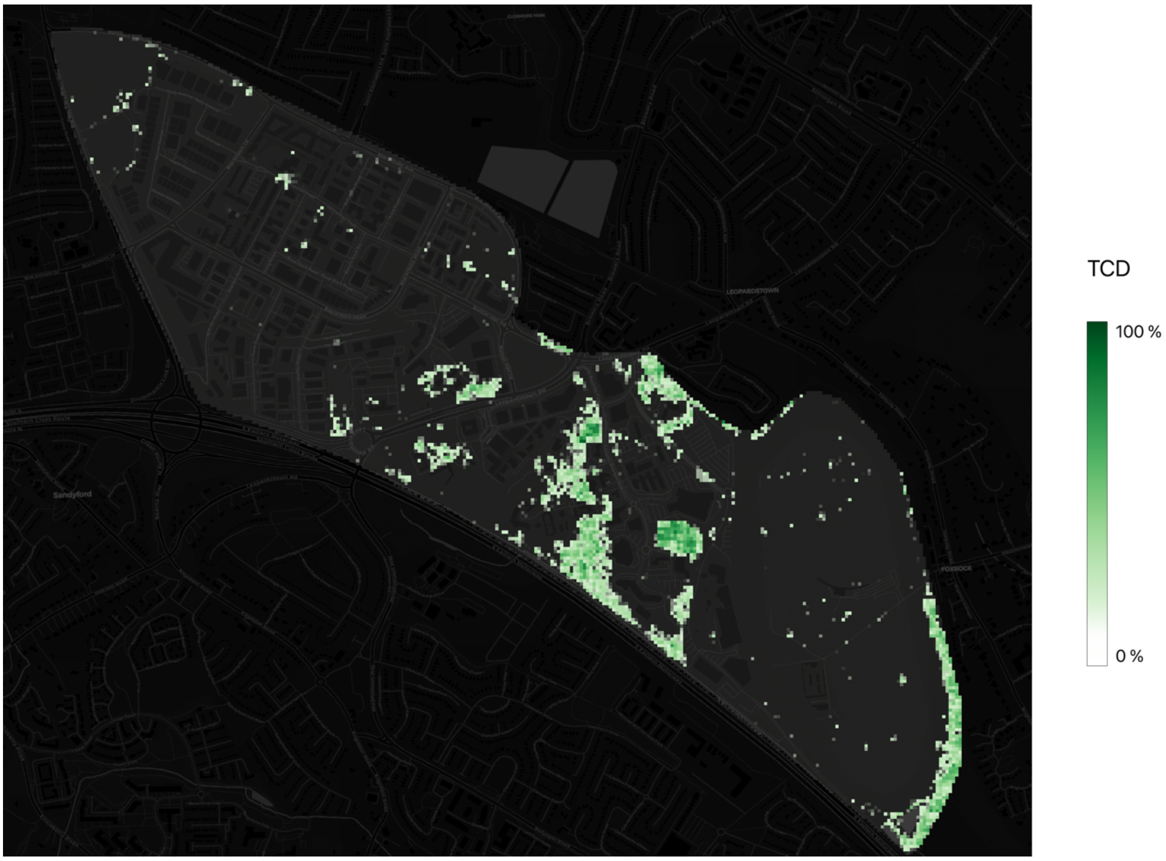


The above map has been generated using Copernicus Sentinel 2 and Landsat 8/9 images in June 2023 (9 and 14 for Sentinel 2 and 14 for Landsat).

The following figure shows one of the Land Surface Temperature map used to produce the SUHI map.

6 Tree Cover Density map

The following figure shows the Tree Cover Density map.
Each pixel of the map provides the percentage of tree cover in a range from 0 to 100.



The above map has been generated using Copernicus Sentinel 2 from August 2022 to July 2023.