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URBAN HEAT ISLANDS CHARACTERIZATION USING SENTINEL 3 SLSTR. A CASE STUDY IN MADRID (SPAIN, SEPTEMBER 2024)

According to a World Bank report (2023), currently more than half of the world's population lives in urban areas, and the growth of these areas is expected to continue in the coming decades, especially in certain regions (Central and South America and Asia), so that by 2050 it is estimated that 7 out of 10 people will be living in urban areas. It is clear that these are areas with special problems, since they imply on the one hand a strong dynamism of change with very important contributions to the GDP (80% of GDP is linked to these areas), but also environmental alterations that must be taken into account, due to the consequences not only for the environment, but also for the quality of life and health of the people who live in them.

This paper presents an example of an application of urban heat island characterization using images from the Sentinel 3 SLSTR sensor over the city of Madrid, and attempts to establish relationships with other parameters, such as population density. The work is based on the methodology proposed by Serco Italia SpA (2018), and has been applied using in all cases available open data (satellite images, statistical information and administrative boundaries) and from the ESA SNAP 11.0 software, also of free use.

The U.S. Environmental Protection Agency (EPA) defines an urban heat island as a phenomenon that occurs in "urbanized areas that experience higher temperatures than the surrounding peripheral areas" as a result of human activity in those areas. In this sense, we could speak of a thermal phenomenon caused by the fact that these are areas in which human activity itself generates a greater emission of energy into the environment (traffic, heating, air conditioning, industry, etc.) and, on the other hand, with materials that tend to exert an inertia effect (buildings, streets, etc.) in which there is also less vegetation cover and the soil is exposed to a higher level of radiation, together with the limitations to the action of the wind by the buildings themselves. Thus, this phenomenon is especially evident at night, since while the city environment has lower temperatures, in the area of the cities the energy accumulated during the day is emitted. This results in differences, which can be significant in temperature between the city and its own geographical environment. See Hibbart et al. (2017) for additional information.

The selected study area corresponds to the city of Madrid (Spain), a city that currently has a population of 3,332,035 people (2023) in an area of 604.45 km2, resulting in a population density of 5418.47 inhabitants/km2, representing 12.7% of the national GDP (2022).

For the characterization of temperature, images from the Sentinel-3 SLSTR sensor have been used, which provides direct LST (land-surface temperature) information (Polehampton et al., 2023). This sensor provides direct LST information over the entire surface of the planet with a native resolution of 1km and a frequency of at least 2 times per day (diurnal and nocturnal). The information has a level of uncertainty that in the image considered for the study area was on average 0.92ºK, also includes information on the elements that can affect the measurement of the same -presence of aerosols or clouds, etc.-. The image used was captured by the Sentinel-3B SLSTR sensor on September 24, 2024 at 22:20:19 UTC, and it is a cloud-free image.

The methodology applied is shown in Figure 1 and consisted basically in selecting the image, cropping it to the area of interest and reprojecting it according to the official coordinate system of the country (in this area EPSG:25830). Then, a series of points have been selected as representative of the temperature of the geographical environment from which the average temperature of the same has been calculated. This average temperature has been subtracted from the information of the image itself in order to highlight the positive and negative anomalies existing in the area, which have been grouped according to the different districts into which the city is divided and are represented considering as a reference the population density calculated in them (from Madrid City Council (https://www.madrid.es/portal/site/munimadrid).

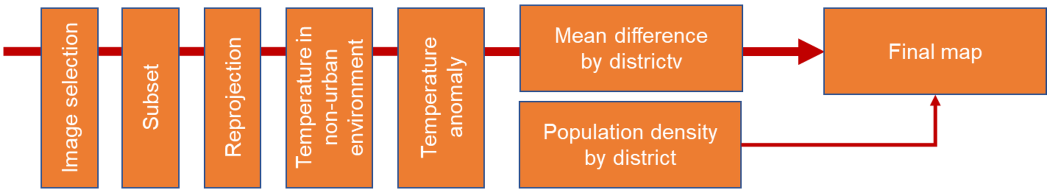

Figure 2. General schema of proposed methodology.

Figure 3 shows the results of the analysis, representing the thermal anomaly at the district level and its population density. It can be seen that the average anomaly is 1.62ºC in the whole area, although it can be observed that there are municipalities in the central area where the anomaly reaches 4-5ºC (4.58ºC). Likewise, in the central zone, the effect of the well-known Retiro Park (a historical park located in the centre of Madrid since the 17th century) can be observed, which reduces the night-time temperature in its surroundings by 2ºC.

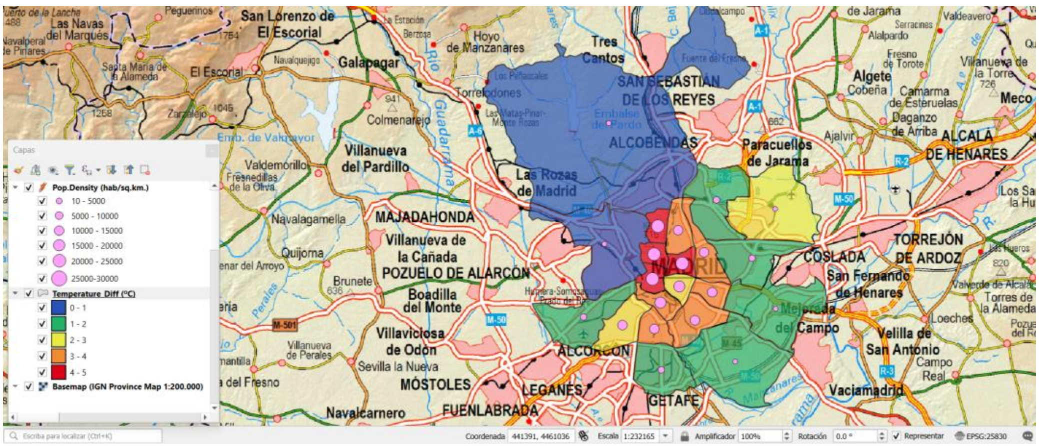

Figure 3. Night temperature anomaly (in colour) and population density (in pink circles) by districts in the Madrid area in QGIS environment.

This study shows the potential of current satellite sensors for measuring the temperature of the earth's surface, providing information of extraordinary quality that allows, even with limited means, a precise characterization of the effects of thermal anomalies of urban heat islands.

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