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NBSOIL
Nature-Based Solutions for Soil Management

# Spatial planning and soil NBS toolkit – initial version.

Deliverable [5.7]

11.10.2024

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[1] **R=Document**, report; **DEM=Demonstrator**, pilot, prototype; **DEC=website**, patent fillings, videos, etc.; OTHER=other
[2] **PU=Public**, **CO=Confidential**, only for members of the consortium (including the Commission Services), CI=Classified

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## List of acronyms

MS - Milestone

WP - Work Package

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# Contents



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The structure here proposed will be filled with more contents after a deep literature search, review of approaches used within NBSOIL test sites or NBSOIL countries and after exploring reports of other similar projects.

# 1 Introduction

The need for sustainable farming methods has increased, which has brought attention to the need of soil management plans that make use of Nature-Based Solutions (NBS). An essential component of the successful deployment of these techniques is spatial data analysis. The integration of spatial data analysis with soil management is summed up in this publication, with an emphasis on using NBS to improve soil health, productivity, and ecosystem services. Geographic Information Systems (GIS) and remote sensing are examples of geospatial technologies that can be used to identify locations that are appropriate for different NBS treatments and to evaluate the spatial variability of soil attributes. The mapping and modelling of soil parameters, which allows for the detection of deterioration trends and the evaluation of the long-term implications of NBS, are made easier by the spatial data. This analysis provides valuable insights into the spatial distribution of soil health indicators, aiding the development of targeted management practices.

Analysing spatial data is helpful in assessing how, in different landscapes, soil characteristics vary from their neighbouring ones. A variety of geospatial datasets, such as soil samples, topographical data, maps of land use and cover, and climate information, must be gathered and integrated during this process. Furthermore, if soil surveyors supply them with their spatial coordinates, other important soil parameters including pH, organic matter content, nutrient levels, soil texture, moisture content, and compaction may be mapped.

The geographical distribution and fluctuation of these soil qualities may be shown on high-resolution maps created by processing and analysing these datasets using GIS. In order to predict soil characteristics in unsampled areas, advanced spatial analysis techniques, like spatial indices and other interpolation methods, can be applied. This will provide a continuous surface of soil property estimations across the study area and notify the end user about the suitability area for hosting NBS. Remote sensing technology can also help with this study by offering large-scale, current observations of changes in land cover, the health of the plants, and the moisture content of the soil. Over time, satellite images and aerial surveys are used to track the execution and efficacy of NBS actions. For instance, Normalized Difference Vegetation Index (NDVI) data or Land surface Temperature (LST) data from satellites are critical for assessing the success of NBS.

In this framework, the following documents is focusing on designing and implementing spatially-based functions for planning NBS.

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# 2 Toolkit

## 2.1 Designing and implementing spatially-based functions

In Geographic Information Systems (GIS), designing and implementing spatially-based functions entails developing tools and algorithms that manage spatial data for a range of analytical and visualization uses. In order to analyse the links, patterns, and trends found in geographic data, spatially-based functions in GIS are essential. Spatial interpolation, overlay analysis, buffering, and querying are some of these features determining the functional requirements is the first step in the design process. Here, spatial data types (such as vector or raster) and the particular spatial operations required are taken into account Python or R programming languages and GIS software platforms are utilized during implementation. Managing huge databases, assuring computing performance, and preserving data correctness and integrity are important problems. To improve prediction power and decision-making processes, advanced spatial functions may use geostatistical techniques, machine learning, and spatial statistics. Robust spatial analysis is made possible by the efficient use of spatially-based functions in GIS, supporting a range of applications like environmental management, urban planning, and disaster response. This article describes these functions design approaches, emphasizes the technical aspects to be taken into account when putting them into practice, and talks about their usefulness and advantages in actual GIS projects.

## 2.2 Zoning

Identifying and classifying similar geographic areas or phenomena based on particular geographical characteristics is the process of recognizing comparable similar conditions utilizing the parameters that determine the designed spatially-based functions inside clustering algorithms. Spatial closeness, population, height, land use, land cover, and other pertinent geographic factors are a few examples of these parameters. Through the examination of these criteria, clustering techniques can reveal patterns and connections in geographical data, making it possible to identify regions that exhibit comparable characteristics or actions. Because it facilitates the formulation of well-informed decisions based on spatial similarities and differences, this method is crucial for a variety of applications, including resource distribution, environmental management, and urban planning.

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# 3 Data

Official spatial data, which can be acquired from public archives such as government databases, environmental monitoring organizations, and national or regional geographic information repositories, is necessary for the spatial analysis used in Nature-Based Solutions (NBS). Numerous layers of information, including maps of land use and cover, topographic and elevation data, hydrological and climatic data, soil types, vegetation cover, and protected areas, are commonly included in this data. The ability to access these extensive and reliable datasets guarantees that the spatial analysis is based on precise, current, and high-quality data, all of which are necessary for the efficient planning, execution, and oversight of NBS projects that address environmental issues and advance sustainable development.

## 3.1 Scale and detail level of maps (global/local)

Map (nominal) scale defines both the level of precision of positioning and the detail level: Minimum Mapping Unit –MMU for vector maps, Ground Sampling Distance/pixel size for raster data.

Global data from public over-national archives are generally provided with a high scientific value and a low geometric resolution (e.g. ESDAC - https://esdac.jrc.ec.europa.eu/resource-type/datasets, ERA5 meteo data - https://cds.climate.copernicus.eu/).

Differently, local data (from administrations) are provided with a higher geometric detail but a lower semantic content.

## 3.2 Data format

Geospatial data can be obtained in different formats:

- **Vector data**: based on geometric primitives (points, lines or polygons) and equipped with attribute tables able to qualify recorded features.
- **Raster data**: numerical information is given in a grid form where pixels dimension defines image geometric resolution.
- **External tables.**
- **Services (WMS, WFS, WCS)**

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## 3.3 Type of mapped information

### 3.3.1 Soils properties

List of soil-related features mapped at EU level (coverage, nominal scale, GSD (if raster), updating, reference system) EU archives – LUCAS, ESDAC, ERA5

### 3.3.2 Administrative layers

(technical maps, population density, administrative constraints)

Availability of technical maps gives data about different levels of administrative information like boundaries, cities, roads, etc.

Maps about population, human activities, other? (e.g. Copernicus GHS-Global Human Settlements).

### 3.3.3 Vegetation-related and land use/cover

(green infrastructures, parks, boulevards, gardens, urban forests)

NBS application inside cities, maps of green infrastructures like parks, boulevards, gardens, urban forests, etc. are useful for making soils indices.

### 3.3.4 Water-related layers

(water bodies, wetlands, blue infrastructures)

Mapping blue infrastructures in all of them declinations are needed to an NBS approach.

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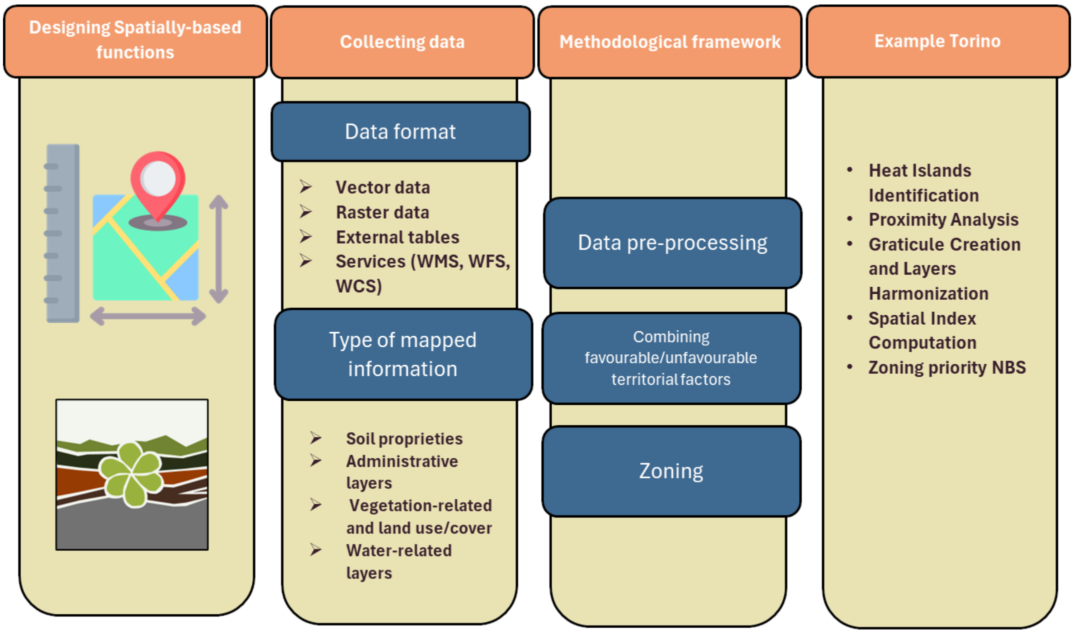
# 4 Methodological framework

The structure to define and implementing a spatial function is proposed follows the Table 1.

*Table 1. Structure to define and implementig a spatial function.*




## 4.1 Data pre-processing (scaling, normalization/standardization)

It is necessary to use data having geometric resolution comparable to the scale of the problem, if those data are not available, it is possible to use more global data and scale it. In order to compare different kind of data, a previous normalization or standardization has to be done.

## 4.2 Designing Spatially Distributed Functions to Support Planning

### 4.2.1 Combining favourable/unfavourable territorial factors

**Function design** -> (i) types of factors (excluding or graduating?); type of aggregation (additive/weighted sum)?, multiplicative, modulated (multiplication of functions)?

Spatial functions (or indices) can provide synthetic information coming from lots of different inputs.

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### 4.2.2 Zoning

The local index value alone is not enough to provide a complete reading of an area, since the same value can result from a highly different combination of predictors. A zoning aimed at recognizing similar situations in terms of predictors is mandatory to have a comprehensive view of the results.

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# 5 Spatial planning example: the "Torino" case study (NBS solutions for Heat Islands Mitigation)

To synthetize information and to practice on spatial analysis for NBS, a local case study about heat island in Torino has been defined:

- mapping heat islands;
- qualifying heat islands considering peculiarities of urbanization in terms of utilization (industrial, residential, commercial, schools and hospitals neighbourhood) and population characterization (young, old, etc.);
- mapping and qualification of existing blue-green infrastructures;
- mapping (detection) and qualification of new areas where NBS can be applied or improved if existing to mitigate heat islands negative effects on population.

## 5.1 Introduction

Heat islands in cities following heat waves are a problem common increasingly in last years due to climate change. Cities are heat islands compared to areas around them, but inside cities, it is possible to identify hotspot where temperature are higher than comfortable ones and where prioritize intervention of mitigation of negative effects on population. Increasing the number of green and blue infrastructure and the size of existing ones can be an approach based on NBS to achieve the objective.

## 5.2 Goals

The aim of this exercise is to define a spatial index able to quantify and map priority areas where NBS can mitigate urban heat island involving geographical data.

## 5.3 Collected data

To prepare the exercise, data were collected from public resources. These data are presented by distinguishing between global and local according to the size of the geographical areas covered.

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## 5.3.1 Global data

### 5.3.1.1 ESDAC - Soil Pb concentration

The European Soil Data Centre (ESDAC) is the thematic centre for soil related data in Europe. Its ambition is to be the single reference point for and to host all relevant soil data and information at European level. It contains several resources that are organized and presented in various ways: datasets, services/applications, maps, documents, events, projects and external links.

Lead (Pb) concentration (mg/kg) raster layer was used to identify areas where, hypothetically, prioritising mitigation interventions. Dataset is released in .tiff format with a resolution of 1 km in ETRS89-LAEA Europe coordinate reference system and a geographical cover of EU-28 Countries except Croatia.

The layer is accessible in the dataset "Maps of heavy metals in the soils of the EU, based on LUCAS 2009 HM data" at the link:

https://esdac.jrc.ec.europa.eu/content/maps-heavy-metals-soils-eu-based-lucas-2009-hm-data-0

In Figure 1 shows the map of lead concentration (mg/kg) in Torino municipality. Red areas show higher concentration of lead in soils than green areas.

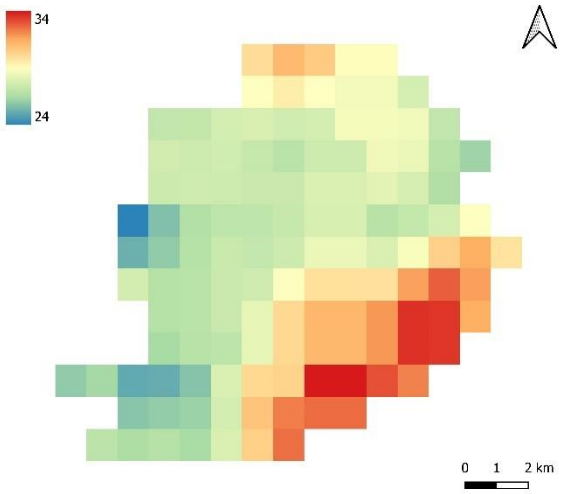


*Figure 1. Lead (Pb) concentration (mg/kg) in Torino municipality.*

It is worth noting that all values reported in the map are below threshold for soils defined from the Italian legislation (Decreto Legislativo 152/2006. Norme in materia ambientale, Gazzetta Ufficiale della Repubblica

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Italiana n. 88 Supplemento n. 96/L.). In particular, maximum lead concentration admitted for public, private and residential green sites is 100 mg/kg and maximum lead concentration admitted for commercial and industrial sites is 1000 mg/kg. Despite this map shows Pb not significant alarming values, the aim of this analysis is proposing a methodological framework that involves pollutants (like Pb) maps in NBS spatial planning toolkit. Therefore, this pollutant layer was adopted as available example in Torino case study.

#### 5.3.1.2 LandsatLST @ summer 2023

Landsat surface temperature measures the Earth's surface temperature in Kelvin and is an important geophysical parameter in global energy balance studies and hydrologic modelling. Surface temperature data are also useful for monitoring crop and vegetation health, and extreme heat events such as natural disasters (e.g., volcanic eruptions, wildfires), and urban heat island effects.

Data available following the page "Landsat Surface Temperature" at the link:

https://www.usgs.gov/landsat-missions/landsat-surface-temperature

In Figure 2, reports the maximum value of LST (K) registered in 2023 in Torino municipality.

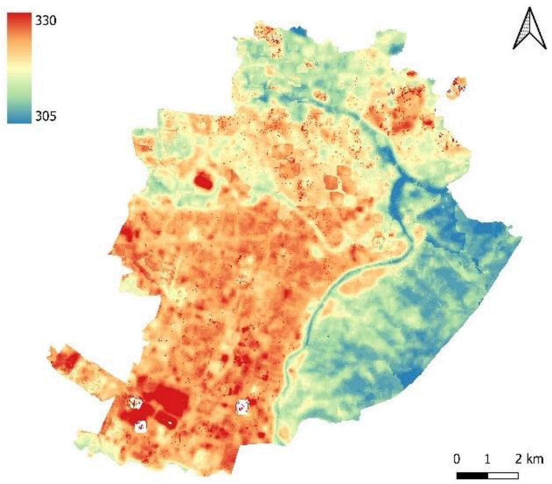


*Figure 2. Composite image of LST (K) in Torino municipality showing the maximum value of LST in 2023.*

### 5.3.2 Local data (GeoPortale Piemonte - BDTRE)

The Piemonte regional geoportal makes available the metadata catalogue of the geographical information of the Piemonte territory, collected and systematised over the years by the various bodies. Through the metadata search it is possible to view the data through visualisation services, download them through download services or obtain them directly as static packages.

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### 5.3.2.1 Regional Technical Map (BDTRE)

In *GeoPortale Piemonte*, it is possible to find the *Banca Dati Territoriale di Riferimento degli Enti* (BDTRE), that is the geo-topographical database of *Regione Piemonte*, structured according to the national technical specifications and organised in Layers, Themes and Classes. The Class is the reference structure and defines the representation of a specific type of spatial object. BDTRE integrates local realisations and information held by *Regione Piemonte* from various sources, and it is continuously updated. A cartographic layout at the scale 1:10,000 in annual editions is derived from BDTRE. Layers of interest are available on a municipal basis. BDTRE of Torino was obtained from "BDTRE 2024 - Database GeoTopografico (dataset vettoriale)", available at:

https://www.geoportale.piemonte.it/geonetwork/srv/ita/catalog.search#/metadata/r_piemon:da9b12ba-866a-4f0f-8704-5b7b753e4f15

In the BDTRE there are several layers, the ones used for the exercise are shown below.

#### 5.3.2.1.1 Residential/Industrial Areas

Vector layer extract by BDTRE. The polygon layer allows to select different types of buildings by querying by attributes and to define accordingly the areas with the highest residential or industrial concentration.

Two macro-categories: industrial and residential buildings (Figure 3) were extracted from BDTRE buildings layers.

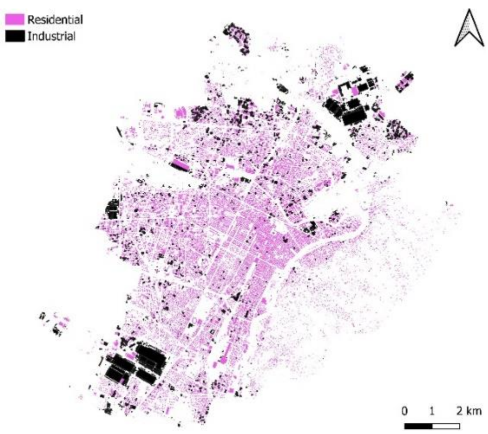


*Figure 3. Torino buildings: industrial and residential.*

#### 5.3.2.1.2 Green Areas

Vector layer extract by BDTRE. The layer is provided as polygon and shows where green areas are located.

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#### 5.3.2.1.3 Roads

Vector layer extract by BDTRE. The layer is provided as polygon and shows where streets are located.

In Figure 4, street areas of Torino are shown.

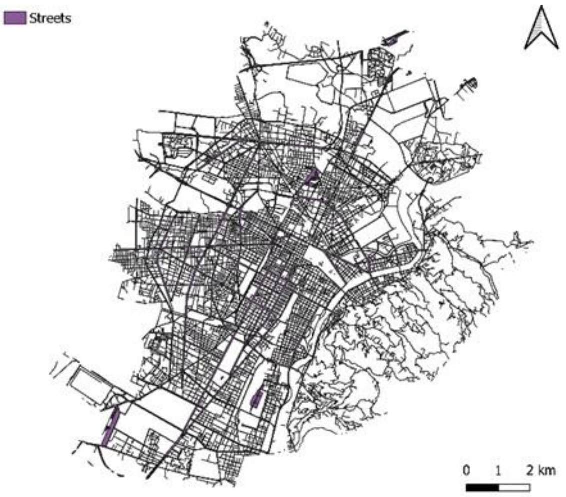


*Figure 4. Torino municipality streets.*

### 5.3.2.2 Trees

The dataset contains the punctual elements relating to the positioning of the trees in the entire municipal territory of Torino, together with detailed information on the types and characteristics of each individual plant or plant place.

It is possible to download the data at:

https://www.geoportale.piemonte.it/geonetwork/srv/ita/catalog.search#/metadata/c_l219:b0493156-2d45-4792-977c-c3ab2937f171

Trees and green areas layers were fused in a single layer showing vegetated and non-vegetated areas (Figure 5).

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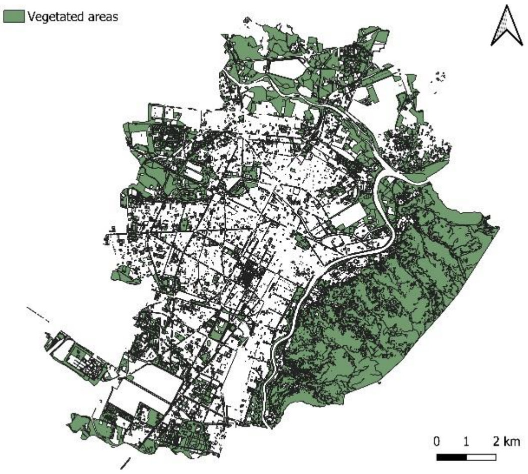


*Figure 5. Torino municipality. Vegetated areas are green highlighted.*

### 5.3.2.3 Population

The dataset displays statistical population data themed on the statistical areas of the municipal territory of Torino relating to the resident population since 2007. The last available annuity (2022) was used for the exercise.

The resource is accessible at the link: https://www.geoportale.piemonte.it/geonetwork/srv/ita/catalog.search#/metadata/c_l219:5908b85c-09de-405f-8183-e71874cc9dcc

The population density (inhabitants/ha) of Torino was used to identify where population is mainly located (Figure 6).

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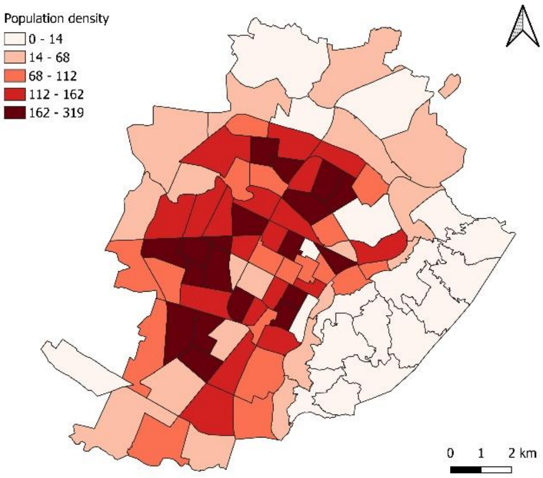


*Figure 6. Population density (inhabitants/ha) of Torino.*

## 5.4 Proposed Method

### 5.4.1 Heat Islands Identification

Identification of heat island was done looking for areas where a positive anomaly of temperatures was calculated starting from temperature data of LST. In particular, the anomaly temperature layer was computed with (1).

$$A(x,y) = \frac{LST(x,y)}{\mu} \quad (1)$$

$A(x,y)$ shows the anomaly LST; $LST(x,y)$ represent LST; $\mu$ denotes the medium value of LST in the area of interest (Torino municipality).

In Figure 7, it is represented the distribution of the anomalies showing that higher values are located in urban areas and lower ones in the vegetated hill close to Torino city centre.

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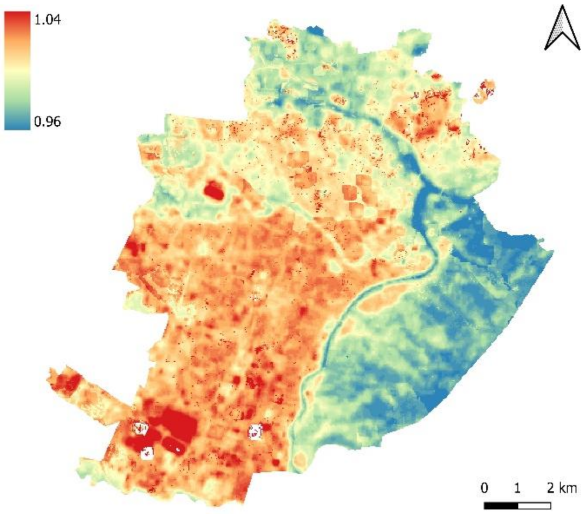


*Figure 7. LST anomalies distribution in Torino municipality. Red areas show positive anomalies of temperature. Blue areas negative anomalies of temperature.*

After anomaly computations, a classification was done to identify areas where focus the exercise. In particular, values under 0.99 were considered as negative anomalies, values between 0.99 and 1.01 as medium values and values greater than 1.01 as positive anomalies (Figure 8).

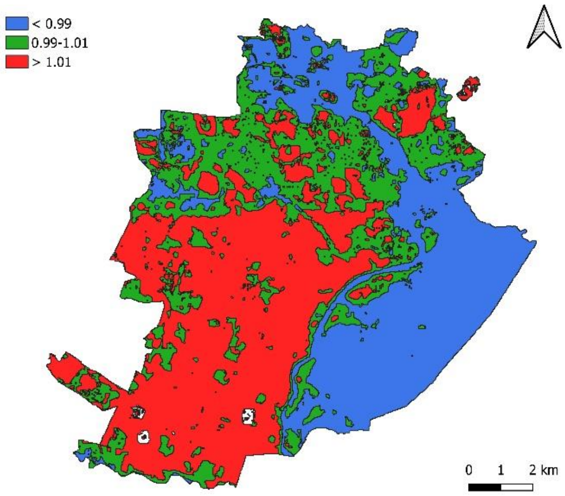


*Figure 8. Blue: negative anomalies of LST; green: medium values of LST; red: positive values of LST.*

Analyses were concentrated on red areas, showing positive anomalies of temperatures.

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### 5.4.2 Proximity Analysis

A proximity analysis was conduct computing the distance (m) (Figure 9) and the surface area ($m^2$) (Figure 10) of the closest vegetated area for each pixel covering Torino municipality raster layer. Related maps are shown below.

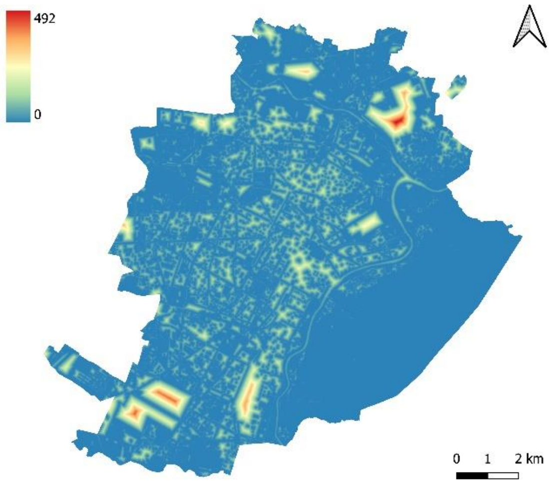


*Figure 9. Distance (m) from the closest vegetated area.*

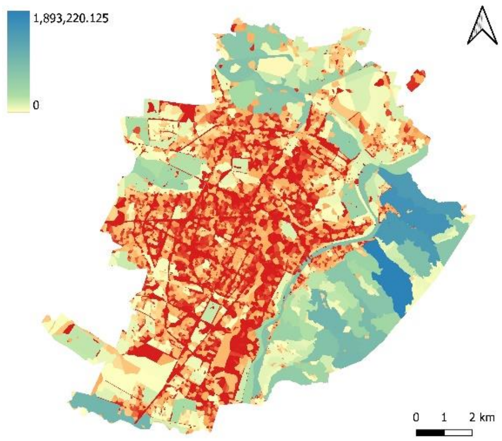


*Figure 10. Surface area ($m^2$) of the nearest green area.*

### 5.4.3 Graticule Creation and Layers Harmonization

A graticule with pixel of 100 m x 100 m (Figure 11) was created to locally analyse data from vector and raster layer with different geometric resolutions.

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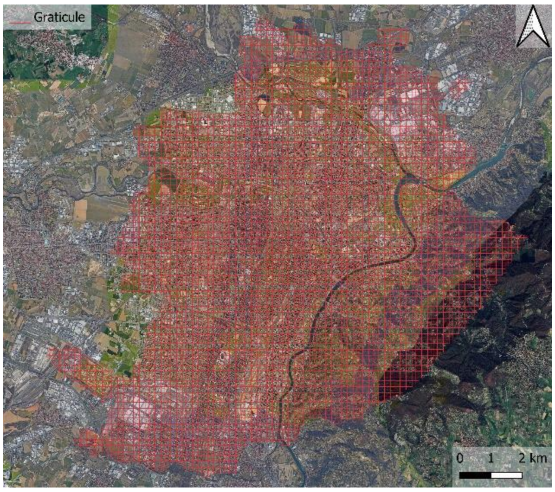


*Figure 11. Graticule with 100 m x 100 m pixel dimension.*

After collecting data in the graticule from each layer described above, a normalization was done (2).

$$x_{norm} = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (2)$$

Where $x_{norm}$ is the normalized value of x; $x$ is the local value of a variable; $x_{min}$ is the lowest value of the variable of a layer; $x_{max}$ is the highest value of the variable of a layer.

### 5.4.4 Spatial Index Computation

A spatial index was defined for each graticule cell involving previously mentioned layers. After a min-max normalization variables can be numerically combined according to formula (3).

$$Priority\ Index = \frac{Res + Pop + Pb + NGA_{dist}}{NGA + NGA_{sur}} * CA \quad (3)$$

Where $Priority\ Index$ is the value of the computed index; $Res$: rate of residential area; $Pop$: population density; $Pb$: lead concentration; $NGA_{dist}$: distance from nearest green area; $NGA$: percentage of green area; $NGA_{sur}$: surface area of the nearest green area: $CA$: rate of streets + rate of industrial area. Rates refer to percentage of normalized values of the considered variable inside the pixel of the graticule.

Criteria adopted for index computation are based on the ratio between factors that may contribute to heat island development intensifying the problem ($Res, Pop, Pb, NGA_{dist}$) and factors that can mitigate the problem ($NGA, NGA_{sur}$). Due to ratio all variables in the numerator increase the spatial index; inversely, variables in the denominator decrease the index improving the mitigation. Moreover, a gain factor (hereafter called *Convertible*

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*Areas - CA*) tunes the index according to the availability of areas potentially hosting NBS. It is worth to note that all variables in the sums (both in the numerator and denominator) are equally weighted (weight = 1). Otherwise, the only multiplication is provided by CA; in fact, it can switch off (zeroing) the index in areas where mitigation actions, here assumed as urban conversion by adopting NBS, are no possible due to urban policy constraints.

### 5.4.5 Zoning priority NBS

After priority index computation, a logarithmic transformation was operated to better understand information related and to visualise priorities zone of interventions for NBS implementation. Resulting map is shown in Figure 12: red areas denote high values of index where NBS application should be prioritised than green areas that highlight lower values of index.

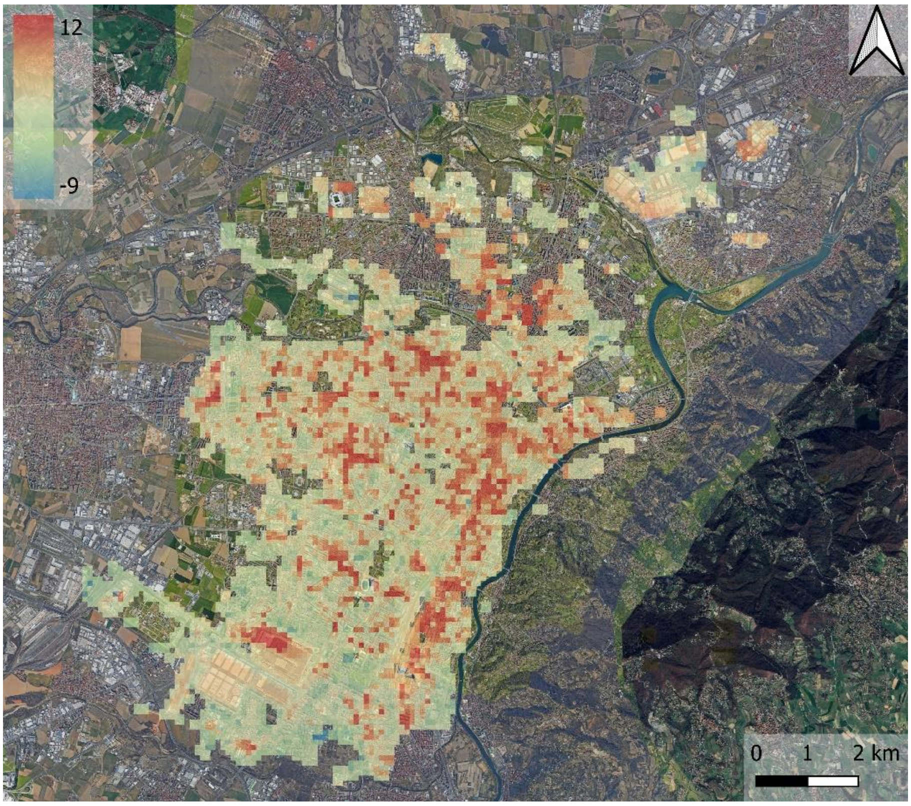


*Figure 12. Zoning priority for NBS implementation.*

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# 6 Conclusions & next steps

Nature-Based Solution (NBS) are very important in soil management and spatial data analysis has a relevant role in this implementation, as demonstrated in the document and illustrated in practical case studies.

Remote sensing and GIS are useful to identify where NBS can be implemented after creating a more, or less, complex model, including a variety of information such as soil properties, population distribution, administrative constraints, land use, water presence, etc.

It's also important to note that geospatial data are provided in different formats and resolutions, that could affect the methodology of analysis and the results that can be extrapolated by them.

Within the scope of the project the next step will be the addition of seven case studies on the same or other ecosystem services provided from NBS and green areas within cities. The case studies will be defined with the help of all the partners by selecting one city in each country participating in the NBSOIL project.

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