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Land Take: From Fabric Classification to Identifying Areas for Sustainable Urban Regeneration

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Abstract

The recent Nature Restoration Law by the European Parliament includes an objective of achieving zero "net land take" by 2050. With the same aim, since 2024, the Territorial Governance law in Tuscany has required municipalities to redefine the perimeter of urbanized territory as it is only within these areas that new buildings can be constructed. The law assigns a fundamental role to regeneration plans as chosen tools to plan marginal contexts where it is possible to reclaim areas for urban development without consuming new land. In addition, it prescribes that the delimitation of urbanized territory must start from the classification of urban fabric in relation to codified morphotypes of contemporary urbanizations. Therefore, to define urban regeneration policies, it is possible to identify critical issues and quality objectives for each of them. The aim of this research is to implement a methodology for the definition of urban morphotypes while ensuring consideration of the fragility conditions of the territory related to environmental factors. In the Municipality of San Giuliano Terme in the province of Pisa, we have identified areas where urban regeneration for settlement development is closely linked to strategies to safeguard and restore green ecosystem services, protect against hydraulic risk, and counter heat islands.

Keywords

Land Take, Sustainable Urban Regeneration, Urban Fabric, Flood Risk Assessment, Environmental Impact

1. Introduction

This research analysed the phenomenon of land take in the municipality of San Giuliano Terme in the province of Pisa. We started with an in-depth classification of the different urban fabrics to identify suitable areas for sustainable urban regeneration. San Giuliano Terme has taken part in the Earth Observation Services for Local Public Administrations (by the European Spatial Agency (ESA)), which include five innovative capacity-building programs that are focused on environmental monitoring. As part of the IRIDE project, this participation has enabled the acquisition of preliminary data that are essential for this analysis.

San Giuliano Terme is located in the Tuscany Region, where the Piano di Indirizzo Territoriale (PIT, 2015) is an essential tool for integrated and sustainable territorial planning. The PIT is a Territorial Address Plan for the region that has been in effect since 2014 in accordance with Regional Law n.65/2014. Details are available on the website of the Tuscany Region (downloadable through the portal at https://www.regione.toscana.it/-/piano-di-indirizzo-territoriale-con-valenza-di-piano-paesaggistico). One of the main objectives of the PIT is the characterization of urban morphotypes; that is, the classification of urban fabrics into different morphological types. Morphotypes are defined through analysis of the physical, functional, and landscape characteristics of urban areas. The methodology to characterize urban morphotypes outlined in the PIT is based on the integrated analysis of data from various databases and photointerpretation (extraction of information from aerial and satellite images). The method allows us to identify the associations of morphotypes proposed by the PIT through a rigorous interpretation of cartographic elaborations (data association, overlay of thematic maps, etc.).

Building upon the guidelines of the PIT, further directions and indicators were developed in this research to enhance the accuracy of classifying various settlement types. This first phase of urban fabric classification was followed by a second phase, in which risk maps were constructed to help identify the most suitable areas for sustainable urban regeneration. Risk maps related to extreme climate events, such as temperature increases and floods, were developed using data from the constellation of satellites called "Sentinels" (downloadable through the portal at https://earthexplorer.usgs.gov/), as well as data from the Geoscopio portal of the Tuscany Region, databases of the Municipality of San Giuliano Terme, and the authorities of the Serchio and Arno River Basin.

The Geoscopio portal of the Tuscany Region is an online platform that provides access to a wide range of territorial and geographical data related to the regional territory. This platform is managed by the Tuscany Region and is part of the territorial and environmental information system SITA (Sistema Informativo Territoriale e Ambientale). The aim of this system is to provide geographical and environmental information to support the planning, management, and sustainable development of the territory. The authorities of the Serchio and Arno River Basins are Italian public bodies that are responsible for planning and coordinating water resource management and soil conservation within the river basin. Basin authorities ensure the sustainable use of water resources, the prevention of hydrogeological risks, and the protection of the river environment.

In-depth classification of urban fabrics integrated with risk assessment allowed us to identify areas falling under a specific morphotypic classification that are not covered by the PIT, where it is necessary to promote environmental resilience and sustainability. We simulated nature-based solutions (NBS) for sustainable regeneration in one of these areas. NBS are actions that incorporate natural features and processes to protect, conserve, restore, and manage natural or modified ecosystems to face socio-environmental challenges. The next phase of the research will involve the application of advanced software to evaluate the effectiveness of previously simulated scenarios concerning the application of NBS to improve responses to extreme climate events. In its current stage, the research has achieved the goal of implementing a model to identify areas of hydrological fragility in urban settings, where the challenges of land take and climate change can be faced through the implementation of sustainable urban regeneration strategies and interventions that use NBS.

2. Materials and Methods

In the context of rapid urbanization, land take poses a significant environmental challenge concerning the increase of impermeable land cover. Based on a critical review of the literature, this study proposes the implementation of a methodology to identify areas of hydrogeological fragility requiring urban regeneration strategies. Practical recommendations are provided to improve stormwater management in the selected study area through the identification of NBS. These interventions are recognized to contribute to promoting environmental conservation and the creation of more resilient and liveable cities (Raymond et al., 2017; Nath et al., 2024; Henderson, 2022).

The procedure is divided into two distinct phases to achieve dual objectives: to implement the methodology to analyse urban fabrics based on the definitions provided in the PIT and to accurately identify study areas characterized by hydrological and heat fragilities that are suitable for testing NBS. These solutions include the creation of urban green spaces, green roofs, permeable pavements, and stormwater management systems that reproduce natural processes (Regione Emilia-Romagna, 2020). NBS can significantly contribute to reducing the urban heat island (UHI) effect, improving air and water quality, and increasing biodiversity in cities (International Water Management Institute, 2023).

The methodology used for the classification and identification in San Giuliano Terme was based on an in-depth critical analysis of the literature. This analysis provided theoretical foundations and practical tools necessary to define useful data and methodologies for identifying areas of vulnerability and developing strategies (including NBS) for the implementation of sustainable urban regeneration actions. The contributions that guided the methodological development include '*ICT, la resilienza e la pianificazione urbana'* (ICT, Resilience and Urban Planning) (Marango, 2019); the paper, 'Nature-Based Solutions Modeling and Cost-Benefit Analysis to Face Climate Change Risks in an Urban Area: The Case of Turin (Italy)' (Biasin et al., 2023); and the paper, 'Climate Justice in the City: Mapping Heat-Related Risk for Climate Change Mitigation of the Urban and Peri-Urban Area of Padua (Italy)' (Todeschi et al., 2022). Marango's (2019) book is a significant contribution to the field of urban adaptation to climate change and describes a detailed methodological framework and advanced tools, such as the Quantum Geographic Information System (QGIS). QGIS is free open-source software that allows users to create, edit, visualize, analyse, and publish geospatial information and is used for vulnerability assessment and adaptation action planning.

Todeschi et al. (2022) examine UHIs and climate change in depth. Through a multidisciplinary approach based on academic sources and scientific data, they explore methodologies and techniques related to UHIs. The methodology uses software such as QGIS and Sentinel-3 satellite data to analyse heat anomalies. They identified UHIs as a problem with significant impacts on public health with a focus on vulnerable groups such as the elderly. Solutions such as increasing urban green spaces and updating building regulations are suggested. Finally, Biasin et al. (2023) highlight the effectiveness of NBS as strategies to face urban climate risks, such as flooding and the UHI effect. They describe a clear methodology based on the evaluation of NBS through a cost-benefit analysis, which was applied in a case study of the city of Turin.

Phase I: The case of San Giuliano Terme: data and tools for the classification of urban fabrics

An initial study of the urban fabrics envisioned by the PIT was necessary to understand the form, spaces, materials, and quality of contemporary urbanisation. We developed a more specific methodology for their classification. The classification of the PIT provides for the following urban fabrics:

Predominantly residential and mixed urban fabrics, which are divided into the following: fabric characterized by closed or semi-closed blocks (TR1); fabric with isolated residential lots (TR2); fabric with open blocks and predominantly residential blocks (TR3); fabric with open blocks and predominantly planned residential buildings (TR4); point-like fabric (TR5); fabric characterized by mixed types (TR6); and fabric with frayed edges (TR7).

Urban or suburban fabrics with predominantly residential and mixed function (peri-urban fringes and dispersed cities): linear fabric (TR8) and grid or scattered fabric (TR9).

Suburban fabrics with predominantly residential and mixed function: inhabited countryside (TR10), urbanized countryside (TR11), and small isolated suburban clusters (TR12).

Productive and specialist city fabrics: fabric characterized by linear productive proliferation (TPS1), fabric with productive, commercial, and directional platforms (TPS2), specialized islands (TPS3), and fabric with residential and tourist-receptive platforms (TPS4).

Starting from the guidelines for the classification of urban morphotypes defined by the PIT, our research used additional indicators to improve the accuracy of the classification. It was essential to have standard indicators that could be integrated into the QGIS software. This made it possible to adopt precise rules to identify specific morphotypes, such as those of edges, open blocks, or linear fabric, instead of relying solely on the observation and interpretation of visible features in satellite images. Additionally, some characteristics of the settlement system related to the presence of services or historic urban fabrics led to the addition of classes that better represent the specificity of the case study. The criteria used and the data sources for each classified fabric in San Giuliano Terme are detailed in Table 1. This table includes the specific indicators adopted, which ensure a comprehensive approach to urban morphotype classification that goes beyond mere visual analysis. By incorporating these refined indicators, our methodology achieves a higher level of precision in identifying and categorizing various urban fabrics, as well as reflecting the diverse and specific characteristics of the area's urban landscape.

Table 1 Indicators for the classification of urban morphotypes

Morphotype classification	Variability	Source
TS: Historical fabric	Lot with historic buildings (before 1954)	The Geoscopio portal is a WebGIS tool with which the Region's spatial data can be viewed, queried and downloaded. A user manual is available for its use.
CS: Public and standard facilities	Presence within the lot of areas for general public utilities	TIS (Territorial Information System) of the Municipality of San Giuliano Terme.
IT: Infrastructures and technical facilities of general interest	Presence of infrastructures and technical facilities of general interest in the lot.	TIS (Territorial Information System) of the Municipality of San Giuliano Terme.
PTS1: Fabric characterized by linear productive proliferation	Lots containing buildings with a covered area ≥ 1000 sqm	Authors' elaboration of the building data from the Geoscopio portal using QGIS software.
TR2: Fabric with isolated residential lots	Lots surrounded by more than 4 road intersections/nodes	Authors' processing using QGIS software of the road network graph extracted from the Geoscopio portal.
TR3: Fabric with open blocks and predominantly residential blocks	Lots surrounded by less than 4 road intersections/nodes	Authors' processing using QGIS software of the road network graph extracted from the Geoscopio portal.
TR8: Linear fabric	Presence within the lot of building footprint area falling within the 20-m road strip ≥ 50%	Authors' processing using QGIS software

As shown in Figure 1, the following fabrics identified by the PIT and classified using formulated indicators are found in the study area: historical fabric (TS), fabric with isolated residential lots (TR2), fabric with frayed edges (TR7), linear fabric (TR8), and fabric characterized by linear productive proliferation (TPS1). We introduced two new typologies representing aspects that are not covered in the criteria identified in the PIT but are specific to the proper definition of the morphotypes in the study area: public and standard facilities (CS) and infrastructures and technical facilities of general interest (IT).

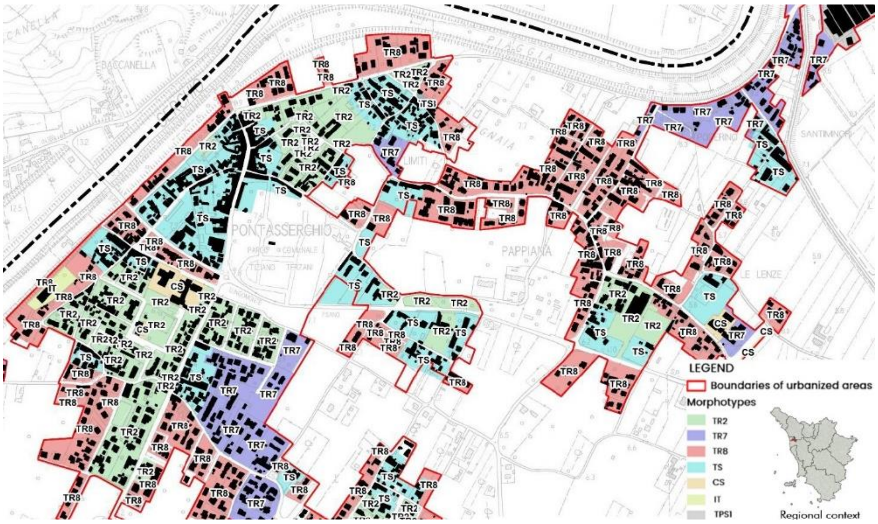

Figure 1 Map of urban morphotype classification: case study in the area of Pontasserchio, Municipality of San Giuliano Terme (PI). (Created by the authors).

Phase II: Identification of the study macro-area for sustainable urban drainage in San Giuliano Terme

Next, we conducted a study to identify areas with specific risks. Table 2 shows the data used, the source, and a brief description of the processing required to construct the thematic layers. The overlapping of the layers made it possible to identify the fragility classes of the territory in relation to water flow and heat islands.

Table 2 Data used and the corresponding sources

Input data	Year	Source	Brief description
Satellite data: B4, B5 and B10 bands of the Landsat 8 satellite	2023	USGS EarthExplorer is a data viewer for geospatial images with a simplified interface and access to a wide range of regional and global datasets available in the Earth Engine Data Catalogue. https://earthexplorer.usgs.gov/	Using QGIS software and open-source statistical analysis, Landsat 8 thermal satellite images are processed to investigate the spatial configurations of land surface temperature.
Vegetation elements, urban space, ground movements, water stress index and island effects.	2023	Earth Observation services for Local Public Administrations, which include five innovative capacity-building programs focused on environmental monitoring. European Space Agency (ESA, 2024) and Italian Space Agency (ASI)	The map, in raster format, is divided into a grid of pixels, where each pixel represents a specific portion of the examined territory measuring 5 meters x 5 meters. The data has been processed to estimate soil sealing.
Demographics	2011 2022	ISTAT (Italian National Institute of Statistics) and Municipality of San Giuliano Terme	Population by census section
Land cover	2019 2022 2023	Geoscopio Portal of Tuscany Region Italian Institute for Environmental Protection and Research (ISPRA, 2020) CORINE Land Cover (CLC) is a pan-European inventory of land cover based on satellite remote sensing aimed at providing consistent and comparable land cover data across Europe	Data on land cover, land use and transition between categories.
Hydrogeological risk assessment	2021	PGRA (*Piano di Gestione Rischio Alluvioni*), the flood risk management plan of the Northern Apennines River Basin District Authority.	Data on flood hazard, flash flood hazard, and river flood risk under Italian Legislative Decree 49/2010
Hydraulic hazard	2019	Municipality of San Giuliano Terme	Hydraulic hazard probability that heavy rainfall, in combination with the specific conditions of an area, may cause landslides or flooding. These are classified into four categories: moderate (P1), moderate-high (P2), high (P3), very high (P4)
Built-up area	1897–1996 2023	Geoscopio Portal of Tuscany Region Municipality of San Giuliano Terme	Comparison of historical series allows for understanding settlement, infrastructural, and landscape transformation dynamics.
Geomorphological map	2019	Municipality of San Giuliano Terme	Geolithological characteristics of soils and classification

Some of these data required specific processing to construct information that can be effectively used. Specifically, we processed satellite data from USGS EarthExplorer and data derived from Earth Observation services for Local Public Administrations. Starting from the methodology indicated by Todeschi et al. (2022), we reprocessed the satellite data from USGS EarthExplorer. The following steps were performed using the B4, B5 and B10 bands of the Landsat 8 satellite to estimate the ground surface temperature in San Giuliano Terme.

Clipping of the three satellite images (bands 4, 5, and 10) with the boundary of the Municipality of San Giuliano Terme using the "Raster - Extraction – Clip Raster by Mask" function.

Determination of reflectance using the formulas defined by Landsat guidelines in section 5.2 for bands 4 and 5, and in sections 5.1 and 5.3 for band 10 using the 'Raster – Raster Calculator' function.

Calculation of the Normalized Difference Vegetation Index (NDVI) (Yuan and Bauer, 2007)

Estimation of the vegetation proportion (VP) (Jeevalakshmi, Reddy, and Manikiam, 2017)

Estimation of land surface emissivity (Anandababu, Purushothaman, and Suresh, 2018)

Estimation of land surface temperature (LST) (Stathopoulou and Cartalis, 2007)

For the reprocessing satellite data derived from Earth Observation services for Local Public Administrations, the following steps were carried out to estimate soil sealing:

Comparison of information from the imperviousness layer of Iride Project lot 2 with existing geological and hydrogeological maps and studies to verify their data

Assessment of a geological risk map that provides details on the safety and suitability of different areas for water infiltration

We conducted the classification of soil permeability by following the guidelines of the USDA Soil Survey Manual. The permeability or hydraulic conductivity coefficient (*k*) was used to represent the soil's ability to infiltrate water. Based on these criteria, soils were divided into six classes.

Table 3 Soil classification into 6 categories described in the Soil Survey manual

n.	Class	Ksat (μm/s)	Ksat (mm/h)
1	Very low	<0,01	< 0,036
2	Low	0,01 – 0,1	0,036 – 0,36
3	Moderately low	0,1 – 1	0,36 – 3,6
4	Moderately high	1 – 10	3,6 - 36
5	High	10 – 100	36 – 360
6	Very high	> 100	> 360

The purpose of this classification is to identify the most suitable areas for the implementation of infiltration systems. In particular, only soils with permeability classes 4, 5, and 6 are recommended for the installation of such systems as they offer better water infiltration capacity. Some vulnerable areas were identified by overlapping the thematic layers obtained through the methods described or were obtained directly from the source. These areas simultaneously present high risk of hydrogeological events, increased susceptibility to flash floods, high population density, high summer surface temperatures, and low soil permeability (Figure 2).

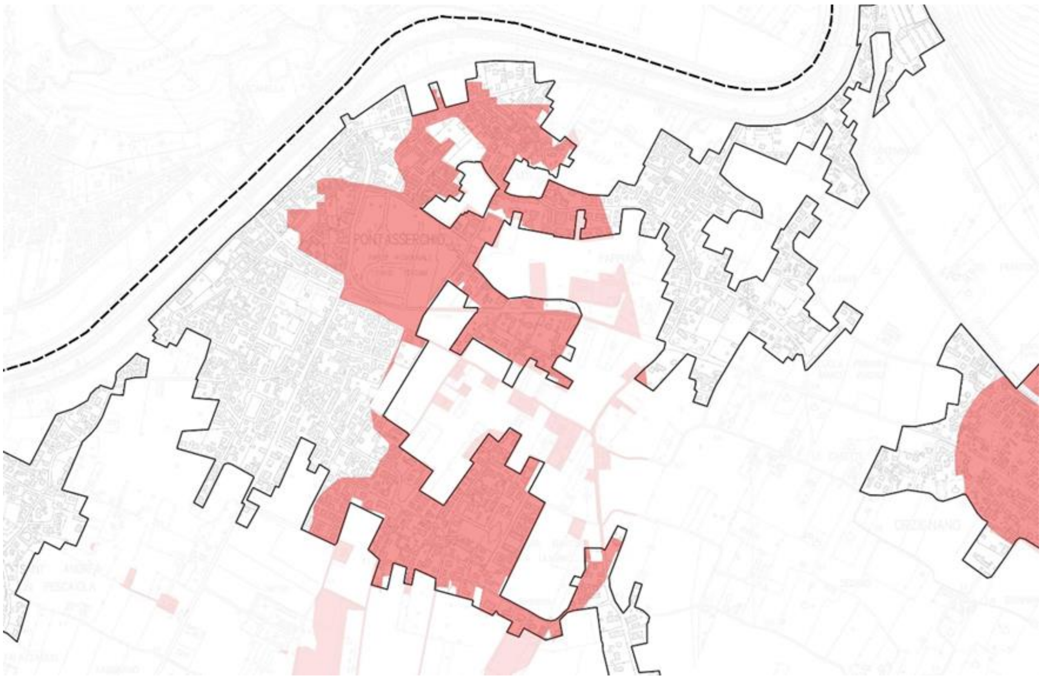

Figure 2 Macro-area obtained from the analyses conducted showing representation of vulnerable areas (highlighted in red). (Created by the authors).

Phase III: Suggestions for nature-based solutions (NBS) for urban water management

The analysis of urban morphotypes combined with the study of vulnerability and exposure to risks has revealed the presence of lots within the urban boundary that are subject to significant risks. These areas require greater attention in the definition of sustainable urban planning strategies and urban regeneration policies. The areas identified as FOCUS 01 and FOCUS 02 in Figure 3 present characteristics of vulnerability. The main critical issues include:

- Plant deficiency: the absence of plants and trees negatively affects air quality
- Elevated surface temperatures: there are many cemented surfaces, which have a low capacity to reflect heat. These contribute to the increase in local temperatures.
- Lack of green spaces: few green areas reduce opportunities for recreation and well-being.
- Stormwater retention: water retention can cause drainage problems and increase the risk of flooding.
- Impermeable parking areas: impermeable parking areas prevent the natural absorption of stormwater, exacerbating drainage problems.

Figure 3 Placement of intervention areas within the context of the macro-area (highlighted in red). (Created by the authors).

The adoption of NBS can mitigate the identified risks and promote sustainable and resilient solutions (IWMI, 2023). For FOCUS 01, we propose the following solutions (Figures 4 and 5):

- Rain gardens. Rain gardens are systems designed to manage surface stormwater by integrating elements such as surface vegetation, filter layers of soil and compost, and drainage systems. These gardens not only improve water quality through phytodepuration but also enhance long-term water-flow management. An example of rain gardens can be observed in the Østerbro district of Copenhagen, Denmark. (https://livingarchitecturemonitor.com). This case study has demonstrated that the integration of rain gardens can both improve stormwater management and enhance the urban landscape by promoting biodiversity and improving quality of life for residents.

- Infiltration trenches. Infiltration trenches are linear structures that promote the slow infiltration of stormwater into the soil, reduce peak flows, and improve water quality through natural filters. A case study of Zollhallen Plaza in Freiburg, Germany, has demonstrated how these structures can both efficiently manage stormwater and contribute to restoring and maintaining urban hydrogeological balance (https://landezine.com).
- Flood storage basin. A flood storage basin is temporary public space designed to collect and discharge stormwater during heavy rainfall. They contribute to sustainable water management and enhance urban biodiversity. An example is the Eco-district Parc du Trapeze in Boulogne-Billancourt, France (https://www.ileseguin-rivesdeseine.fr).

Figure 4 Modified state of FOCUS 01 area with the integration of NBS (Created by the authors).

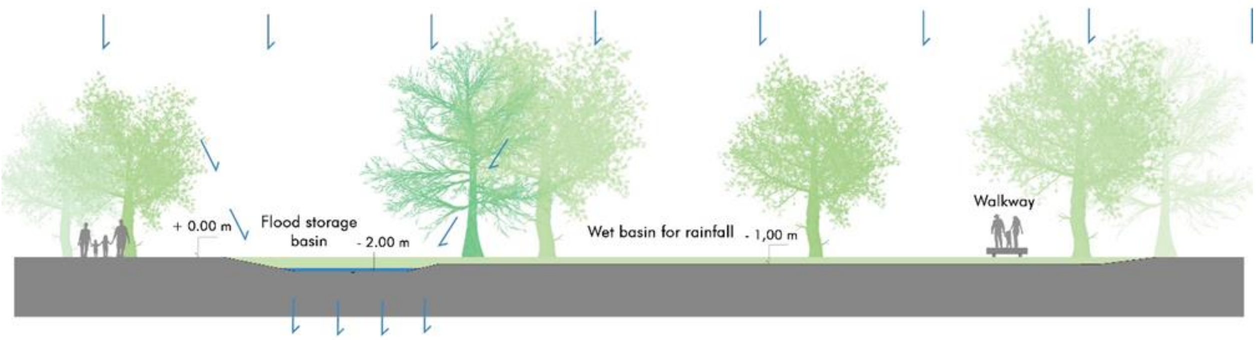

Figure 5 Flood storage basin section (Created by the authors).

The proposals for FOCUS 02 include:

- Swales. Swales are shallow canals with vegetated banks designed to collect and treat rainwater, which promote infiltration into the ground and reduce surface runoff. One example is the Parc du Trapeze eco-neighbourhood in Boulogne-Billancourt (France), where these structures have improved the aesthetic appearance and environmental quality of urban areas (https://www.ileseguin-rivesdeseine.fr). Another example that confirms the role of swales in promoting environmental sustainability is the Clicy-Batignolles eco-neighbourhood in Paris (https://archello.com).
- Permeable parking lots. Permeable parking lots are designed to filter and drain rainwater and contribute to reducing soil sealing and improving urban climate comfort. An example is the Eco-district of Boulogne-Billancourt, where such parking lots have both optimized stormwater management and promoted a more sustainable and resilient urban environment (https://www.district-immo.com).

The combined adoption of swales and permeable mineral parking lots represents a step towards reducing urban impermeability and promoting eco-friendly and sustainable building practices. These solutions not only improve stormwater management, but also contribute to the creation of more pleasant urban spaces that are resilient to the effects of climate change (Emilia-Romagna Region,2020).

3. Results

The analyses conducted in phases 1, 2, and 3 allowed for the following outputs. At the end of phase 1, we obtained the following vector processing outputs:

- Historical building map
- Map of covered surfaces and building heights
- Map of buildings for infrastructure and general technical facilities
- Map of building footprint and lot area
- Coverage report: ratio of covered area to lot area
- Road network graph map with intersection nodes highlighted
- Map of the 20-meter strip from the road axis and identification of lots predominantly falling within the strip

All these outputs have been used as indicators for the classification of urban morphotypes, which led to the creation of the Urban Morphotype Classification Map as result of phase 1.

During the second phase, we conducted the following:

- NDVI for vegetation and built-up areas (raster processing)
- LST anomaly temperature compared to non-urban areas (raster processing)
- Green space map, hexagonal grid (vector processing)
- Heat island map, hexagonal grid (vector processing)
- Soil permeability map (vector processing)
- Population density per square kilometre within the municipality, hexagonal grid (vector processing)

All of this processing has been used to create map of areas at risk with higher vulnerability as result of phase 2.

Finally, during Phase 3, we conducted the following analyses to formulate NBS proposals for sustainable urban water management:

- Overlay map between areas of vulnerability and urban fabric to define the application area (vector processing); see Figure 6

- Graphic proposals for integrating NBS within the most critical and vulnerable areas (graphic processing)

To select NBS for stormwater management and formulate a sustainable urban regeneration project, we rely on the specificities of the identified macro-areas. We were able to identify solutions such as rain gardens, infiltration trenches, flood storage basins, swales, and permeable car parks because the availability of surfaces and the geological characteristics of the area allowed us to do so. The combination of the draining subsoil and the presence of drainage channels in agricultural areas ensure adequate water management, reducing pressure on the existing disposal infrastructure.

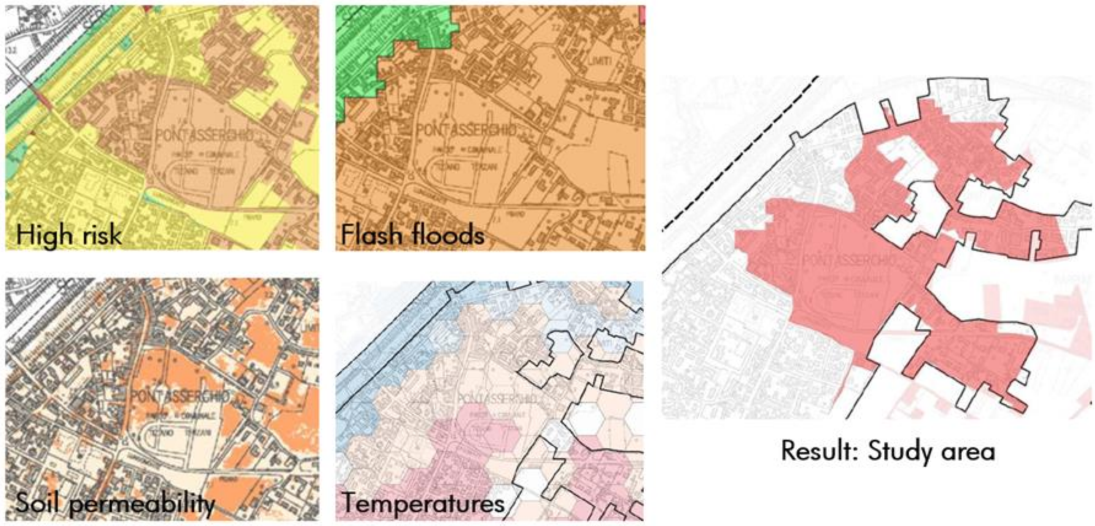

Figure 6: Overlay of a map of areas with high risk of hydrogeological events, increased susceptibility to flash floods, high summer surface temperatures, and low soil permeability (Created by the authors).

4. Discussion

In the context of increasing necessity to address and prevent climate change, this research started from an in-depth analysis of San Giuliano Terme with the aim of identifying areas where the principles of urban regeneration can be applied and intervening with specific NBS. This classification identified vulnerable areas where regulations should mandate the implementation of NBS. The contributions could help to make urban areas more sustainable and resilient.

The design hypothesis regarding the adoption of NBS in the two identified study areas should be considered as a simulation aimed at the future development of research. On a theoretical level, the solutions identified could significantly contribute to the definition of policies against climate change and foster a more harmonious urban development that is resilient to the impacts of climate change. As Biasin et al. (2023) point out, however, it is necessary to address the issue from a practical point of view. In particular, three aspects should be carefully considered in the development of research aimed at implementing policies for land-use control and hydraulic-risk management through sustainable urban regeneration interventions using NBS:

- There is a need to implement methodologies with demonstrated replicability in different urban contexts.
- It is necessary to further quantify the benefits in economic, environmental, and hydrological terms.
- It would also be appropriate to develop continuous monitoring methodologies that public administrations should use to ensure that risk assessments are constantly updated.

5. Conclusion

Although still in progress, this research has achieved the goal of developing a methodology to identify areas that are most suitable for NBS. The process started with the definition of the urbanized territory and the morphology of urban fabrics (required by the PIT of the Tuscany Region) and has led to the identification of the study area where NBS will be applied in this phase of the research. This was done by overlapping maps of areas at high risk of extreme hydrogeological events such as flash floods, areas with high population density, and areas subject to high summer surface temperatures and low soil permeability (see Figure 6). The next phase will involve applying specific software to demonstrate the effectiveness of NBS, which have only been hypothesized at a theoretical level at the current stage of the research.

Additional development of the research will also involve identifying study areas in other urban or regional contexts to which the same methodology can be applied and the use of specific software to support the analyses. Among the software to be employed are InfoWorks or InfoDrainage, which allows the simulation of sewer networks (usually piped) and natural watercourses with open sections and floodplain areas. This software will be used to model and analyse the behaviour of urban drainage networks and to evaluate the interactions between sewer systems and natural watercourses. Another example is The Storm Water Management Model (SWMM), which will be utilised to verify the effects of NBS on the urban hydrological system, which will help to assess how infrastructure modifications or stormwater management projects will impact runoff, infiltration, and other hydrological dynamics.

Additionally, i-Tree, a software suite developed by the USDA Forest Service, provides tools to analyse and evaluate the role and value of urban forests and trees in urban and rural settings. This software will be used to support the sustainable management of arboreal resources, which will offer assessments of the environmental and economic benefits of trees, such as carbon sequestration, air quality improvement, and reduction of rainwater runoff. By using these tools, we aim to deepen our understanding of the effects of urban interventions on drainage networks, natural watercourses, and urban greenery. The developed methodologies will be applied to a variety of contexts to improve the sustainable and integrated management of water and arboreal resources.

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Conflict of interest:

The authors declare that there is no competing interest.

References

Anandababu D., Purushothaman B.M., Suresh Babu S., (2018), Estimation of Land Surface Temperature using LANDSAT 8 Data, International Journal of Advance Research, ideas and innovations in technology, Vol. 4, Issue 2.

Biasin, A. et al. (2023). Nature-Based Solutions Modeling and Cost-Benefit Analysis to Face Climate Change Risks in an Urban Area: The Case of Turin (Italy), in Land.

European Space Agency (ESA) (2024). Programma spaziale Copernicus. https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Introducing_Copernicus

Henderson, M. (2022). Urban Resilience. In Brears, R.C. (Ed.), The Palgrave Encyclopedia of Urban and Regional Futures. Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-030-87745-3_86

IWMI (International Water Management Institute) (2023). How nature-based solutions can build urban resilience. Retrieved from IWMI.

ISPRA (Institute for Environmental Protection and Research) (2020). Report on Flood Hazard Conditions in Italy and Associated Risk Indicators, n.353/2021.https://www.isprambiente.gov.it/it/pubblicazioni/rapporti/rapporto-sulle-condizioni-di-pericolosita-da-alluvione-in-italia-e-indicatori-di-rischio-associati

Jeevalakshmi. D., Narayana R., Manikiam B. (2017) Land Surface Temperature Retrieval from LANDSAT data using Emissivity Estimation, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 20 (2017) pp. 9679-9687

Marango, D. (2019). ICT la resilienza e la pianificazione urbana. Franco Angeli.

Nath, H., Acharya, P., Gupta, A.K. (2024). NbS Interventions as Tool for Urban Climate Resilience: A Case Study of Peri-Urban Ecosystem in Noida. In: Gupta, A.K., Gupta, A., Acharya, P. (eds) Disaster Risk and Management Under Climate Change. Disaster Resilience and Green Growth. Springer, Singapore. https://doi.org/10.1007/978-981-99-4105-6_17

Emilia-Romagna Region (2020). Save Soil for Life Project, Freeing the Soil – Guidelines to Enhance Resilience to Climate Change in Urban Regeneration Projects. https://territorio.regione.emilia-romagna.it/urbanistica/sosforlife

Tuscany Region. Territorial Address Plan (PIT) (2015), General Report of the Landscape Plan. https://www.regione.toscana.it/documents/10180/12604066/Relazione+generale+del+Piano+paesaggistico.pdf

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas, in Environmental Science & Policy, 77, pp. 15-24.

Stathopoulou M., Cartalis C., (2007) Daytime urban heat islands from Landsat ETM+ and Corine land cover data: An application to major cities in Greece, Solar Energy, Volume 81, Issue 3

Todeschi, V., Pappalardo, S.E., Zanetti, C., Peroni, F., & Marchi, M.D. (2022). Climate Justice in the City: Mapping Heat-Related Risk for Climate Change Mitigation of the Urban and Peri-Urban Area of Padua (Italy), in ISPRS International Journal of Geo-Information, 11(9), p. 490.

Yuan F., Bauer M. (2007) Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery, Remote Sensing of Environment, Vol 106, Issue 3, Pages 375-386,