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Learning from Two Early Brownfield Redevelopment Projects in Italy: Soil Desealing, Cooling Effects, and Implementation of Nature-Based Solutions Through Traditional Planning Tools

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Abstract: Consideration of the future fate of brownfields in urban environments has driven a complex 'season' of decisions, planning, and implementation that has seen the emergence of different approaches and actions for their reuse. Among the various experiences of brownfield redevelopment, some projects have also promoted the partial renaturalisation of areas through soil desealing and demolition of existing buildings. These greening initiatives have provided new public facilities, e.g., parks and green areas, helping to improve the conditions of urban environments both from ecological and social perspectives. This article adopts ex ante and ex post methods to analyse two Italian case studies of brownfield regeneration involving desealing interventions and investigates two key aspects: (i) the planning process and tools that were put in place to implement the projects and (ii) the impacts for human wellbeing that were produced in terms of cooling effects. The analyses conducted show the real effectiveness of renaturation interventions especially related to reforestation measures in terms of temperature reduction. The examination of the two case studies also revealed the importance and potential success of traditional planning and implementation tools in promoting interventions that can now be considered innovative in terms of their actual contribution to current urban challenges. The results therefore allow us to emphasize the fundamental importance of the philosophy and basic principles of a transformation process, even guided by traditional planning tools, for the improvement of the environmental conditions of an urban context and the successful implementation of nature-based solutions.

Keywords: green spaces; desealing; brownfield redevelopment; urban heat island; spatial planning; NbS implementation

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1. Introduction

Cities do not change by their own unknowable instincts, but are built piece by piece by their communities [1]. Individuals continue to modify human environments [2] to meet specific needs through intentional interventions and multiple actions according to an alternation between use, disuse, and reuse that appears as an entirely physiological occurrence in the history of human societies [3]. Within this sequence, we can also include the processes of decommissioning large industrial facilities, which have taken place in many areas of the planet, especially since the 1980s. It was a complex season that recognised, in brownfield redevelopment, a common challenge for public policies [4] and a relevant factor for the activation of territorial redevelopment processes [5]. In 2014, it was estimated that there were 4.2 million brownfield sites in the European Union, of which about 340,000 were characterised by contaminated soils in need of remediation prior to redevelopment [6].

Since their recognition, brownfields have been the subject of different proposals for definition and interpretation by national and local institutions and agencies [7]. As mentioned by Alker et al. [8], the term 'brownfield' has had two main derivations. The first arose from the contrast with the concept of greenfield sites by understanding the latter term as an area not previously developed [9]. The second interpretation, emphasising the circumstantial reading proposed by the US Environmental Protection Agency, considered those unused commercial and industrial facilities linked to recovery processes challenged by the presence of contaminated soils. Regardless of the semantic uncertainties that have long accompanied this expression, there are numerous and heterogeneous positive impacts [10] that brownfield redevelopment is able to bring about in the restoration and regeneration of open spaces.

In the transition from a society with a strong industrial identity to a new post-industrial one [11], different approaches have arisen to rethink these places. In the case of existing structures not worthy of conservation and re-functioning, the regeneration of former industrial sites has often implied a partial or total removal of existing buildings and anthropogenic structures with a consequent increase in soil permeability and renaturalisation. This approach, which is in line with an idea of 'urbanism of demolition' [12], implements the concept of desealing [13] defined as "restoring part of the former soil profile by removing sealing layers, such as asphalt or concrete, loosening the underlying soil, removing foreign materials, and restructuring the profile" [14]. By desealing areas previously 'sealed' by buildings or impermeable surfaces, it is possible to increase soil permeability, creating the conditions for the restoration of certain ecological functions inhibited by sealing processes [15] and for the activation of renaturalisation processes.

The advantages that can be obtained by desealing interventions and the consequent renaturalisation acquire great importance for urban areas, especially those characterised by intense soil sealing processes [16]. In fact, anthropogenic soil sealing generates numerous negative effects, including increased risk of urban flooding, greater urban heat island intensity, habitat loss and fragmentation, and disconnection from nature [17,18]. With desealing, it is possible to mitigate or compensate for this negative situation by ensuring: (i) to re-activate or increase soil infiltration and restore the water cycle management capacity [19]; (ii) to mitigate the urban heat island phenomenon [20]; (iii) to create green areas that are important for the public health [21]; and (iv) to restore the ecological function of soils by supporting 'ecological reconciliation' [22]. Therefore, by creating new urban porosities [23] and (re)activating ecosystem functions [24], the regeneration of former industrial sites could make a significant contribution to targets of creating green spaces and, in doing so, delivering multiple benefits [4]. Desealing and re-greening interventions in former industrial sites can be seen as nature-based solutions (NbSs), i.e., as interventions aimed at bringing more and more diverse nature into the city through cost-effective actions that provide environmental, social, and economic benefits [25]. While the term "nature-based solutions" became popular only recently [26], some authors have argued that NbSs themselves are nothing new and that cases of effective NbS projects can be identified throughout the history of our co-evolution with nature [27]. Practitioners involved in NbS projects have also recognized that the term might be seen as a reframing of previous concepts, such as green and blue infrastructures, at the same time acknowledging the potential strengths and weaknesses of the new concept [28]. Moving from the concept to its operationalization, many scholars have focused on implementation as a key aspect of NbS and highlighted that several barriers to successful NbS implementation still exist, such as a lack of concrete planning recommendations and action-oriented frameworks, as well as gaps in knowledge regarding stages of NbS implementation [29–32]. Moreover, it has been stressed that the "discourse on NbS implementation could advance towards more operational understanding" and that NbSs have to be integrated into urban planning [32]. As such, it seems that new urban challenges and nature-based solutions seem to require brand new planning tools to be respectively tackled and implemented. However, the case studies presented and analysed in this article suggest that the introduction of nature-based interventions does not necessarily need the creation of novel implementation instruments. Significant results can be achieved by leveraging existing planning instruments within the given regulatory context.

The objective of the paper is to analyse two case studies of brownfield regeneration involving desealing interventions to investigate both the planning process and implementation tools that were put in place, and the impacts in terms of human wellbeing that were produced. From the analysis, we draw lessons about planning implementation tools that can be adopted in similar (NbS) interventions, as well as on the different approaches that can be applied to assess their impacts. Specifically, we focus on the cooling capacity of the new green spaces as an essential contribution to reducing the heat island effect towards increased wellbeing of the urban population and illustrate the application of two methods that can be used to assess the impact of the project ex ante and ex post.

The structure of this paper is as follows: in Section 2, we provide condensed background literature on the cooling capacity of green areas. Section 3 is dedicated to a detailed description of the case studies in terms of renaturalisation interventions and planning tools employed to implement the regeneration projects. Section 4 is dedicated to the results, while Section 5 focuses on the discussion. Section 6 outlines the main conclusions.

2. The Cooling Capacity of Green Areas

Among the various benefits offered by urban greenery is its cooling capacity. Urban green spaces contribute to reducing high temperatures in cities (linked to health risks and hospitalization costs) due to their cooling power [33]. Empirical studies show that urban green space can lower air temperatures in cities by up to 6 °C [34]. However, not all greenery cools in the same way, and both when evaluating an investment and when designing a green space (new, or the improvement of an existing one), it is necessary to know what the cooling capacity of a green area depends on and to be able to quantify the possible cooling effect.

The capacity of urban green spaces to provide cooling depends on their physical features or components [35]. Based on a review of the scientific literature, Zardo et al. [36] identified, as major contributing factors to the cooling power of green urban spaces: (i) its land cover; (ii) its tree canopy coverage; (iii) its size; and (iv) its climatic zone. The climatic zone in which an urban green space is located cannot be decided (this is a fact), but it determines its cooling effect. In fact, the same green space (same size, same ground cover, and same tree cover) in two different climatic zones produces different effects in terms of cooling, because different climates lead to different evapotranspiration behaviour (up to 2.5 °C difference) [37–42].

Regarding the other three factors, in a nutshell, we can say that the scale, the ground cover of an urban green space, and the percentage of tree cover determine its evapotranspiration, while the percentage of tree cover alone determines the shading effect. These two ecosystem functions (evapotranspiration and shading) are the ones that affect the cooling power of an area the most [43]. That said, empirical studies (which imply on-site measurements) show that, in the continental climatic zone (Koppen Cfa), the minimum cooling power provided by a green area amounts to 1 °C, while the maximum is around 4.8° [42,44]. It is of paramount importance to specify that the size of an urban green area determines the relative importance of evapotranspiration and shading, and that this aspect presents non-linear behaviour. Hence, for areas smaller than two hectares, shading is much more impactful than evapotranspiration in the overall final cooling effect. On the contrary, for areas bigger than two hectares, it works the other way round and evapotranspiration has a much bigger effect than shading. Last but not least, only areas larger than two hectares can achieve the best cooling performances in absolute terms (°C difference compared with the areas far from urban green spaces).

3. Case Studies Presentation

This contribution deals with the issues mentioned in the previous paragraph through the analysis of two experiences of brownfield redevelopment of industrial areas in the Italian cities of Trento and Milan (Figure 1), both involving desealing and renaturalisation. In both cases, we are dealing with complex processes of radical transformation of physical and functional structures that have fostered the creation of new green areas through the desealing of soils previously occupied by buildings and impermeable surfaces. The two areas were selected because of certain common characteristics:

- Two implemented redevelopment processes since all the interventions foreseen in the implementation plans and projects have been almost completely realized;
- The industrial areas preceding the decommissioning and transformation were characterized by the presence of a similar architectural structure in typological terms;
- The areas had high levels of soil sealing before the implementation of the project;
- The development of new green areas and public urban parks has been an important aspect and theme of both urban planning instruments and specific urban projects.

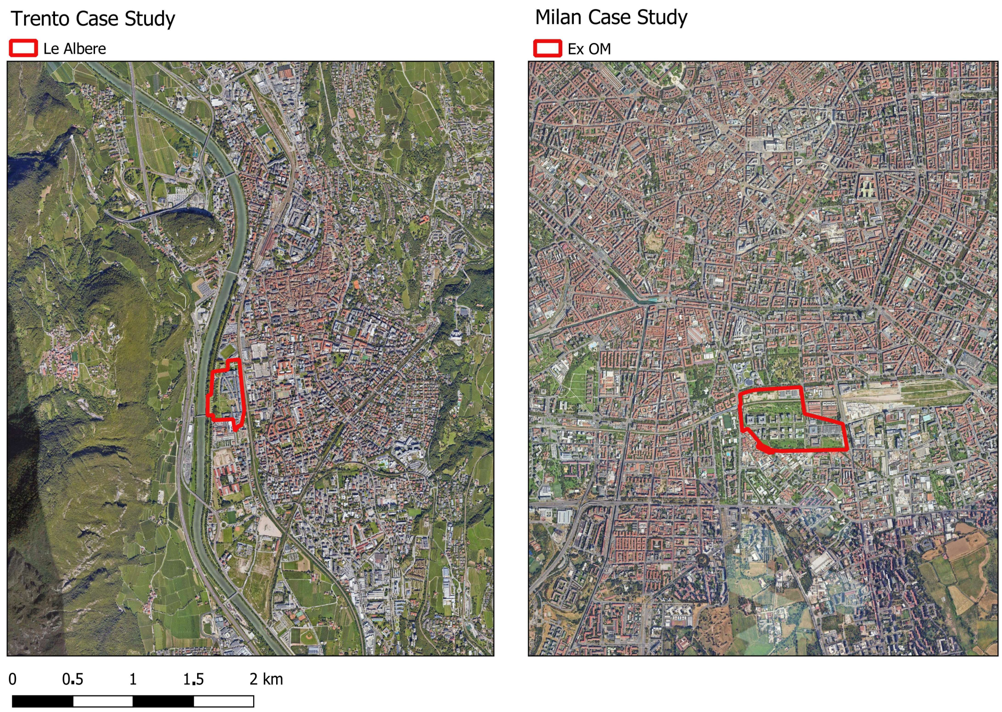


Figure 1. Location of the two case study areas. Michelin Area in Trento (**left**) and OM Area in Milan (**right**).

The following Sections 3.1 and 3.2 present the complex biographies of the two case studies, focusing both on the synthetic restitution of the main aspects that characterised the evolution of the sites and on the urban planning instruments that have been adopted to foster the transformation of the areas.

3.1. The Michelin Area in Trento

The biography of the area began in the 1920s, when the Michelin company decided to build a factory in Trento, whose size increased over the years. The Michelin area has been a very important presence for the city due to several reasons beyond its territorial extension (116,000 square meters): (i) the importance of the economic operator that has owned this place for decades; (ii) the historical conditions of the labour market (1800 workers in the 1980s); (iii) the multi-scalar functional choices hypothesised for the transformation project (e.g., the Science Museum); and (iv) the interaction with territorial elements at the centre of political and urban planning debate (e.g., the Adige River). At the same time, this area can be considered as a metaphor for a city that, in the last few decades, like other Italian cities, has been confronted with structural phenomena [45] such as demographic contraction, the ageing of the population, the decommissioning of some military structures, and crises of the industrial sector. The debate around these issues has influenced municipal urban planning instruments, also due to the strategic role attributed to many of these areas [46]. After the new urban plan of 1989, there were numerous amendments, including the hypotheses proposed in the early 2000s by the Catalan urban planner Joan Busquets [47].

The new neighbourhood that replaced the industrial area, now called Le Albere, is the result of a transformation process that, since the year of decommissioning (1998), has called for spaces, stakeholders, and planning tools. The first hypotheses had already been proposed by the 1989 Urban Plan, which had envisaged the fragmentation of the area into residential blocks inserted in green spaces. This provision, given the criticism it received, was eliminated in 1994 [48]. A few years later (1998), the Municipality of Trento changed its mind by initiating the process of revising the master plan with the aim of reconsidering the ex-Michelin site.

With the 2001 update of the urban plan, general issues were addressed, such as the need to consider the Adige River as a structuring element for urban planning policies, as well as the need to develop a 'guiding plan' to promote the transformation of the Michelin area.

The masterplan was realised by the studio of architect Renzo Piano thanks to the direct commission of Iniziative Urbane, the company that owned the area. The project addressed themes that have become recurrent in the ex-Michelin experience, such as the need to connect the area to the city and the Adige River. The two main design choices concerned the creation of both a mix of functions and a large park obtained by demolishing all the industrial buildings and concentrating the new buildings in a limited part of the area.

The master plan not only provided for different interventions on specific issues within the area (tree-lined paths, road network, building fabric, etc.), but also identified interventions along the boundaries of the project area to accelerate and improve the urban regeneration process [49]. These interventions included the construction of several pedestrian subways under the railway (elevated), road, and pedestrian bridges over the Adige River, and the construction of interchange car parks. These works also included moving the road underground (Via Sanseverino) that physically separated the project area from the Adige River.

In 2005, about a year after the approval of the master plan by the municipality, the subdivision plan was realised by the same architect. This second level of in-depth study led to the definition of six design guidelines concerning different 'systems' (energy, water, green and built), the road system (including paths), and the relationship between park and water. Again, great importance was given to the theme of green spaces and the idea of creating a large urban park.

The construction works that began in 2008 led to the construction of new residential (approximately 44,000 square metres), tertiary (approximately 29,000 square metres), and commercial (approximately 10,500 square metres) buildings. Another important project was the construction of the Museo delle Scienze—Science Museum (MUSE) in the northern part of the district. In addition to an important share of mainly underground parking spaces (approximately 2000 parking spaces), interventions on open spaces should also be mentioned, which involved both squares, pedestrian paths, and water channels (approximately 28,000 square metres), and the construction of the new public park (approximately 50,000 square metres).

A considerable part of the project area was involved in the construction of new green areas and a new public park (about 43%), which, as mentioned above, was a characterising decision for the entire redevelopment process. Desealing took the form of a necessary action to facilitate the creation of the new public park and meet certain needs [15]. The first need, emphasized by the planning documents, concerned the attractive role given to the large, equipped park, which was supported by the provision of specific elements. The spatial components, intended to ensure attractiveness and that characterized its spatial composition and organization, concerned the creation of paths, equipped meadows, and wetlands. The second requirement proposed by the project was related to the desire to restore connections with the Adige River by encouraging a return to the dialectical relationship that had been denied with the progressive urbanization of these areas. The park was, likewise, considered as a connecting element between the consolidated city and the river, and between the latter with the new architecture of the neighbourhood and the planned receptive/commercial functions. The specific choices adopted included both the proposed burying of Via Sanseverino, which was essential to give continuity to the park, and the creation of a network of canals and bodies of water intended to serve different functions.

The proposed design framework for the final subdivision plan adopted a taxonomic approach because, in it, the different "elements" that made up the large, equipped park are treated separately. In the technical–descriptive report and the in-depth documentation, the organization of the spaces took place through the use of "diversified landscape environments" that corresponded to: (i) a central environment treated as a lawn and equipped with paths; (ii) a wet garden composed of essences usual for river environments; and (iii) groves consisting of prime tree essences distributed along the edges. It is an archipelago of spaces with a strong ecological, physical, and functional characterization that has found, as stressed in the project, in the tree rows, a connective system together with networks of pedestrian paths and water channels.

The complex system of green areas that now characterize the Le Albere neighbourhood accurately respects the principles and design directions provided by the former Michelin transformation project. It is possible to recognize both the spatial design imagined in the various elaborations of the project, and the variety of elements that characterize it which return a certain complexity in the interpretation of the concepts of "urban nature".

3.2. The OM Area in Milan

The history of the OM (acronym for Officine Meccaniche—Mechanical Workshops) area began in the late 19th century, when the Miani Silvestri industry, then engaged in the production of railway materials, decided to settle in this part of Milan. Within a few years, thanks to the positive effects of its proximity to the Porta Romana railway station, it became one of the most important industrial areas in Milan. Between the 1980s and 1990s, the gradual process of divestment of production activities began. This was a historic phase for Milan, which, like other large European and North American urban areas, saw the start of a new season of design, political, and cultural reflections on disused sites.

Milan's urban planning policies have often dealt with the issue of large 'urban voids' with newly introduced instruments that differ from ordinary municipal urban plans. Starting in the 1980s, the city decided to adopt rather innovative 'Documents' that, moving away from the traditional forms of planning, assumed a more strategic dimension. The first relevant act, developed to analyse the impacts of new underground rail links [50], was the *Documento Direttore per il Progetto Passante* (1984). This was an instrument introduced to coordinate public and private interests [51] and to foster the activation of urban projects. Many of the areas considered by this instrument, then affected by decline, returned frequently in the reflections of the following years, also because of their dimension and strategic position. The former OM still appeared with a secondary role, but as an area eligible for urban redevelopment by rethinking functions and redesigning areas [52].

A second relevant moment for the political debate was the 'Nove Parchi per Milano' (Nine Parks for Milan) project developed in the mid-1990s. This initiative proposed a set of interventions to transform extensive peripheral areas with the simultaneous creation of new parks and services to oppose the monocentrism that traditionally characterised the forma urbis of Milan. Similar to the experiences proposed for Barcelona and Paris, the structure of the city was rethought through urban projects and new urban parks [53]. In this new vision for the OM area, several hypotheses were foreseen, which were taken up in subsequent years in other more tangible and effective initiatives. For example, an expansion of the existing Parco Ravizza, located north of the OM area, was proposed through the creation of new green areas in the industrial zone, obtained by demolishing the industrial buildings.

The area's transformation process started with the municipality's participation in a national funding call to support urban redevelopment. After applying for funding, real estate companies submitted a proposal for an Urban Redevelopment Programme (PRU in Italian) of the former OM (later named 'PRU OM-Pompeo Leoni'), for an area of 313,652 square metres. After the financing was awarded, in 1997 the Programme Agreement was signed between the Municipality, the Lombardy Region, and the Ministry of Public Works, and all the design indications were defined for the subsequent technical phases (and for the modification of the current master plan, which did not provide for the transformation of the area). Development work began in 1999, while construction was mainly concentrated between 2003 and 2005. The reconversion of the area led to the creation of a new neighbourhood characterised by a rather ordinary mix of functions with a majority of residential spaces (in terms of floor area: 153,000 square metres for residential use, 79,000 square metres of commercial facilities, 34,000 square metres of space for the tertiary sector, and 31,000 square metres of space for production functions).

One aspect of the area's redevelopment project concerns the creation of new public green areas. According to the design proposed by the French landscape architect Frederic Cristophe Girot, the green area system was organised into different spatial and thematic areas. This hypothesis can be compared with the indications included in the PRU project carried out by the municipal administration, albeit with some difficulties and limitations related to the impossibility of overcoming the physical barrier constituted by the railway line and Viale Toscana. The obvious criticalities prevented the implementation of the idea of a unified public park, also envisaged by the Nine Parks for Milan project. The latter promoted the connection and continuity between the existing Ravizza Park, located north of the area beyond Viale Toscana, and the new park planned within the former OM area. The architect proposed a park structured in three environments alternating with the new buildings, organized along the east–west direction, and integrated with the Vettabbia canal that ran through the entire area (for which reclamation and redevelopment were planned).

Further north, between the railway and Toscana Avenue, the "Culture Park" was planned, characterized by the construction of a large amphitheatre for 1500 people, new wooded and planted areas with fruit trees, and outdoor sports facilities. In the centre, some technological and architectural elements were maintained to preserve the historical memory of the industrial area. This area was called the "Park of Industrial Memories" and aimed to ensure a possible integration with the new green areas (lawns and rarefied trees). To the south, the project envisioned the "Vettabbia Park," which derived its name from the presence of the Vettabbia Canal and its relationship with this hydraulic element. In this case, the design indications were oriented toward the enhancement of the canal through the creation of bicycle and pedestrian paths, tree-lined strips, and small squares that were overall related to the new lawn areas to be placed between the Vettabbia and the new built-up areas. Between the Memorial Park and the Vettabbia Park were the areas intended for the construction of the new residential and tertiary buildings.

In the centre of the built-up spaces, again along the east–west axis, was the main road axis of the entire project (the present Giovanni Spadolini and Carlo de Angeli streets), whose design was characterized by the presence of paths alternating with green spaces (lawns and tree rows) aimed at improving the aesthetic and environmental quality of the new road system. Given the current condition of the area, this specific part of the new neighbourhood can be considered as a boulevard with retail uses.

The various thematic sections were connected along the north–south axis by pedestrian–cycle paths intended to provide continuity between the areas due to the discontinuities planned to interrupt the otherwise wide frontage of new blocks and buildings. Girot's proposals were later considered in the project carried out in 1998/99 by the land studio and renowned landscape architect Andreas Kipar, who developed the executive proposal by adapting it to new requirements agreed upon with the City of Milan without radically altering the original layout of the project. The park construction started immediately after and was completed in 2006, except for the Culture Park, which is still under construction. After several decades of disuse and the emergence of large fragments of the "third landscape," a decision was recently made to build an underground station for electric buses and new green-roofed areas set aside for loisir-related functions.

4. Methods: Two Approaches to Assess the Cooling Effects of Desealing Interventions

In this section, we present two different approaches that can be used to assess the cooling effect of desealing interventions. The first approach was developed as a planning support tool to help practitioners assess ex ante the potential impact of greening interventions, thus aiding in their design. The second approach uses land surface temperature (LST) as a common way to assess temperature differences across different areas using remote sensing data, which provides an understanding of the conditions of the urban environment at a specific moment.

4.1. Predictive Expectations

To determine the potential cooling capacity of each of the two areas, before, during, and after their transformation, we adopted a predictive model developed by Zardo et al. [36] The model links the physical features of green urban areas to a class of cooling capacity, which corresponds to the range of cooling effects expressed in degrees Celsius (based on empirical data collected).

In this subsection, first, we determine the soil cover of the areas (expressed in %) and for each soil cover type, we determine the tree canopy coverage (expressed in %). In this case, there are no trees on water surfaces, for "water" no tree canopy coverage is quantified. The quantified mapping is done for both study cases (the area in Trento and the area in Milan) and for two different years. See Table 1 for Trento and Table 2 for Milan.

Table 1. Soil cover types for the study area in Trento.

	1998		**2023**	
	Hectares (Ha)	**%**	**Ha**	**%**
Total area	12.23	100	12.23	100
Grass	1.57	12.80	5.69	46.49
Sealed	10.57	86.44	6.55	53.51
Bare soil	0.09	0.75	0.00	0.00
TOTAL	12.23	100.00	12.23	100.00
Canopy cover	1.40 *	11.44	1.26 *	10.29

* For areas bigger than 2 hectares in the continental climate zone, with overall tree canopy coverage lower than 20%, the cooling power values for grass, sealed, and bare soil are 69, 20, and 58, respectively.

Table 2. Soil cover types for the study area in Milan.

	1998		**2023**	
	Hectares (Ha)	**%**	**Ha**	**%**
Total area	33.15	100.00	33.15	100.00
Grass	3.86	11.64	15.08	45.49
Heterogeneous	0.25	0.75	0.00	0.00
Sealed	21.77	65.68	16.11	48.61
Bare soil	7.27	21.94	1.45	4.38
Water	0.00	0.00	0.51	1.53
Canopy cover	2.97 *	8.96	5.45 *	16.44

* For areas bigger than 2 hectares in the continental climate zone, with overall tree canopy coverage lower than the 20%, cooling power values for grass, heterogeneous vegetation, sealed, bare soil, and water are 69, 68, 20, 58, and 75 respectively.

As a second step, following the model proposed by Zardo et al. [36], a cooling power value (on a scale from 0 to 100, where 0 represents the absence of cooling power and 100 the highest cooling power possible) is associated with each area for each period by calculating the average cooling power value:

((Value for the sealed surface * % sealed soil) + (Value for bare soil * % of bare soil) + (Value for heterogeneous vegetation * % of heterogeneous vegetation) + (Value for grass * % of grass soil) + (Value for water * % of water))

To select the cooling power values for each soil cover type, we used the values for the specific tree canopy coverage of the areas (which, in both time periods and for both areas, are below 20%), the continental climatic zone and values for areas bigger than 2 hectares (see caption of Tables 1 and 2 for the specific cooling power values for each soil cover type). Once the cooling power value was obtained for each area in each of the two years, we can associate the expected a degree Celsius difference compared with the areas far from the green urban space through the following Table 3.

Table 3. Cooling power values and expected cooling capacity in degrees Celsius for the continental climatic zone, where Trento and Milan are located.

Region	Cooling Power Values 0–20	Cooling Power Values 21–40	Cooling Power Values 41–60	Cooling Power Values 61–80	Cooling Power Values 81–100
Delta T (°C) for the continental region	Up to 1 °C	Up to 1.9 °C	Up to 2.9 °C	Up to 3.8 °C	Up to 4.8 °C

Adopted from Zardo et al., 2017 [36].

4.2. Land Surface Temperature Analysis

To verify the actual effects produced by desealing interventions and consequent renaturalisation of the soil in relation to the urban heat island phenomenon in the analysed areas, we used the calculation of land surface temperature (LST) as a proxy. Specifically, to analyse the LST, we utilized data from Band 6 and Band 10 ST in the thermal infrared (TIR) spectrum of the United States Geological Survey (USGS) Landsat 8 and 5 satellite data. We processed the data with QGIS software, version 3.22.10 for the boundaries of the areas from municipal databases. For both areas, Landsat 8 and 5 data were selected for three dates ensuring clear sky conditions to avoid interference from cloud cover. For Trento, the selected dates were 3 July 1998, 22 July 2006, and 22 August 2023. For Milan, the selected dates were 23 July 1998, 8 August 2001, and 21 July 2023. The three years were chosen based on the progress of renaturalisation works. In 1998 (Milan) and 1999 (Trento), industrial buildings were still present in both areas. In Milan, works started in late 2001 whereas in Trento, works did not start until late 2006/early 2007. By 2023, the renaturalisation and regeneration interventions were completed, and the neighbourhoods were fully inhabited. For both cities on the three selected dates, we calculated: (i) the maximum and minimum LST for the areas under analysis; and (ii) the average LST for the area. The results are reported in the following paragraph.

5. Results of the Cooling Assessment

5.1. Land Surface Temperature

The results show that the study area in Trento experienced an overall upgrade in its cooling capacity, from an average cooling power value of 26.5 in 1999 (on a scale from 0 to 100, where 0 corresponds to the inability to cool and 100 corresponds to the highest cooling power of an area) to an average cooling power of 42.8 in 2023 (see Table 4). These values can be translated into a potential cooling capacity of the area of 1.9 °C compared with a sealed or built-up area with no vegetation for the area in 1999, and into a potential cooling capacity of the area of 2.9 °C compared with a sealed or built-up area with no vegetation for the area in 2023. The change in the land cover of the site enables the area to gain one degree Celsius of cooling power from the state of the area in 1999 to the state of the area in 2023.

Table 4. Results of average cooling power for the study area in Trento.

Year	**Class**	**Average Cooling Power Value**	**°C**
1999	21 ≤ x < 41	26.5	Up to 1.9 °C
2023	41 ≤ x < 61	42.8	Up to 2.9 °C

As mentioned, the improvement from 1999 to 2023 was due to the change in land cover. In particular, the types of soil cover remained the same, but the share of sealed area (which is the one presenting no cooling power, or very low cooling power in presence of trees) decreased dramatically (from 86.4% to 53.5% of the total area), and the grass-covered area increased (from 12.8% to 45.5%).

The results show that the study area in Milan experienced an overall upgrade in its cooling capacity from an average cooling power value of 34.4 in 1999 (on a scale from 0 to 100, where 0 corresponds to the inability to cool and 100 corresponds to the highest cooling power of an area) to an average cooling power of 44.8 in 2023 (see Table 5). These values can be translated into a potential cooling capacity of the area of 1.9 °C compared with a sealed or built-up area with no vegetation for the area in 1999 and of 2.9 °C in 2023.

Table 5. Results of average cooling power for the study area in Milan.

Year	**Class**	**Average Cooling Power Value**	**°C**
1998	21 ≤ x < 41	34.4	Up to 1.9 °C
2023	41 ≤ x < 61	44.8	Up to 2.9 °C

Similar to the Trento case, the change in the land cover if the site determined an improvement in cooling power from the state of the area in 1999 to the state of the area in 2023. As mentioned, such an improvement is due to the change in the land cover. The types of soil cover changed: a small water surface was added from 1998 to 2023, and heterogeneous vegetation surface disappeared, passing from 0.25% to 0%. The share of built-up or sealed area (which is the one presenting no cooling power, or very low cooling power in presence of trees) decreased from 1999 to 2023 (from 65.7% to 48.6% of the total area), the grass-covered area increased (from 11.6% to 45.5%), and the bare soil area decreased.

5.2. Land Surface Temperature Results

The results of LST analysis show, for both areas, the influence and cooling capacity of de-sealed and re-greened surfaces. In the case of Trento, Figure 2 shows both the process of demolition and regeneration the Michelin area went through (top row) and the corresponding LST analysis (bottom row). In this case, the effects of the greening interventions are clearly visible. The variation in LST within the area clearly reflects the location of buildings for 1999 and 2023 and the colours of roofs for the year 1999. In fact, in 1999, the darker roof in the bottom half of the area showed higher temperatures. Despite the year 2023 having higher air temperatures (reflected also by hotter nights and days preceding the dates chosen, the minimum and maximum LST are comparable to those in the year 1999. The average and median LST were, however, still higher in 2023, due to the fresher nights for 1999 and the cooling effect of the river Adige (see Tables 6 and 7 below).

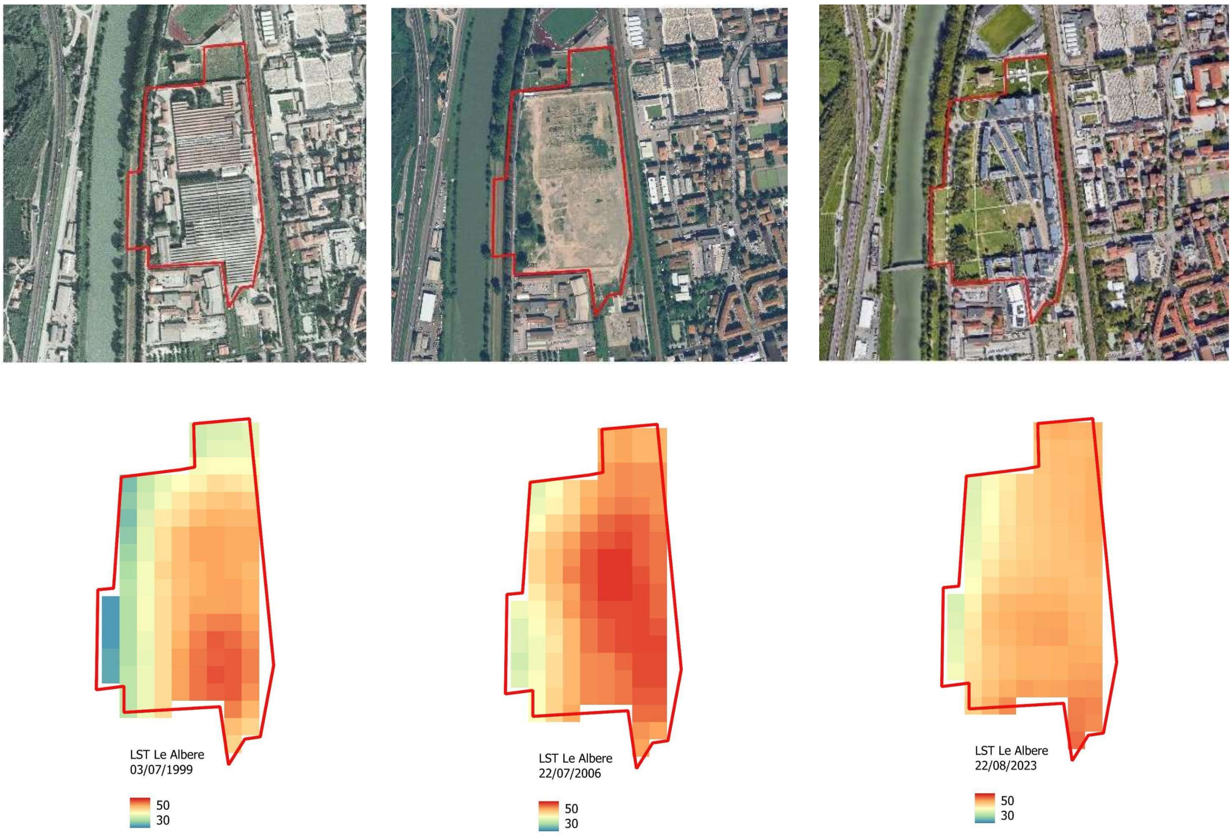


Figure 2. LST analysis for the Michelin Area in Trento. Source of satellite images: 1999 and 2006: Geoportale Nazionale http://www.pcn.minambiente.it/viewer/ (accessed on 26 July 2024). 2023: Google Earth.

Table 6. Air temperature and LST results for the Michelin area in Trento.

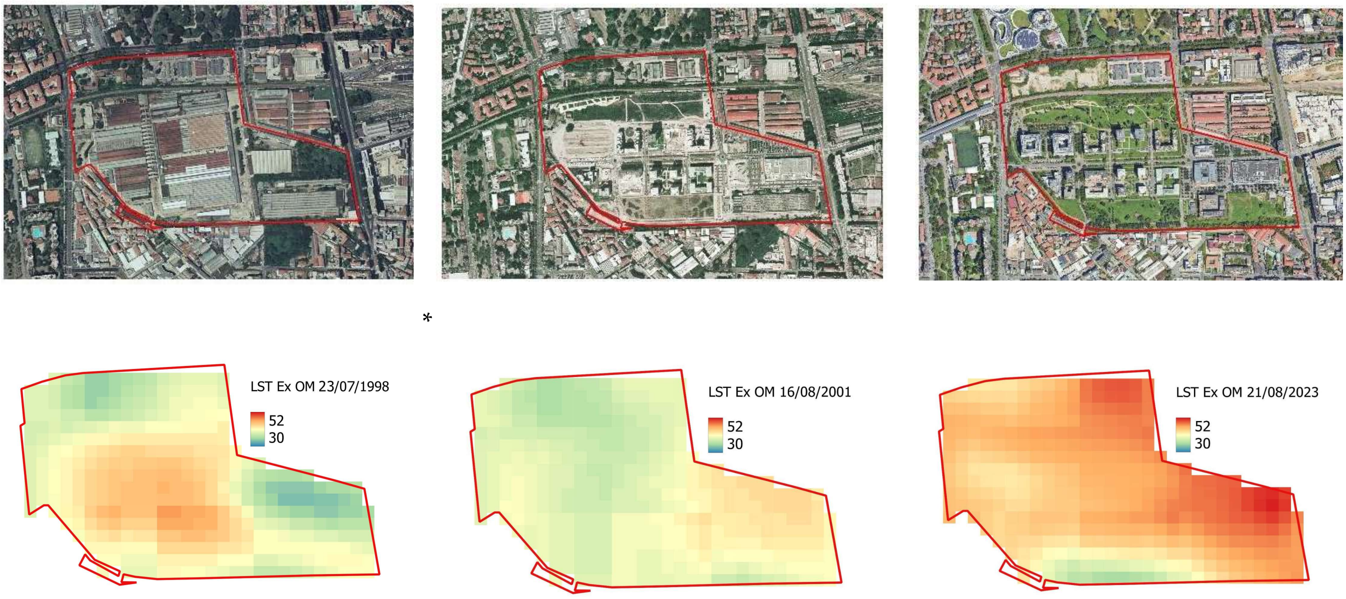
	Max Air Temperature Recorded on Day °C *:	LST Max °C	LST Min °C	LST Average °C	LST Median °C
3 July 1999	34.6	48.2	31.4	42.0	42.6
22 July 2006	35.7	49.0	37.3	45.4	45.6
22 August 2023	36.5	48.2	31.4	43.4	43.9

* Data from: http://storico.meteotrentino.it/ (accessed on 12 September 2024)—Weather Station T0129 Trento (Laste). For the year 1999, we used air temperature data from a different weather station T0136 Trento (Ufficio) due to the lack of data for Station T0129 Trento (Laste).

Table 7. Air temperatures on the selected dates and the days prior for years 1999 and 2023 for the case of Trento.

Year 1999	Mean	Min	Max	Year 2023	Mean	Min	Max
1 July	24.1	16.9	31.5	20 August	27.1	21.1	34.1
2 July	25.2	18.4	32.4	21 August	28.0	22.4	35.1
3 July	27.3	20.2	34.6	22 August	28.6	22.7	36.2

Figure 3 shows the regeneration process implemented in the OM area (top row) and the changes in LST following demolition and greening (bottom row). Here, the impact of desealing and greening interventions is relative to the specific year compared with sealed and built-up parts of the area. In fact, considering a specific year, it is possible to notice patches of lower LST (in green/blue) that overlap with tree canopy cover. However, in absolute terms, both the minimum and maximum LST first decreased from 1998 to 2001 following demolition, and then increased considerably in 2023 (Table 8). The reason for the increase can be attributed to multiple causes. It might be hypothesised that a role was played by the high temperatures in the days before and on 21 August 2023. In effect, in 2023 in the two days preceding 21 August, the minimum and maximum air temperature recorded oscillated between 22.8 °C and 36 °C, whereas in 1998, the minimum and maximum air temperature recorded were 22.0 and 34.3 °C. In 2001, the air temperatures recorded ranged from 18.1 °C to 33.8 °C, with fresher days and especially nights (Table 9).



*

Figure 3. LST analysis for the OM area in Milan. * No available image for 2001. We used an image for the year 2003 to show advancement of works. Source of Satellite Images: 1998 and 2003: https://www.regione.lombardia.it/wps/portal/istituzionale/ (accessed on 26 July 2024). 2023: Google Earth was used.

Table 8. Air temperature and LST results for the OM area in Milan.

Date	Max Air Temperature Recorded on Day °C:	LST Max °C	LST Min °C	LST Average °C	LST Median °C
23 July 1998	35.8	47.1	33.6	40.5	40.6
16 August 2001	34.6	43.5	35.8	39.9	39.6
21 August 2023	37.6	51.7	35.5	45.4	45.6

Air temperature data from: https://www.arpalombardia.it/temi-ambientali/meteo-e-clima/form-richiesta-dati/ (accessed on 12 September 2024). Weather station: Lambrate.

Table 9. Air temperatures on the selected dates and the days prior for years 1998 and 2023 for the case of Milan.

Year 1998	Mean	Min	Max	Year 2001	Mean	Min	Max	Year 2023	Mean	Min	Max
21 July	28.9	23.5	34.3	14 August	25.5	18.1	33.0	19 August	29.4	22.8	35.7
22 July	28.7	22.0	34.8	15 August	26.4	18.1	33.8	20 August	30.4	24.6	36.0
23 July	28.5	21.0	35.8	16 August	26.9	19.0	34.6	21 August	32.0	24.2	37.6

Moreover, the renaturalisation interventions were designed to provide grass areas and land cover with a reduced tree canopy cover. This might have played a role, together with the higher temperatures. In fact, the role of tree-planted areas is visible and has a buffer effect, whereas the LST maximum is higher in correspondence with a supermarket building with a roof with a low albedo effect. This case shows that, if the aim is to obtain a cooling effect to moderate the urban heat island effect, attention must be paid to land cover and treen canopy should be preferred compared with grass.

6. Discussion and Conclusions

In brownfield redevelopment processes, renaturalisation interventions play an important role in improving the quality of built-up spaces and wellbeing of the population [54]. The analysis of the Trento and Milan cases allows us to make considerations in relation to several aspects, such as: desealing, implementation of nature-based solutions and their inclusion in spatial planning tools, and the needs of spatial planners for a combination of predictive and monitoring tools.

6.1. Desealing of Former Industrial Areas

The first aspect concerns the concept and objective of desealing, which in both case studies was absent and was attained as a result of the demolition of buildings and sealed surfaces, the creation of new equipped green areas and NbS, and the consequent increase in soil permeability. However, for both cases, the increased soil permeability was the indirect result of a planning approach more focused on meeting the demand for new recreational spaces (e.g., new park facilities), rather than achieving desealing itself and contributing to recent urban challenges.

This is associated with the planning language and objectives that guided the two proposals designed in a phase prior to the awareness we have today regarding the numerous global crises. As our analysis of the planning documents shows, the two proposals were in fact characterised by the use of concepts not directly related to the current debate on urban regeneration. Indeed, the two proposals did not intend to provide a potential contribution to tackling the negative effects of climate change through the reconfiguration of urban spaces by employing increasingly familiar concepts (e.g., NbS, ecosystem services, and green infrastructure). In spite of this, this article shows that the two projects offer real benefit for the new resident population and the urban contexts in which the case study areas are located, for example in terms of the ecosystem services provided for microclimate regulation in addition to the original recreational component and objectives.

6.2. Planning Instruments for Implementation of NbS

Another aspect concerns the implementation tools used to guide the transformation of the two industrial areas. Starting from the same starting conditions, i.e., areas with relatively similar architectural and morphological characteristics, the two cases revealed the adoption of different planning and implementation tools. For the former Michelin area in Trento, the redevelopment process was supported by the more traditional approach, both with respect to the type of implementation plan used (introduced in Italy at the end of the 1960s) and to the direct relationship between the provisions of the municipal plan (always updated to support transformations) and the adopted implementation plan. For the ex-OM area in Milan, the process benefited from planning instruments introduced at the local scale directly by the Milan Municipality (such as the '*Documento Direttore*' as an update to the municipal plan) and by tools introduced by national laws to intervene on a local scale (indifferent to the indications of municipal plans). Despite the difference with respect to the Trento case, the instruments used in Milan over time have nevertheless become traditional for the Italian context and their use is quite widespread. Considering the rather similar results in relation to the creation of open spaces through the use of traditional implementation instruments, it could be argued that the design and adoption of new frameworks or recommendations are not always indispensable for the implementation of an innovative idea or concept as green infrastructure or nature-based solutions could be. In fact, contrary to the belief that new urban challenges require entirely new planning tools to be faced, our findings suggest that the introduction of nature-based interventions does not necessarily need the creation of novel technical, regulatory, and implementation instruments, frameworks, or recommendations. Instead, it is possible to meet contemporary needs by leveraging or adapting traditional implementation instruments that have been introduced, as in the case of Trento, over half a century ago with a completely different rationale and underlying objectives. This approach aligns with the principle that innovation can often be realised by rethinking or leveraging existing frameworks and instruments, rather than waiting for entirely new systems to emerge, in line with the diffusion of innovation theory [55]. The case studies analysed in our article show indeed that it is the underpinning purposes and philosophy of the project/plan that matter in being able to achieve and implement nature-based solutions, rather than the tools themselves. It has been shown that nature-based and re-naturalisation projects within newly built neighbourhoods have been implemented well before the debate and concept of NbS arose in the academic literature, let alone planning practice. As such, planners and policymakers are encouraged to: (i) critically reassess traditional tools and apply them in more dynamic ways; (ii) define core objectives and philosophy for the project/plan that align with current needs for facing urban challenges induced by climate change; and (iii) translate core objectives and philosophy into specific actions and solutions whose impact can be assessed ex ante and monitored ex post over time after the project/plan has been implemented.

6.3. Environmental Advantages and Assessment Approaches

The comparison between the system of green areas created in the two districts reveals significant differences with respect to their spatial and compositional organisation. In Trento, the new park and its associated secondary elements have the function of ensuring integration between the architectural elements and of creating strong relations with an important territorial and ecological component beyond the borders of the new district (the Adige River). The concentration of new green spaces, especially wooded areas, along the west side, moving via Sanseverino underground (a physical separation element between the former Michelin and the river), are part of a strategy to redefine the dialogue between the city and the Adige River. Regarding the single elements that characterise the overall system, there is considerable variety and diversity between spaces intended to provide outdoor recreational functions (equipped gardens, footpaths), wooded areas, and wetlands. This variety not only guarantees a certain diversity in the ecological and ecosystem functions provided, but also pursues an educational and dissemination objective consistent with that proposed by the Museum of Science (MUSE) in the Le Albere district. These are spaces that, between two-dimensional elements (lawns) and three-dimensional elements (wooded areas), are characterised by using plant essences consistent with the territorial context of reference.

The structure of the green system present in the former OM area of Milan shows different features. Its division by thematic areas and the absence of prominent structural and multiscalar elements, as in the case of Trento, reduce the perception of a general pattern of organisation. Observing and walking through these spaces, one has the perception of a ‘buffer zone role’ to separate and distance the new architecture built at the centre of the neighbourhood and the urban context of reference, thus seeking spatial, psychological, and symbolic isolation. From an organisational and environmental point of view, the new surfaces reveal less articulation due to the greater occurrence of lawns compared with trees that, on the whole, respond more to recreational purposes for the residential functions of the neighbourhood and the urban context of reference. From an ecological–environmental and biodiversity point of view, the case of Milan shows less variety in contrast with the case of Trento. Tree-covered surfaces are less present and this has a negative impact on the potential of the nature-based solution to provide cooling power and mitigate land surface temperatures. The project could have used a greater variety of green solutions to mitigate the urban heat island effect. However, as mentioned above, this was not the intention of the project itself, considering the historical period in which it was conceived.

In terms of environmental advantages, this study confirms the diverse impacts of renaturalisation projects, particularly when comparing grassland areas with wooded areas. Our analysis indicates that wooded areas tend to have a greater cooling power, particularly when biomass is concentrated and placed in specific locations. This suggests that, when designing green spaces, urban planners may achieve more significant environmental and social benefits by incorporating wooded areas, rather than focusing solely on grasslands and that design options must necessarily stem from the core objectives and challenges at hand. The use we made of the two assessment methods offers another critical insight that is quite relevant for the work of planners. Rather than viewing these methods as mutually exclusive, we argue that they should be integrated into a broader, more comprehensive framework of analysis and decision-making. This integrated approach would allow for a more nuanced application of urban planning policies, ensuring that diverse needs and contexts are addressed in a coherent manner. By combining traditional techniques with new insights, planners can better guide the development of sustainable urban environments and thus be able to better address the challenges they are facing As a matter of fact, another key conclusion from this study is the importance of using both predictive and monitoring methods in different phases and stages of the plan/project-making process, as they underpin and support different needs and purposes. This calls for a flexible, multidisciplinary approach to urban planning, where different methods and tools are combined to create more holistic and adaptive planning processes, with ex ante and predictive analyses that support the design phase, whilst ex post assessment is essential for monitoring the real impacts of the new proposals. The introduction of these two methods serves as a valuable tool for urban planners seeking to navigate the increasing complexity of modern cities. This study offers practical guidance for planners who must balance technical, ecological, and social considerations. Through the combination of these methods, planners are better equipped to make informed decisions that promote sustainability, resilience, and liveability in urban areas.

6.4. Concluding Remarks

The redesign of brownfield sites and the contextual release of soil are the first steps in a series of possible choices to get nature back to densely urbanised areas and, as presented in the previous pages, for the reduction or mitigation of certain challenges produced by soil sealing (e.g., the urban heat island). However, in defining the objectives and choices for areas to be subjected to de-sealing and NbS application measures, it is important to consider some aspects that concern: (i) the exact location of these measures in order to promote the interaction with the environmental context (as in the case of external environmental corridors) or with built-up areas potentially affected by the benefits of such measures; (ii) the size of the areas to be de-impermeabilised and transformed into green spaces, which will have to be of such a size and continuity as to guarantee an adequate design and density (of green elements); and (iii) the characteristics, type, and intensity of green equipment (such as trees and shrubs) that will have to take place through their concentration and proximity in order to increase the benefits in terms of reducing land temperatures. With respect to the promotion of this type of combined action between the selective demolition of built spaces and consequent renaturalisation of areas, the cases presented highlight the possibility of promoting innovative actions consistent with the current debate even through the use of traditional and ordinary tools. This last consideration is not meant to be a criticism of the need to update or modify the framework of planning instruments; rather, it is a recommendation to extend the principles and innovative actions within all ordinary and extraordinary public instruments precisely to foster their implementation.

In consideration of our results, future research might consider applying the analysis models to other similar cases in order to verify their validity and to highlight the effects produced by soil desealing and consequent greening actions. It will also be interesting to further investigate how the analytical models and their application can support municipal-level planning activities through a specific case study with respect to decisions to be made for brownfield redevelopment and greening of areas. The combined use of these models could be considered to better guide the actions of policymakers and urban planners with respect to the priorities for intervention, such as those parts of the municipal area affected by higher levels of land temperature and imperviousness.

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