Urban Sustainability

Ali Cheshmehzangi · Maycon Sedrez ·
Hang Zhao · Tian Li · Tim Heath ·
Ayotunde Dawodu *Editors*

Resilience vs Pandemics

Innovations in Public Places and Buildings

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Urban Sustainability

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We collectively dedicate this book to our friends and family members who lost their lives or loved ones during the COVID-19 pandemic.

…only if thoughtful actions could have superseded thoughtless inactions!

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About This Book

We recall from our first volume that the COVID-19 pandemic and other highly transmissible disease outbreaks have given a new significance to the concept of '*resilience*', placing it in the spotlight of built environment-related studies. This also includes studies at micro scales of public places and buildings. New directions have emerged from expanding on adaptive planning, urban layouts, urban morphologies, spatial planning, healthy cities, etc. To enhance resilience in the post-pandemic era, various theories, practices and hypotheses are being formulated by scholars around the world.

The second volume of this series delves into the theme of resilience in the post-pandemic era, with a specific focus on ***public places and buildings***. In contrast to the first book, which explored the evolving concept of 'resilience' in the built environment, this volume narrows its scope to the research of the built environment at a smaller scale. This book aims to analyse and discuss the profound changes in architecture and urban design that have risen in response to pressing pandemic-related issues, such as social distancing, air renovation, social behaviour and other relevant topics.

Resilience vs Pandemics: Innovations in Public Places and Buildings explores innovative solutions for architecture and public places during and after the pandemic. Additionally, the authors contribute to the documentation of architectural and social transformations that have been prompted by previous transmissible diseases, as this knowledge can inform responses to future pandemics. In this volume, the chapters present critical, exploratory, multi- and interdisciplinary and cutting-edge research approaches; with a particular focus on the effects of COVID-19 and other highly transmissible diseases on the design, use, performance and perception of the built environment, particularly at the building scale. This volume aims to organize a collection of scientific studies, reviews, analysis, recommendations and solutions in the fields of urban design, architecture, design, landscape design, etc.

The overarching goal is to document new approaches to create and enhance built environment resilience. Chapters shed light on novel methods, tools, processes, regulations, behaviours and other relevant details contributing to a comprehensive understanding of this crucial issue. The two scales of the built environment under consideration are:

(1) Public Places, including research on transformations (death, emergencies, changes), requirements, adaptability, usability, virtual immersion, historical perspectives, interactivity, shifts in use and programmes, etc.
(2) Buildings, including regulations, shifts in use and programme, non-pharmaceutical interventions, human interactions and human–machine interfaces.

The book covers a wide range of studies, including physical and non-physical studies, which may refer to the city infrastructure, green/blue spaces, housing, policy-making, health services, social and economic issues, etc. The findings and results of various global case study examples contribute to the decision-making of governments, organizations and institutions, as well as inspire scholars and future research for developing resilience in the post-pandemic era.

Target audience of the book is from diverse multi- and interdisciplinary backgrounds, including—but not limited to—scholars, institutions, practitioners and stakeholders performing research and plans in the fields of urban studies, architecture, urbanism, social sciences, computer sciences, history, politics, etc. The target audience recognizes the relevance of resilience in the built environment to achieve more sustainable cities.

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Chapter 3
New Green Spaces for Urban Areas: A Resilient Opportunity for Urban Health

Lorenzo Diana, Francesco Sommese, Gigliola Ausiello, and Francesco Polverino

Abstract The Covid-19 pandemic underlined the positive role of public green spaces for the physical and mental health of citizens forced into long periods of immobility and social distancing. In cities with high population density, these restrictions have underlined the need to increase public green spaces and their accessibility. Indeed, green spaces have the role of improving urban health in terms of mitigating environmental impact, improving air quality, reducing the transmission of diseases, and promoting the psycho-physical well-being of citizens. After analysing the possible Nature-Based Solutions (NBSs) applicable at urban scale and their advantages in terms of urban health, this chapter aims to apply them to public spaces (such as streets and squares) and large public buildings located in the central areas of historic high-density cities. The use of NBSs in the transformation and regeneration of consolidated urban fabrics aims at enhancing their resilience, constituting new public spaces with social purpose, useful even in emergency periods of physical distancing. A new methodological approach is implemented and applied in the compact fabric of the historic city centre of Naples, through two phases: (i) as built analysis, (ii) intervention. Several buildings and public spaces are identified and the readiness to increase accessible and non-accessible green spaces is assessed, to obtain spaces for social use, as well as to mitigate the environmental impact. Pre- and post-intervention results show that non-accessible green spaces are easier to increase through the construction of green roofs, while accessible green spaces that can be used by citizens are more complex. Nevertheless, a significant increase in accessible green spaces is achieved. The application of NBSs in urban areas, is not only a technical strategy, but also a resilient solution, as it can transform some existing spaces into green ones with social value, and improve urban health.

Keywords Green spaces · Nature Based Solutions · Urban health · Urban resilience · Pandemic emergency

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1 Introduction

The concentration of a relevant rate of the world population in urban areas (up to 70% by 2050 according to World Health Organization) forces adaptation systems and regenerative strategies for healthy and liveable cities. The scarcity of green spaces, along with the urban heat island phenomenon and the general pollution of urban areas, contributes to drastically limiting the overall sense of urban health. Whilst international governments in the last few years have been committed to reducing polluting emissions through the development of protocols and directives, little interest has yet been paid to the issue of urban health, resulting even more evident during the COVID-19 pandemic. The pandemic strongly affected urban contexts both directly—showing higher rates of infection recorded in urban contexts (Barbarossa, 2020; Johns Hopkins University, n.d.)—and indirectly—strongly entailing social effects due to distancing and limitation in visiting accessible green spaces.

Current urban regeneration strategies, tending towards a holistic manner to improve urban decayed contexts according to different (social, environmental, and economic) aspects (Musco, 2009), pay specific attention to climate change adaptation strategies, especially given the growing number of extreme events affecting urban contexts in recent years. Among the various adaptation strategies, Nature-Based Solutions (NBSs) foster the integration of natural green spaces into land management, thus coupling the preservation of the urban environment and the socioeconomic development of cities, triggering urban health and urban resilience (Frantzeskaki, 2019; Sommese & Diana, 2022). The combination of environmental, resilience, and health goals is achieved through the creation of healthier and more liveable spaces by ensuring the creation of green spaces that can be walked on comfortably by the population even in highly urbanised contexts, and through greater soil permeability. It must be underlined how the environmental benefits resulting from the application of greening strategies have been extensively studied in the literature over the last decades, while little has been said about the health benefits for inhabitants. Due to the lack of extensive green public spaces, the application of NBSs is particularly interesting in regeneration interventions on central areas of historic cities. The simple reconversion of courtyards and cloisters of historic public buildings, for example, and their inclusion into urban itineraries would increase the outdoor walkable public space with positive consequences on the health of citizens.

1.1 The Role of Urban Green Spaces During Pandemic Emergency

Coronavirus impacted strongly on European cities and common people's lives, determining direct and indirect consequences for human wellness. Directly, a huge number of patients with contagious Covid-19 diseases blocked up hospitals, emergency departments, and intensive care units. Such congestion shows that health systems, especially in Italy, are not resilient and even standard disease surveillance and prevention has been reduced. This reduction is mainly due to the March–May lockdown of 2020. During this period, clinics were considered unnecessary healthcare structures providing activities that could be postponed and for such a reason they were temporarily closed (Osservatorio Nazionale Screening, 2020).

The experience of the Covid-19 pandemic impacted even indirectly, showing how important, especially in the period of mobility restrictions, the role of natural green spaces is for physical and mental health (Lopez, 2020). Social isolation made the population more vulnerable to the risk of anxiety, depression, and loneliness, especially the elders who were the most encouraged to maintain social distances. Nevertheless, despite these negative drivers, the pandemic experience has directed citizens towards mobility patterns and recreational spaces other than their usual ones (Korpilo et al., 2021). Green spaces have become refuge places for citizens forced into isolation and social distancing, with detrimental consequences for their well-being, especially when living in high populated urban areas with a shortage of public spaces (Samuelsson et al., 2020).

Due to their ability to reduce stress and provide physical and mental relaxation, green spaces, such as parks and gardens, and spaces for pedestrian mobility have been favoured, becoming an alternative to grey and enclosed spaces for motor and recreational activities (Fong et al., 2018). It's necessary to underline that the social distancing measures imposed by various world governments varied according to the severity of the pandemic emergency. In Italy, for example, restrictive measures allowed sports activities and outdoor walks only close to homes (Ugolini et al., 2020). Despite that, several recent studies, presented in the literature, have underlined the advantage of urban green spaces. The study proposed by (Venter et al., 2020) demonstrates the increase in pedestrian mobility in city parks and peri-urban forests of Oslo. (Ugolini et al., 2020) proposed an online survey in six European countries on changes in citizens' habits related to visiting green spaces, showing that green parks and urban gardens were the most visited places during the pandemic. (Lu et al., 2021) showed that the propensity to visit green spaces in Asian regions increased significantly during pandemic periods due to the physical and mental benefits, including maintaining physical activity, reducing the use of electronic devices, reducing stress, and avoiding household stressors. Therefore, green spaces are also able to promote social cohesion, as it is possible to maintain social contact while respecting imposed distancing measures.

1.2 Urban Resilience

Urban areas characterised by dense and compact fabrics are often not equipped with large green spaces, so different strategies are required to create resilient urban systems depending on the intervention scenario. (Meerow et al., 2016) define urban resilience as "*the ability of an urban system–and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or* *rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity*". Adaptation strategies deal with possible disruptive events (climate change, food shortage, energy stress), including potential epidemic scenarios whose likelihood has constantly increased over the past decades (Madhav et al., 2017). The urban resilience perspective allows (Meerow et al., 2016) to emphasise the role of proactive planning in the management of emergency events, the redevelopment of buildings and urban areas, the increase of green spaces (floors, roofs, facades) in existing urban fabrics.

Clear planning of urban resilience strategies through greening measures requires long-term actions involving multiple actors at different scales. Indeed, greening planning is effective from social, economic, and ecological perspectives (Grădinaru & Hersperger, 2018). The involvement of citizens is also evident from the multiplying of initiatives by private individuals such as "*adoption of public green*" (Sturiale & Scuderi, 2019). Linking with regional green systems is also crucial for the development of urban green spaces (Hersperger et al., 2019). Investment in urban green spaces should concern both proactive measures for urban resilience, public and social health, and ecological opportunities to balance the human-nature relationship as a protection against future pandemics (Geary et al., 2021).

1.3 Aims and Scope

While cities are the main places where a greater number of infections occurred due to larger social relations and activities, they are also the most favourable places where it is possible to outline and test solutions to increase green spaces aimed at encouraging outdoor social activities. Thus, the increasing use of green spaces makes it possible to interpret the pandemic as an opportunity for city government to find sustainable solutions to improve the living conditions of citizens and the built environment (Ding et al., 2022). The green hanging gardens with public access (e.g. project of the Roof Garden of the Polyclinic of Milan (Boeri Architetti, 2019) with sensorial and chromo-therapeutic paths) can be considered a best practice in the perspective of a broader urban regeneration project. Such improvements in living conditions and quality of neighbourhoods, especially if undertaken in the poorest and most socially deprived contexts, could trigger gentrification processes, by excluding segments of the population from buying or renting houses (Anguelovski et al., 2018; Wolch et al., 2014). The inclusion of green spaces in densely built contexts is mainly aimed at outdoor interventions, which require adequate funding from the government and, at the same time, are often met with the opposition from private owners (Bengston et al., 2004).

Nevertheless, despite the relevant interest in the literature, it must be stressed how research on urban health has been developed especially after Covid-19 pandemic. Therefore, the impacts obtained by the application of technical strategies have been analysed in the last decades exclusively from an environmental point of view while they may have interesting consequences even from the urban health point of view. A comprehensive approach for the estimation of greening impacts in urban contexts is still lacking, thus giving space to the development of tools able to determine the impacts of green solutions in the increase of urban health. This chapter aims to: outline methods for new urban green space definition in areas with high urban density and very compact fabric; increase urban resilience and health by applying new green solutions (NBSs) in built areas with large urban blocks. The advantages in terms of increased urban health and resilience are estimated indirectly in terms of increase of public green spaces. Looking at existing extensive public buildings thus seems an effective strategy to make greening interventions feasible. Their size, typological features, and spread across the urban territory, even in particularly dense contexts, characterises them as ideal objects for the application of green strategies. Determining a rating of buildings based on their adaptability to undergo transformation interventions may results of help (Diana et al., 2022).

2 Nature-Based Solutions (NBSs)

Epidemiological emergencies, together with climatic ones, increasing urbanisation and ecosystem degradation, pose a challenge to the resilience of urban areas, the quality of life, and the well-being of citizens. By promoting socio-economic development and preserving ecosystems, NBSs provide a way to address these challenges. The application of these technical strategies to increase urban green spaces, can be beneficial, not only from an environmental perspective, but also in terms of quality of life of urban spaces, which has a direct and indirect impact on the citizens' health. Indeed, with the expansion of green and blue areas, the heat island effect decreases and consequently the health of urban spaces is improved through biodiversity (Bayulken et al., 2021). The concept of NBSs is still quite young. It was first introduced by the European Commission in 2015 as "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions*" (Ascenso et al., 2021). Later, the International Union for Conservation of Nature (IUCN) defines NBSs as "*actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*" (IUCN). The various definitions highlight how the NBSs aim to address social, environmental, and economic problems in a sustainable way, and integrate solutions inspired, supported, or copied from nature (European Commission, 2016; Faivre et al., 2017; Pauleit et al., 2017).

According to these definitions, most of the scientific literature underlines exclusively the ability of NBSs to mitigate and adapt to the phenomena associated with climate change. Really, the implementation of NBS in urban contexts implies benefits not only for urban health but also for the health of citizens, especially in times of health emergency as demonstrated by the Covid-19 pandemic. The application of NBSs is thus not only an important technical intervention, but also an instrument for improving the usability of urban spaces by users and for improving urban health.

Combining environmental and social benefits, NBSs offer several advantages: the insertion or increase of urban trees, parks, gardens, green roofs, and green facades, favours the interception of particulate matter, absorbs pollutants, lowers temperatures, and acts as a buffer against flooding (European Environment Agency, 2022). At the same time, they provide opportunities for recreation and social cohesion, creating spaces for socialization and well-being of citizens. In addition, NBSs support biodiversity and species conservation.

The European Commission's report (European Commission, 2015) on NBSs provides examples of how nature can be brought back to cities and degraded ecosystems to improve urban health, and citizens' well-being, thereby promoting climate change adaptation (Faivre et al., 2017). The main NBS solutions at urban scale and their associated beneficial functions, as reported by EC reports, are summarized in Table 1 and shown graphically in Fig. 1.

3 Methodology

The improvement of the quality of existing urban contexts in terms of urban resilience and health is here reached by a clear methodology. Such improvement is calculated as the increased area of public green spaces through the application of NBSs to public buildings. Both new accessible public gardens and meadows, and non-accessible areas with green roofs and facades are computed. Especially in dense urban contests, implementing greening measures on large public urban blocks, both on inner uncovered spaces and building components, seems the privileged procedure for the procurement of additional public green space. Several steps have been identified and collected into two major phases: the first phase collects the analysis of the as built state of the analysed case study; the second phase is referred to the definition of interventions and the analysis of the related impacts.

3.1 As Built Analysis Phase

The steps collected in this phase are: identification of existing green spaces; identification of extensive public urban buildings; calculation of covered and uncovered surfaces; evaluation of historical-architectural value of the buildings analysed and the related transformability; analysis of the accessibility of green spaces.

Table 1 Benefits of NBS applications in urban areas

Possible Nature Based Solutions			
Regulation	ID	Urban settings	Functions
Air quality regulation	A1 A2	Protect urban green spaces Plant trees along streets	Absorb gaseous pollutants and trap particulate matter
Climate regulation	A1	Protect urban green spaces	Store carbon
Water flow regulation	A3	Green roofs and green walls	Facilitate the interception of rainfall
Water purification and waste treatment	A4	Ponds and wetlands	Collect, store and clean water before storing it in streams
Disease regulation	A1 A5	Protect urban green spaces Use permeable surfaces and vegetation	Improve the quality of the air and the environment Promote biodiversity
	A6	Provide bird feeders and promote the establishment of species	Reduce sources of stagnant water Regulation of vector insects
Pollination	A6	Encourage planting of plants from suitable resources and food plants for caterpillars	Promote nesting opportunities
Disaster Risk Reduction	A7 A3 A2 A5	Sustainable Urban Drainage Systems Green roofs and green walls Trees in urban areas Permeable surfaces	Promote the recharge of the aquifer
Soundscape management	A2	Trees and bushes between streets and houses	Hide adverse sounds in public places Provide shelter for songbirds
Health	A7 A7 A6	Attractive green spaces for access Connect the different services (schools, work, housing) through green spaces Increase biodiversity	Improve the quality of life Improve human and urban health

A.1 Identification of existing green spaces

The identification of existing green spaces is the required starting point of all greening interventions at urban scale. Once that the boundary of the intervention area has been defined, existing green spaces such as parks, gardens, lawn areas, trees on draining pavement, parking lots with draining surfaces are calculated. Considering the goals

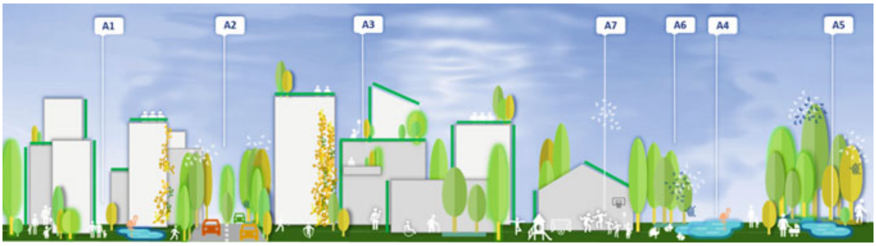

Fig. 1 Nature based solutions in urban areas (*Source* © 2023, Francesco Sommese)

of the present article, only public properties are considered both in terms of green outdoor public spaces and green spaces inside public buildings.

A.2 Identification of extensive public urban buildings

In this step, all the potential areas where greening interventions can be realized are computed. Specifically, lot sizes of public buildings such as healthcare structures and hospitals, schools and universities, administrative offices, and public social housing buildings are considered.

A.3 Calculation of covered and uncovered surfaces

For the lots of buildings computed in step A.2, covered and uncovered surfaces are calculated.

A.4 Evaluation of historical-architectural value

Buildings that have been identified in step A.3 and that are involved in the greening strategies of the considered urban context, may have significant historical, architectural, and cultural limitation to their transformability. Therefore, the considered buildings, throughout a parametric reading of facades, roofs, and courts, are classified based on their readiness to undergo transformation intervention. Indicators considered are related to the ratio between surfaces without any kind of constraint—artistic/architectural or structural—and the whole facade/roof/court surface. A ranking of most transformable buildings is provided.

A.5 Analysis of the accessibility of green spaces

Existing green spaces are not always accessible for external visitors therefore not determining a direct improvement in urban health. The application of NBSs aimed at increasing public green spaces may be triggered especially in those buildings where accessibility is already guaranteed. In this step, only accessible green spaces are considered and calculated based on their current use.

3.2 Intervention Phase

The steps collected in this phase are: definition of new green solutions; calculation of the building reduction impact factor; calculation of new public spaces; calculation of new green spaces; calculation of new accessibility.

B.1 Definition of new green solutions

Once accomplished all the procedures described in Sect. 3.1, it is possible to plan possible greening interventions. By the analysis of results obtained in steps A.1, A.2, and A.3, and after the considerations of steps A.4 and A.5, the surfaces to consider for the application of new green solutions are exactly defined. The new green solutions considered are the NBSs introduced in Sect. 2. The regeneration of large urban buildings, by means of NBSs, determine the transformation of materials of courts, facades, and roofs and allow the access to inner open spaces, often hidden, and difficult to reach to citizens who would appreciate their existing artistic-architectural and environmental qualities while experiencing green and healthy itineraries. In this way the role of open and green spaces in highly urbanised contexts is highlighted.

B.2 Calculation of the building reduction impact factor

The Building Reducing Impact Factor (BRIF)—introduced as RIE in (Comune di Bolzano)—is an environmental quality assessment index, applied to a specific area or building, aimed at certifying the quality of the intervention with respect to the permeability of soil and greenery (Ausiello & Santoro, 2019). This tool is not related to specific climatic conditions and, therefore, it is applicable to any area. The factor is based on the calculation (1). It distinguishes two types of surfaces: green (S_{Vi}) and not green surfaces (S_{ij}). To each of them a specific runoff coefficient (ψ) is assigned based on the permeability of the considered surface. The calculation also considers the equivalent tree surfaces (S_e), defined according to tree height and foliage dimension.

$$BRIF = \frac{\sum_{i=1}^{n} S_{Vi}\frac{1}{\psi} + (S_e)}{\sum_{i=1}^{n} S_{Vi} + \sum_{j=1}^{m} S_{ij}\psi} \quad (1)$$

The index can vary between 0, in the case of completely sealed surfaces with consequent problems to water runoff and surface temperature, and 10, for surfaces without impermeable zones with high performance in terms of water regulation and urban microclimate. The increase of BRIF is calculated for each lot involved in the framework of interventions defined in step B.1.

B.3 Calculation of new public spaces

The intervention planned in step B.1 has a direct impact in enriching the equipment of public spaces in the considered intervention area. The expansion of public spaces to interior open portions of some public buildings is strictly related to accessibility issues (step A.5). Augmenting the accessibility of inner spaces of buildings should be related to the use of the building itself.

B.4 Calculation of new green spaces

The total green spaces in the considered intervention area are calculated after the definition of interventions. The green spaces here computed are those identified in step A.1 with the addition of those defined in step B.1 such as new green roofs, facades, pavements, and gardens.

B.5 Calculation of new accessibility

The new green spaces introduced in step B.1 imply an augmented accessibility to new public spaces in the inner areas of considered buildings. Nevertheless, some new green spaces are not always accessible to public visitors such as unreachable green roofs or facades. In this final step, only accessible green spaces are calculated. Figure 2 show a graphic workflow of the whole methodology.

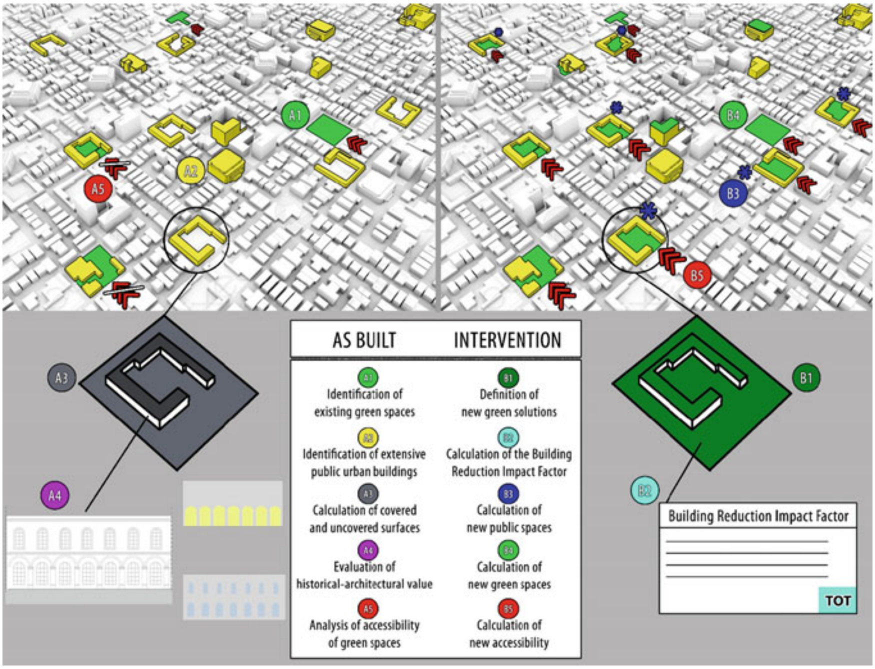

Fig. 2 Graphic workflow of the methodology (*Source*: © 2023, Lorenzo Diana)

4 Case Study

The central areas of the city of Naples evidence a lack of large pedestrian public spaces treated with greenery. However, several historic public buildings show large inner open spaces, courtyards, and cloisters around which buildings are organised. These spaces are often unreachable, either because they are partially or totally abandoned, or because the access is forbidden. The area bounded by corso Umberto, via Duomo, via Foria, via D. Cirillo / via Carbonara / via A. Poerio, Piazza Garibaldi in the Forcella district has been selected as testing area for the development of NBSs (see Fig. 3). The aim is to transform existing courtyards, roofs, and facades, to reopen inner spaces of public buildings to wider itineraries, and to increase the amount of public pedestrian green spaces in a strategic central area with consequences in urban resilience, urban health, and permeability of soils.

The considered area measures approximately 400,000 m^2 and shows a significant lack in the presence of green spaces, becoming an ideal case study for the

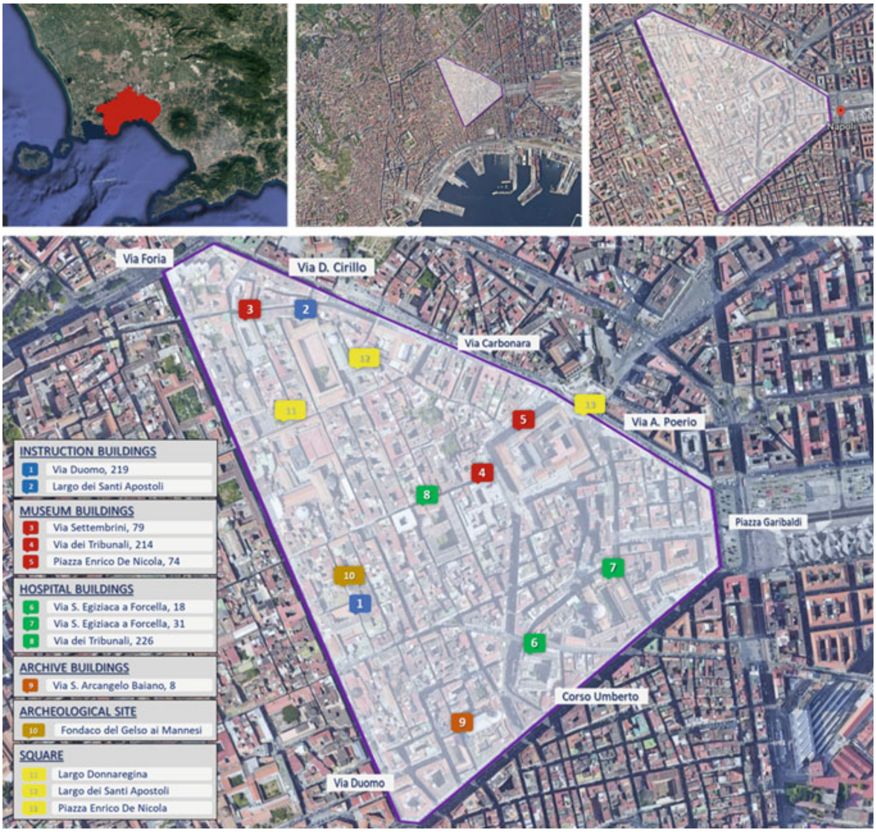

Fig. 3 Case study location (*Source* © 2023, Francesco Sommese; base maps: Google Maps)

application of the methodology proposed in Sect. 3. Within the boundaries of the considered case study, public green gardens and meadows in practice do not exist. Only some flowerbeds with trees can be found in Largo Donnaregina (#11) covering approximately 530 m^2. Considering also inner courtyards of public properties such as schools, museums, hospitals, archives, and archaeological areas, the amount of green spaces rises to only 0.67%—for a total surface of 2,706 m^2 (step A.1). These figures prove the need for intervention on the existing public estate in order to acquire new green spaces. The total surface of public lots (see Fig. 4) is 49,539 m^2 equal to 12% of the total case study surface (step A.2). These public buildings are organized around large, uncovered courts and cloisters which on average represent the 25% of the lot size (step A.3). Lists and quantities of public buildings have been retrieved on the open access database of the Ministry of Economy and Finance, archive drawings, and land register data. The analysed public estate appears to be particularly dated. Some buildings have historical and architectural significance and are even listed by the Ministry of Cultural Heritage thus further analyses are needed to determine the related adaptability to transformation. The SS. Annunziata Monumental Hospital (#7) has been selected as a pilot case study for the parametric deepening of the transformability of courts, roofs, and facades. The hospital is a compact four-story structure organized around two courtyards. It was erected in the fourteenth century and continuous additions occurred until the end of the nineteenth century (Sicignano et al., 2022). Nowadays it is partially abandoned. The building is particularly limited to vertical facade transformations for the presence of valuable and ornamental components that limit the free facade to only 6.80% (Diana et al., 2022) while a higher freedom of intervention can been appreciated concerning the roofs (77.55%) and the courts (68.92%). In fact, if the monumental court should be preserved in its architectural value by limiting major interventions, the second court that nowadays is used essentially as a parking for workers, can undergo deep transformations (step A.4). The analysis of the "*as built*" phase ends with the "*Analysis of accessibility of green spaces*" (step A.5). The accessible green spaces are limited to a surface of 1,114 m^2, equal to 0.28% of total case study surface, and represent around the 40% of the total green spaces since the access to back gardens (#3), school courts (#2), archaeological sites (#10), and some hospital courts (#6) is limited or forbidden.

The intervention phase starts with the definition, on the considered buildings and based on the transformability results of step A.4, of the optimal NBSs. For the pilot case study (#7), considering the artistic value of the monumental courtyard, where already several trees can be found, the focus is on the application of interventions on the secondary courtyard and the building's roofs. The application of the following NBSs was considered: on the secondary courtyard, the existing paving (asphalt) was replaced with drainage paving and second-order trees have been planted; on the top of the building, that is almost exclusively flat, green roofs have been installed in portions free from planting facilities. The application led to an increase in the BRIF from 0.06 to 3.58, resulting in a 35% improvement and guaranteeing the creation of high environmental quality green pedestrian accessible spaces (surface of 1,238 m^2).

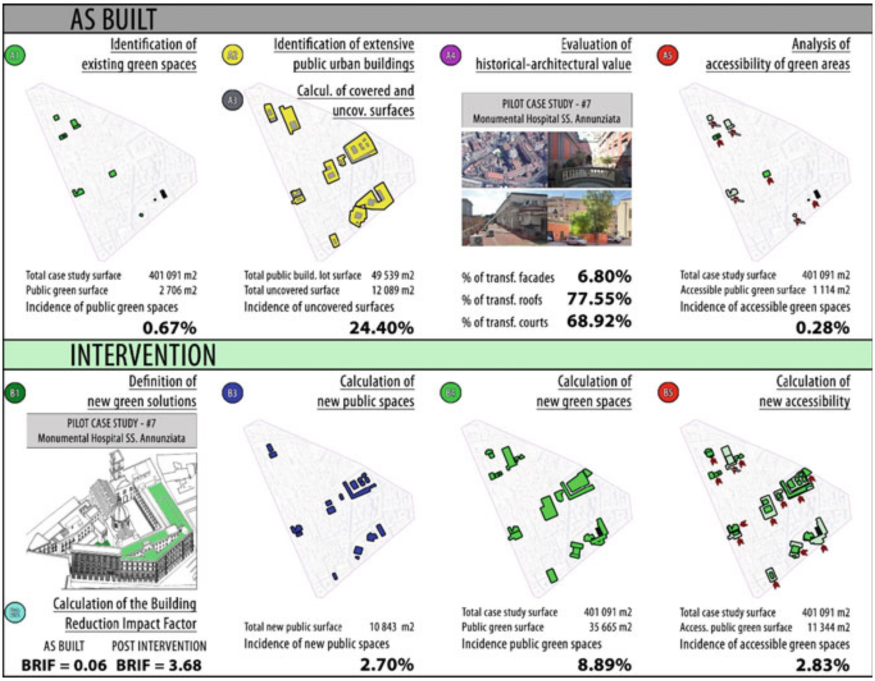

Fig. 4 Application of the methodology to the case study of the centre of Naples (*Source* © 2023, Lorenzo Diana)

This procedure is applied to the nine public buildings considered and on the archaeological site bringing to an augmentation in public space of 10,843 m^2 (step B.3), equal to 2.70% of the total study surface. Such value differs from the uncovered surface of step A.3 since the internal courtyard of the school (#2) cannot be considered as possible public space in case of a wider regeneration intervention. The definition of NBSs leads to a total amount of public green spaces (step B.4) of 35,665 m^2, passing from an incidence of 0.67% to 8.89% on the total case study surface. A large quantity of such new public green spaces are green roofs and therefore most of the time not accessible to common visitors. The accessible green spaces are limited to new courts of considered buildings and small gardens and meadows in public squares (#11, #12, and #13). New accessible green areas amount to totally 11,344 m^2 (step B.5), equal to 2.83% of the total case study surface and strongly higher than the as built figure.

5 Conclusions

The urgent need to provide more accessible public green spaces for psycho-physical well-being of citizens has been greatly demonstrated by the health emergency of the Covid-19 pandemic. The aim of this study is to make urban areas more resilient and improve urban health by implementing the methodological approach described and studied. Large cities, with a high population density, although lacking in public spaces, are configured as privileged places to test the application of NBSs with the aim of directly improving environmental impact—as a result of the purely technical application of these solutions—and indirectly restoring urban health, fostering biodiversity, limiting the transmission of infectious diseases, and creating much healthier living environments. The application of NBSs in highly urbanised contexts can also be considered a good practice for a broader process of urban transformation and regeneration, in line with the European instruments for achieving climate neutrality by 2050.

In hard urban contexts, where it is particularly difficult to find transformable areas for greening intervention in public space, it is necessary to look at large buildings in central areas—such as monumental hospitals, offices, schools, universities, etc.—that go beyond the building scale and take the form of urban blocks. In this way, public buildings prove to be a favourable planning scenario due to their widespread distribution in the urban territory, their large dimensions, and their typological characteristics, as they lend themselves to green transformation interventions and guarantee the provision of a significant number of green spaces thanks to the easy transformation of materials and functions of courtyards and roofs. This becomes trivial in dense historical central areas, as demonstrated in the case study of Naples, where it is possible to go from 2,706 m^2 of green space to more than 13 times that amount (35,665 m^2) by intervening on only nine public buildings, one archaeological site, and three public squares. The results (Sect. 4) show that non-accessible green spaces (24,321 m^2 equal to 68%) are easier to be realized through the construction of green roofs—it must be stressed that considered buildings present mainly flat roofs—while accessible green spaces for citizens are more complex (11,344 m^2 equal to 32%)—it must be underlined that for architectural and historical reasons not all buildings' courtyards can be transformed. Interventions on vertical walls appear even more difficult, as the vertical envelopes of historic buildings in central areas are subject to strict artistic and architectural constraints. In the pilot case study (#7), only 6.80% of the vertical envelope can be transformed, while 77.50% of the roofs and 68.92% of the courtyards can be transformed.

The methodology proposed in this chapter can be a useful tool for researchers to advance studies on improving quality of life and urban health in highly urbanised contexts.

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