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PLANNING AS A TRANSFORMATIVE ACTION IN AN AGE OF PLANETARY CRISIS

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Urban Green Areas as a Tool for City Care: Insights from Medium-Sized Italian Cities

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Abstract
This paper introduces a research methodology to investigate the impact of urban green areas on human health, focusing on medium-sized Italian cities. Recognizing the critical link between urban environments and health outcomes, particularly concerning non-communicable diseases exacerbated by urbanization, the study employs concepts of spatial justice, place-based health, and environmental vulnerability. The methodology involves calculating the Normalised Difference Vegetation Index from satellite imagery, determining Pro Capita Green Space, and estimating Real Accessibility to urban parks within a 15-minute walk. Applied to six diverse Italian cities, the analysis reveals varying distributions and accessibility of green spaces, highlighting the influence of historical urban layouts, population density, and natural features on environmental equity. The findings underscore the importance of strategically integrated urban green infrastructure for promoting public health.

Keywords: Green Areas; Public Health; Accessibility; Medium-sized City; Climate Change

Introduction
This paper aims to propose the research methodology developed in the first phase of *Urban green infrastructure, policies on green spaces and health outcomes*, a European Union-Next Generation EU funded research project, which aims to investigate the impact that green areas in urban contexts can potentially have on physical and mental human health.

The relationship between human health and green areas is a dialectical pairing that has always characterized the theoretical and operational interest of urban planning since the formation of the modern discipline. The relentless urbanization processes of recent decades have further prompted the scientific community to explore the relationship between urban areas and citizens' health. On the one hand, urbanization has been shown to facilitate access to health services and offer greater social and employment opportunities. On the other hand, urban environments tend to be less conducive to health, increasing the incidence of chronic diseases, particularly cardiovascular, respiratory, and mental disorders.

Urban environments play a significant role in influencing the risk factors for noncommunicable diseases (NCDs), which include cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes. These conditions are largely driven by behavioral and environmental factors that are often intensified in cities. Air pollution—both indoor and outdoor—is a major environmental risk in urban areas, contributing to millions of NCD-related deaths each year.

In addition, urban settings often promote unhealthy lifestyles, such as poor diets, physical inactivity, tobacco use, and harmful alcohol consumption. These behaviors increase metabolic risk factors like high blood pressure, obesity, elevated blood glucose, and abnormal blood lipids, all of which are linked to a higher incidence of NCDs.

Socioeconomic disparities in cities further exacerbate the problem, as low-income and marginalized populations may have less access to healthcare, healthy food, green spaces, and opportunities for physical activity. To combat the NCD burden in urban areas, it is essential to implement cross-sectoral policies that promote healthy environments, improve access to preventive care, and reduce exposure to risk factors (WHO, 2024).

The idea that space influences well-being is therefore not new, but it has been rediscovered through interdisciplinary research over the past two decades. From a geographical perspective, concepts such as *spatial justice, place-based health, and environmental vulnerability* have made it possible to go beyond an exclusively clinical approach, instead considering health as a shared goal across multiple disciplinary fields (Cummins et al., 2007). A much-discussed and debated concept in the literature, *spatial justice* in this context refers to the equitable distribution of resources and opportunities across different territories. Spatial justice does not merely involve considering social justice *in* space, but rather recognizing the active role that space plays in producing both justice and injustice:

"everything that is social (justice included) is simultaneously and inherently spatial, just as everything spatial, at least with regard to the human world, is simultaneously and inherently socialized" (Soja, 2010, p. 5).

In the specific case of the relationship between territory and health, spatial justice implies that access to healthcare services, green spaces, and infrastructure that promote a better quality of life should not depend on a person's geographic location, as this creates direct injustices and indirect implications for their health. One example is the differing opportunities between rural and urban areas: while both face similar challenges, they respond differently to significant issues such as healthcare access, promoting active mobility policies, and fostering social cohesion. This concept has been explored in recent studies highlighting the role spatial inequalities play in shaping the health of rural populations (Martino et al., 2024).

The concept of *place-based health* supports the connection between people's health and the specific characteristics of the places where they live, work, and interact. This includes factors such as air quality, access to healthy food, neighborhood safety, and the availability of spaces for physical activity. Inequalities in these environmental factors can lead to significant health disparities across different communities. For example, low-income populations often live in areas with less access to health-promoting resources, contributing to poorer health outcomes (Diez Roux, 2016; Boyd et al., 2023).

Another key concept guiding this research is *environmental vulnerability*. This refers to the capacity of territories to suffer harm due to exposure to various types of stress, including environmental and social changes, and conversely, to their lack of capacity to adapt to such changes. This vulnerability is often the result of political decisions and urban planning that fail to consider the needs of territories and their populations, especially the most vulnerable ones. Geographic studies have shown how such decisions contribute to significant disparities in health across different geographic areas (Anderson et al., 2025).

The organization of urban space, the distribution of services, the quality of infrastructure, and the presence of green areas are not neutral elements, but rather determinants of physical and mental health—particularly for older adults (Xu et al., 2023). Cities do not merely host the elderly; they shape their life experiences, either amplifying or mitigating risks. To promote a better quality of life during aging, it is essential to integrate health and psychological dimensions with spatial and environmental ones.

This idea is supported not only by territorial studies but also by the evolving definition of health itself. Since its founding in 1948, the WHO has defined health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." This individual-centered definition has given way to the concept of health as *Global Health*, placing strong emphasis on inequalities. The AIDS epidemic in the 1980s highlighted how human health is closely linked to environmental, social, and cultural factors. Since the 2000s, the concept of *One Health* has entered the public health discourse, connecting human health with that of animals and the planet. In recent years, particularly due to the effects of the Anthropocene, a paradigm shift has become necessary to counter a socio-economic system that neglects human, environmental, and planetary well-being—while generating socioeconomic and health inequalities—through the *Planetary Health* approach.

It is also useful to clarify the notion of *health determinants*, particularly within public health: these are elements that, directly or indirectly, significantly impact quality of life and include everything that can contribute to improving or worsening individual health conditions. A highly illustrative and well-known framework (figure 1) was published in 1991 by Dahlgren and Whitehead, which describes the role of social determinants of health, highlighting their cascading influence from general socioeconomic, cultural, and environmental conditions down to the individual, through various layers that also include the urban environment (Capolongo and D'Alessandro, 2017).

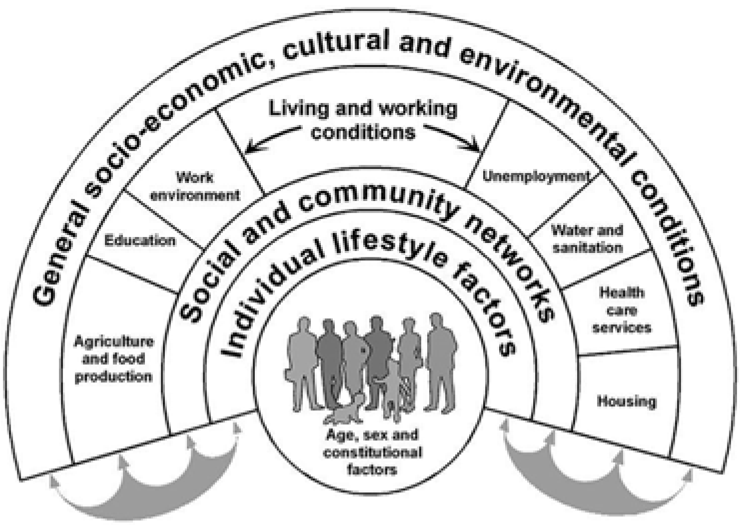

Figure 1: the role of social determinants of health. Dahlgren and Whitehead, 1991 (as cited in Dahlgren and Whitehead, 2021)

The work is based on the premise that urban green spaces must be easily accessible to all population groups and equitably distributed throughout the city. The links between urban greenery and health have been demonstrated by numerous scientific publications and reports (Kondo et al., 2018; WHO Regional Office for Europe, 2016). This contribution aims to present an analysis of the distribution and accessibility of urban green spaces in six medium-sized Italian cities, which serve as case studies for the research. This mapping enables reflections on the spatial configuration of urban greenery and its ease of access. It is considered that this aspect should be seen as a priority when addressing the issue of nature in urban contexts and its impact on human health. In particular, these areas are an essential component of outdoor public spaces and services, providing an ideal setting for the equitable and just promotion of health for all members of the community.

Methodology

The methodological approach is divided into three phases. Firstly, the Normalised Difference Vegetation Index is calculated. This index is based on the analysis of satellite images and provides an overview of the greenery within the municipality. In the next stage of the process, the Pro Capita Green Space is calculated, which highlights the surface of green space per inhabitant. Finally, the estimation of real accessibility is provided, indicating the walking distance to urban green areas.

The Normalised Difference Vegetation Index (NDVI) is an index that facilitates the identification of vegetated areas through the utilisation of multispectral remote sensing images. In this analysis, the images are derived from ESA's Sentinel-2 satellites. Sentinel-2 satellites boast a temporal resolution of five days and are equipped with the MSI (MultiSpectral Instrument). This instrument is capable of acquiring four bands in the visible and near-infrared with a spatial resolution of 10 metres, six bands in the infrared with a spatial resolution of 20 metres, and three bands with a resolution of 60 metres. Two bands (band 4 and band 8) with 10 metres of geometric resolution are utilised in the calculation of the NDVI. The index is derived from the ratio between the difference and the sum of the radiation reflected in the near infrared and red, as outlined in the following formula:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

The index has a range of values from -1 to 1: negative values are typically indicative of anthropogenic areas or water, while positive values are indicative of areas with vegetation. The raw images, collected during the period spanning from January to December 2023, have undergone a process of correction to compensate for the presence of clouds or snow. Subsequent to this preliminary processing, the formula for calculating the NDVI is applied to each pixel of each raster image. The final processing of the data is a composite image with aggregated average values.

The NDVI index can be utilised as a foundational metric in the calculation of another indicator, which is instrumental in ascertaining citizens' exposure to green space and acquiring data pertaining to the spatial organisation of the case studies. The index in question is the Pro Capita Green Space (PCGS) index (Aryal et al., 2022), which quantifies the amount of green space (in m2) available per inhabitant. The designated case study areas were subdivided into a hexagonal grid measuring 60 metres. The formula is as follows:

$$PCGSi = \frac{Gi}{PNi}$$

- is the total area of green spaces (m2) in in zone
- is The total population of zone

The number of inhabitants was estimated based on data from the 2021 ISTAT Permanent Population Census. For each hexagon, the resident population was calculated using geoprocessing and proportions.

The initial two index encompass all green areas within municipal boundaries, incorporating agricultural areas, parks, and woodlands, among others. In order to investigate the relationship between population and green areas from the point of view of accessibility, only urban parks were selected in this last phase of the methodology. The methodology for deriving Real Accessibility (RA) catchment areas involves the integration of morphological data with road networks, barriers and population data, and the association of different travel costs depending on the characteristics of the area (Romo et al., 2022). The scenario modelling is based on a maximum distance from green areas of 15 minutes walking (Moreno et al., 2021). Speeds were diversified according to the characteristics of the terrain, starting from a speed considered average, which is strongly influenced by factors such as age, physical condition, etc. (Giuliani et al., 2021). The speeds set are as follows:

- 5 km/h on roads/pavements without obstacles;
- 4 km/h on rural paths and built-up areas where there may be obstacles;
- 2 km/h in rural areas outside and away from roads.

The methodology calculates the distance of 15 minutes, at the speeds indicated above, from the centroid of the green area. The decision to utilise the centroid was necessitated by the lack of data concerning actual access to the selected urban parks (Giuliani et al., 2021). The following data were utilised in the calculation:

- The centroid of urban parks.
- The 10x10 m Digital Terrain Model (DTM) produced as part of the INGV's TINITALY project (Tarquini et al., 2023).
- The build-up areas obtained from the Lazio Region Land Use Map (2012) and the Tuscany Land Use and Land Cover Map (2019).
- The road network, extracted from the OpenStreetMap (OSM) database.
- The elements that act as barriers to pedestrian movement: motorways, railway lines, lakes and the hydrographic network.
- The census sections of the ISTAT Permanent Population Census of 2021.

The processing was conducted utilising the open-source software GRASS GIS, with particular reference to the r.cost module (Sacchelli et al., 2013; Becker et al., 2017; Cadez et al., 2023). The module facilitates the calculation of cumulative travel costs on the pixel matrix, with the calculation initiated from the centroids and a threshold time of 15 minutes. The matrix calculation is based on an anisotropic friction map that combines morphological data and barriers. The barriers element indicates the designated pedestrian thoroughfares, while the first element modifies walking speed according to gradients (Tobler, 1993). Consequently, the maximum velocity is attainable on level terrain and declines exponentially as the gradient rises, with a threshold limit of 30°. Beyond this limit, crossing is prohibited. The result of the r.cost module is a map with accumulation times commencing from the centroids of the nearest urban parks, as well as a map of the accessibility basins identified for each urban park. The accessibility basins model can be utilised to identify the population residing within a 15-minute radius of green areas.

Case studies

The municipalities of Arezzo, Siena, Grosseto, Latina, Viterbo, and Rieti, located across Tuscany and Lazio, were selected for this research due to their classification as medium-sized cities. Italy is predominantly composed of such cities, which often exhibit complex territorial dynamics while having limited tools to address them. These six cities offer a diverse mosaic of demographic, environmental, and cultural characteristics, with significant differences shaped by geography, history, and economic orientation.

Arezzo, with approximately 99,000 inhabitants, lies in eastern Tuscany, nestled among green hills and along the Arno River. Its historic center is rich in medieval and Renaissance heritage, and the municipal territory features a balance between woodland, agricultural, and urbanized areas. Tourism maintains a steady presence throughout the year, driven by historic events such as the *Giostra del Saracino*.

Siena has around 53,700 residents in its urban core, with a greater metropolitan area exceeding 98,000 inhabitants. It is renowned worldwide for its perfectly preserved medieval historic center, recognized as a UNESCO World Heritage Site. The territory, hilly and relatively small (118 km²), also includes valuable rural and wine-producing areas. Tourism, strongly tied to the *Palio di Siena* and its university tradition, is a key component of the local economy.

Grosseto, home to about 82,000 people, is located on the Tyrrhenian Sea and lies within the Tuscan Maremma region. Its historic center, enclosed by 16th-century hexagonal walls, is entirely pedestrianized. The territory is characterized by a significant presence of protected areas, including the Maremma Natural Park, which features beaches, Mediterranean scrubland, wetlands, and wildlife habitats. Tourism is closely linked to these natural features.

Latina, with approximately 116,000 residents, is a relatively young city, founded in 1932 during the reclamation of the Pontine Marshes. The municipality spans a vast flat and agricultural area, which also includes part of the Circeo National Park, featuring valuable environments such as Lake Fogliano and coastal dunes. Tourism is growing and focuses on beach destinations (like Capoportiere and Foce Verde), as well as nature-based and food and wine experiences.

Viterbo, with a population of around 67,000, is located in the historical region of Tuscia. Its historic center is one of the largest and best-preserved in Lazio, rich in medieval palaces and Etruscan remains. The surrounding hilly and forested territory includes thermal areas and nature reserves. Tourism is strongly influenced by the *Macchina di Santa Rosa*, a spectacular religious tradition, as well as the thermal baths and wellness-related routes.

Rieti, finally, with about 47,700 inhabitants, is set in the Rieti Plain at the foot of Mount Terminillo. The municipal territory offers a remarkable environmental variety, including mountains, hills, lakes, and nature reserves such as those of the Lungo and Ripasottile Lakes. The *Cammino di Francesco* (Path of Saint Francis), which passes through the so-called Holy Valley, is also of great importance. Tourism is focused on wellness, spirituality, and outdoor activities, particularly hiking and winter sports.

Data analysis and discussion

The NDVI map of Arezzo (figure 2) reveals a landscape predominantly characterised by a high presence of green, particularly in the areas surrounding the primary urban centre. The presence of dark green shades, which are indicative of very healthy and dense vegetation, is pervasive in the areas outside the central built-up area. The green infrastructure is characterised by large continuous blocks of high NDVI surrounding the city, including forests and large agricultural fields. Within the primary urbanised area, the presence of greenery is considerably lower, a reflection of the density of buildings and impervious surfaces. However, there are some linear green areas that penetrate the urban fabric. The primary urbanised area exhibits a distinct and irregular pattern characterised by low NDVI values, suggesting a high concentration of human activity.

The NDVI map for Grosseto (figure 2) reveals a landscape predominantly characterised by moderate to high green in its surroundings, which is indicative of substantial agricultural activity. The chromatic variations in green that characterise the peripheral regions of urban areas tend to exhibit a paler intensity when compared to the verdant shades typically associated with dense forest ecosystems. This phenomenon is particularly evident in the expansive cultivated fields that are commonly present in these peripheral regions. The green infrastructure in the surrounding areas is characterised by a high degree of structuring, exhibiting clear rectangular patterns that are indicative of substantial agricultural plots. Within the confines of the primary urbanised area, the NDVI values are low, creating a pronounced contrast with the rural environment. The transition from urbanised areas to agricultural land is clear. The primary urban centre exhibits minimal green values.

The NDVI map for Latina (figure 2) reveals a landscape predominantly characterised by moderate and widespread greenery in non-urbanised areas, primarily attributable to substantial agricultural activity. The chromatic variations in green exhibited a high degree of uniformity across the expansive rural regions. The green infrastructure in the surrounding areas is characterised by a distinct grid pattern, indicative of highly organised agricultural fields. The urbanised area itself is more extensive and less densely populated than other cities, with a presence of lighter green areas within the urban boundaries. This suggests a more integrated approach to green spaces in residential or public areas. The primary urban zone is distinguished by its low NDVI values. However, the irregular and fragmented nature of its outer boundary, characterised by numerous smaller pockets of low NDVI extending outwards into the rural landscape, suggests a fragmented urban development pattern rather than a single, compact core. The widespread and geometrically organised agricultural patterns in the surrounding areas are a distinctive feature. The presence of lighter green areas interspersed within the urban fabric could imply a design that incorporates more internal green elements than older, more compact cities.

The NDVI map of Rieti (figure 2) demonstrates the city's deep embedding within a lush, topographically complex landscape. Outside the urban boundaries, the predominant colouration is dark green, indicative of elevated NDVI values and dense natural vegetation. The green infrastructure is characterised by extensive, contiguous expanses of forest. Urbanised areas are smaller and more irregular in shape, conforming to the contours of the terrain and often appearing to be nestled between these large green masses. The built-up areas of the city demonstrate a low NDVI. However, the influence of the rugged morphology is evident, with green areas interspersed with or immediately adjacent to urban areas. The urban footprint is fragmented due to the topography of the surrounding area, which is mountainous and densely vegetated. The pronounced visual contrast between the compact urban settlements and the expansive dark green natural environment is a salient feature. This underscores a context in which the challenge may reside in optimising access to the abundant natural greenery that surrounds the city, whilst concomitantly integrating small accessible green areas within the confines of the urban footprint.

The NDVI map of Siena (figure 2) reveals a city situated within a landscape of considerable diversity, marked by a combination of dense natural vegetation and intensive agricultural activity. The topographical map is characterised by an alternation of dark green areas, indicative of forests, and light green areas representing cultivated land. The green infrastructure encompassing Siena is characterised by an intricate network of wooded areas and agricultural fields, which reflect the undulating topography of the region. The overall vegetation is high in density but heterogeneous in its distribution. The primary urban nucleus is highly distinctive, exhibiting a dense and compact historic core with minimal vegetative cover. The urban profile of Siena is characterised by its irregular and organic nature, with strips of lower vegetation extending outwards into the landscape. This morphology is indicative of development that is closely linked to the natural territory. The transition from high urban density to varied green spaces is evident in the immediate outskirts of the city. The map provides a clear visual representation of the historical compactness of Siena's urban core, where the NDVI highlights a minimal presence of internal greenery.

The NDVI map for Viterbo (figure 2) reveals a landscape that combines the moderate green of agricultural fields with areas of vegetation exhibiting a higher NDVI index. The chromatic variations in green are notable, with a predominance of lighter hues when compared to the darker tones characteristic of densely wooded areas. The green infrastructure in the wider area around Viterbo consists of a combination of defined agricultural plots and darker, less structured patches of green. The primary urbanised area exhibits a low NDVI index, which is characteristic of an urban centre. The presence of several distinct, smaller pockets with low NDVI indices has been identified in the surrounding area, indicative of satellite developments or specific land uses.

Two dominant landscapes can be identified around the case study cities. The municipalities of Arezzo, Rieti and Siena are characterised by a landscape dominated by natural greenery, featuring extensive forests and undulating hills covered with vegetation. The urban form of Rieti and Siena is significantly influenced by the topography of the area, with cities often developed along or within natural green spaces. Arezzo also benefits from a rural fringe rich in vegetation, although its immediate urban surroundings show agricultural patterns rather than dense forests. In contrast, Grosseto, Latina and Viterbo are situated in the plains, which are characterised by their flatter topography and intensive cultivation. The surrounding area is characterised by extensive greenery, predominantly comprising agricultural fields.

There is a correlation between the urban topography and the NDVI index. Arezzo, Grosseto and Siena exhibit a markedly distinct central urban core, characterised by a consistently low surface permeability index (NDVI), indicative of a high concentration of impervious surfaces. This phenomenon is especially evident in Siena, a city with a historically dense and compact urban structure. Despite the presence of green belts in these cities, a paucity of green space within the urban centre is evident. The city of Latina is distinguished by its diffuse urban form and the presence of clearly delineated green areas that appear to be more interspersed within its urban boundaries. This finding indicates a shift towards a more modern approach to urban planning, one that incorporates a greater proportion of green spaces within residential areas.

As previously mentioned, the PCGS (figure 3) is particularly useful for analyzing the spatial distribution of urban greenery, supporting territorial planning, and assessing environmental equity among urban areas. The map presented here applies a similar method for calculating the PCGS, translating NDVI values into a pro capita measure of actual green cover over land and population, in support of ecological and urban planning analyses at the local scale.

The three maps offer a comparative overview of the distribution of urban green space per capita (PCGS) in the municipalities of Siena, Arezzo, and Grosseto, highlighting both territorial similarities and differences in the per capita availability of green areas.

Siena displays a fairly uniform distribution of green space per capita, with a wide presence of low-density areas (light-colored hexagons) that maintain a decent amount of greenery. However, the urban center appears to have less green space per capita, likely reflecting the demographic concentration in the historic core and the compactness of the medieval urban fabric. Peripheral and hilly zones offer more abundant green space per person but are not always densely populated.

Arezzo, in contrast, presents a more uneven pattern. Areas with a high per capita green space (dark purple tones) emerge in scattered and peripheral locations, while many central areas show medium or low values. The broader and more mixed territorial morphology—urban, agricultural, and hilly—seems to influence the PCGS distribution more significantly, highlighting a certain fragmentation in green space access.

Grosseto stands out for a wider presence of dark-colored hexagons, indicating high green space availability per capita across many areas, especially along the coast and in the southwestern periphery. This is likely linked to low settlement density and the significant presence of natural and protected areas, such as the Maremma Regional Park. However, there are also hexagons with no coloration (indicating no population), revealing vast uninhabited green zones.

In comparative terms:

• Grosseto appears to have the highest per capita green space, due to its large area and low population density in many sectors;
• Siena is more balanced overall but penalized in its central areas by the density of its historic urban structure;
• Arezzo shows greater spatial heterogeneity, reflecting a more fragmented distribution of greenery in relation to population.

In summary, PCGS proves to be an effective tool for capturing spatial inequalities in urban green space provision. The maps reveal how population density, historical urban layout, and the presence of natural areas significantly affect the availability of accessible green space per inhabitant—insights that are highly relevant for urban planning and environmental equity.

As for the cities in Lazio, Viterbo shows a fairly balanced distribution of per capita green space, with numerous dark green hexagons spread across almost the entire territory. This indicates a good availability of green areas per inhabitant, even near the urban center. Both central and peripheral areas display relatively homogeneous levels, suggesting a moderate population density and a significant presence of natural or agricultural spaces. White hexagons, indicating areas with no population, are present but not predominant.

Rieti is characterized by a more fragmented distribution. While some peripheral areas show a high availability of green space, certain central hexagons lack color, pointing to large uninhabited or very sparsely populated zones. Compared to Viterbo, per capita green space is often high but less evenly distributed and more concentrated in specific areas.

Latina presents a more uneven situation, with less green space per capita. A wide presence of light green hexagons suggests lower availability of green areas for inhabitants in many parts of the city. White areas are also relatively widespread, indicating uninhabited zones. Coastal and southern areas appear to be slightly better equipped with green space per capita, possibly due to the presence of natural or agricultural areas. However, overall, the map shows a lower level of green space compared to Viterbo and Rieti, likely linked to higher urban density or urban planning less focused on green infrastructure.

In conclusion, Viterbo emerges as the area with the best per capita green space, thanks to a more consistent distribution and a good balance between population and green areas. Rieti stands out for its abundant but scattered green spaces, with many uninhabited areas reducing the average impact on the resident population. Latina appears to be the most disadvantaged in terms of PCGS, with a more irregular distribution and generally lower levels of green space per inhabitant.

The Real Accessibility (figure 4) analysis yielded the results presented in Table 1, particularly in the final two rows. A significant proportion of the population in all six cities resides within a 15-minute walking distance of an urban park. Grosseto and Siena demonstrate the highest percentages, at 86% and 84%, respectively, with Arezzo and Viterbo following closely behind at 80%. Latina has the lowest coverage, at 75%, although this still represents a substantial three quarters of its population. Especially in the case of Latina and considering the NDVI results indicating a more spread-out urban layout, it is possible that urban parks are less evenly distributed within the city. The average travel time to reach the nearest urban park is low in all cities, ranging from 8 minutes and 55 seconds (Siena) to 11 minutes and 21 seconds (Viterbo). This finding serves to substantiate the hypothesis that access is efficient for the population within the 15-minute catchment area. Despite its complex topography, as highlighted in the NDVI analysis, Siena shows the fastest average travel time. This finding suggests the hypothesis that the city's urban parks are strategically or historically well integrated into its dense urban core. Viterbo has the longest average travel time, which may be influenced by the greater dispersion of urban parks compared to population centres, as indicated by the substantial non-vegetated area observed in its NDVI map. There is a considerable degree of variability in the absolute number of urban parks, ranging from 41 in Viterbo to 155 in Latina. The average size of these parks is subject to variation. Grosseto has the largest average park size (8,685 m²), while Siena and Rieti have the smallest average sizes (4,618 m² and 4,708 m² respectively). A comparison of the number of parks and population coverage reveals certain observations. Latina has the highest number of green areas (155), but the lowest population coverage (75%). This finding suggests that, despite the presence of numerous parks, their distribution or individual size may not be optimally aligned to serve the city's population in an efficient manner. Siena has a modest number of parks (99) with the smallest average size, but achieves excellent demographic coverage and the fastest average travel time. This suggests that the organisation of its parks is highly effective. Grosseto demonstrates a high level of coverage (86%) with an average number of parks (99), yet the largest average size. This suggests a reduced number of parks, but larger ones that are well positioned to serve a significant portion of the population.

Table 1: Real Accessibility data for the six cities

	Arezzo	Grosseto	Latina	Rieti	Siena	Viterbo
Population (total)	96.527	81.412	127.732	45.169	52.991	66.365
Surface (km²)	385	474	278	206	119	406
n° of green areas	143	99	155	55	99	41
Average surface green areas (m²)	7.165	8.685	5.421	4.708	4.618	8.186
Population (15 min)	77.206 80%	69.719 86%	96.225 75%	37.794 84%	45.542 86%	52.895 80%
Average time (min)	10' 20''	9' 26''	9' 01''	10' 05''	8' 55''	11' 21''

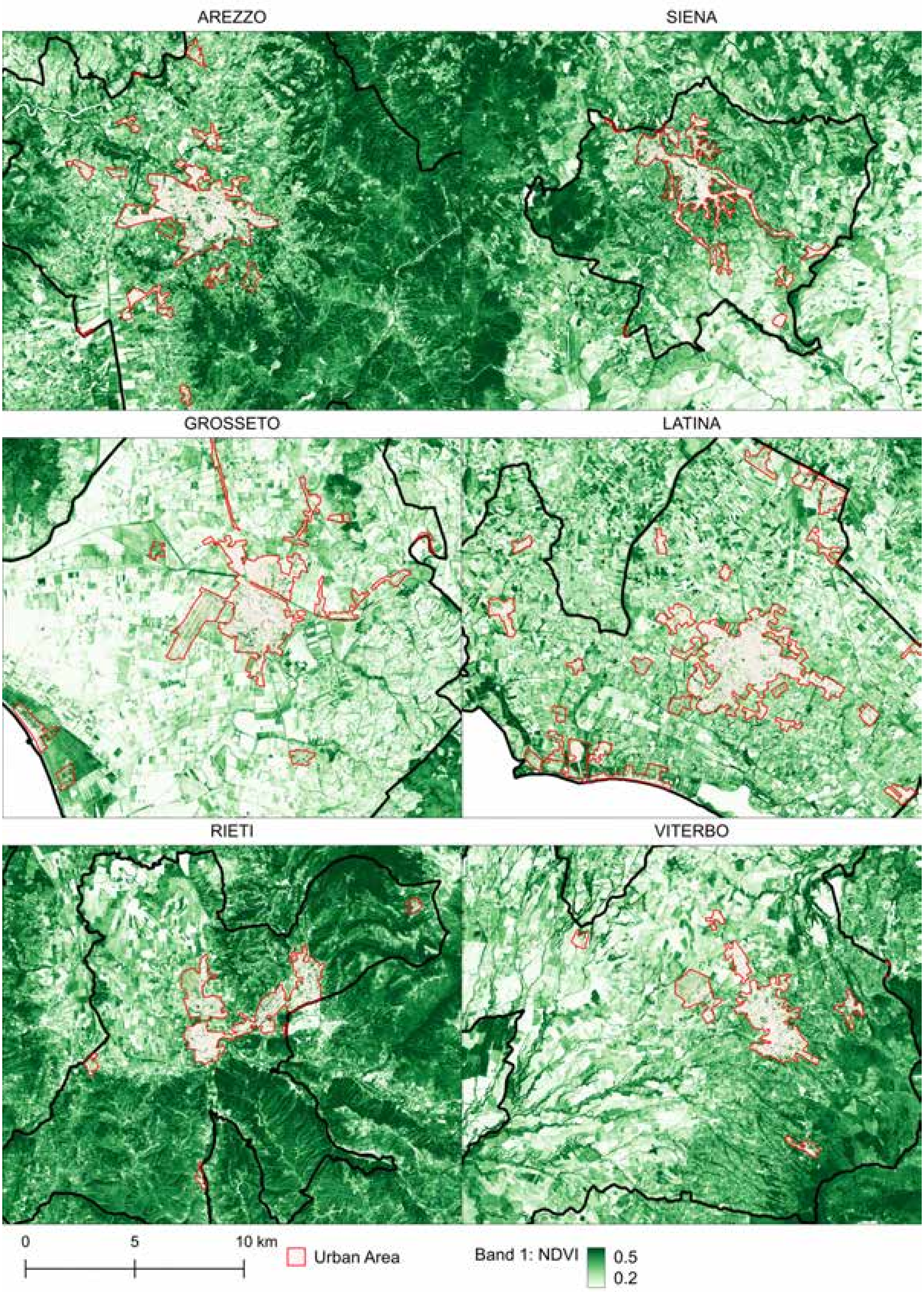

Figure 2: NDVI maps for the six cities

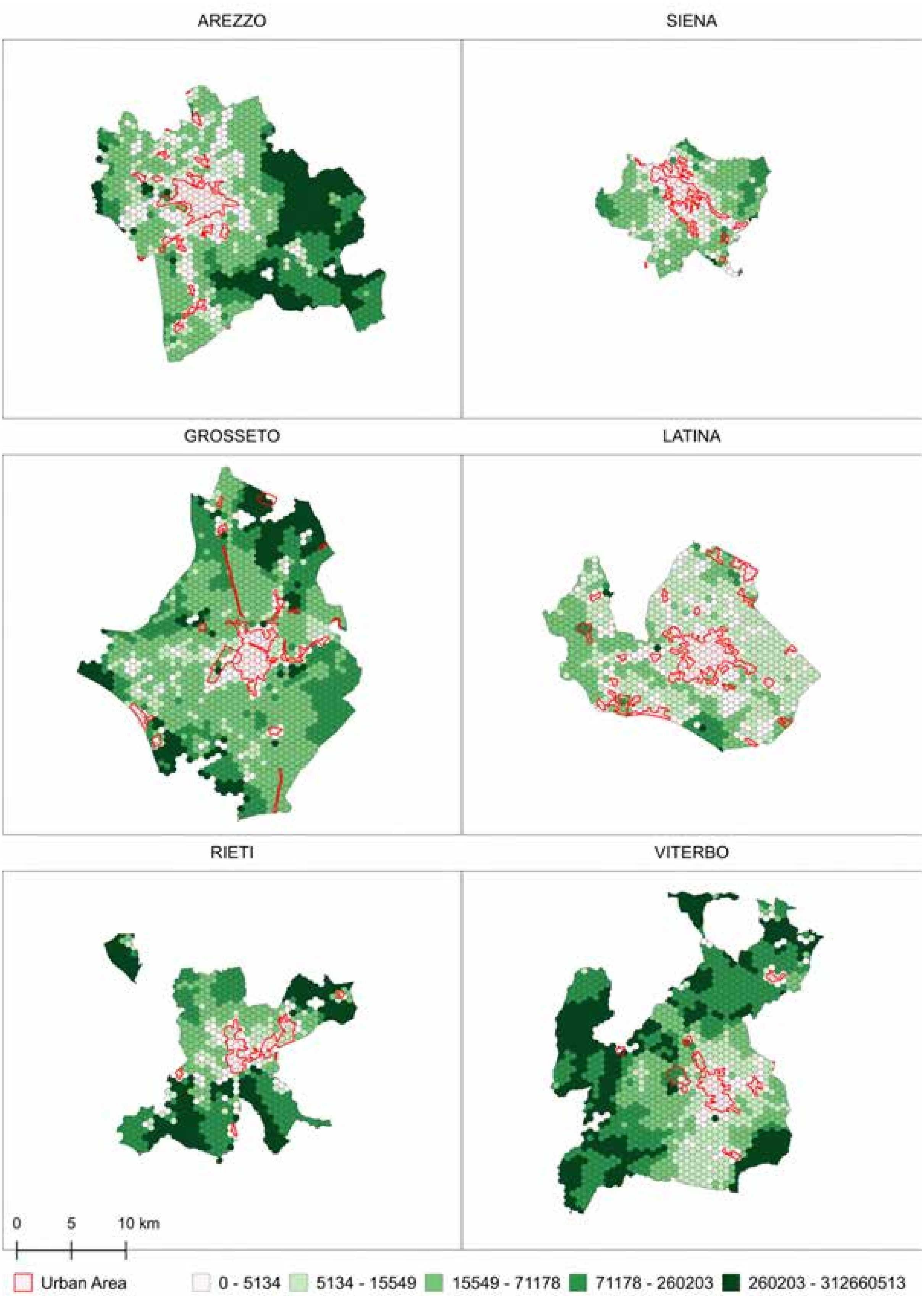

Figure 3: PCGS maps for the six cities

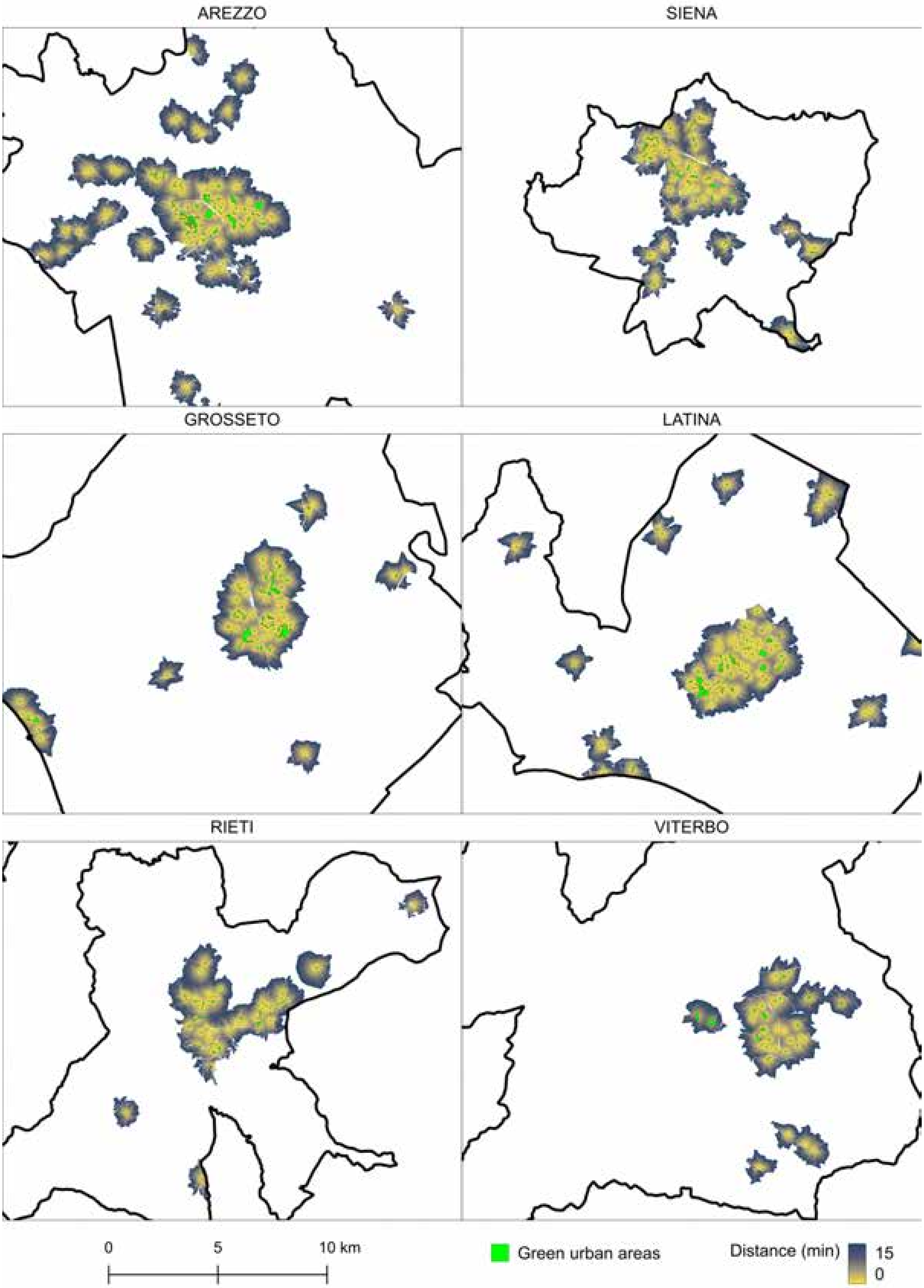

Figure 4: Real Accessibility maps for the six cities

Conclusion

The study outlines a methodology for evaluating the distribution and accessibility of urban green spaces in medium-sized Italian cities, highlighting their importance for public health and urban planning. Recognising that health is linked to environmental, social and cultural factors, the study adopts a broader approach that embraces concepts such as spatial justice, place-related health and environmental vulnerability, moving beyond a clinical perspective. The growing trend of global urbanisation necessitates a thorough investigation into how urban planning and the provision of green infrastructure can enhance citizens' health.

The methodology includes calculating NDVI, green space per capita (PCGS) and real accessibility estimates to provide information on the spatial configuration and ease of access to urban green spaces in the six cities studied: Arezzo, Siena, Grosseto, Latina, Viterbo and Rieti. NDVI analysis revealed distinct patterns influenced by topography and historical urban development. Cities such as Arezzo, Rieti and Siena are immersed in naturally green landscapes, while Grosseto, Latina and Viterbo are characterised by flatter, predominantly agricultural environments. A correlation was observed between urban topography and NDVI, with densely populated historic centres presenting low green cover. This underlines the need for more integrated green spaces within central urban areas.

The PCGS analysis also revealed disparities in the distribution of green spaces. Grosseto, with its low population density and large protected areas, had the highest amount of green space per capita. Despite its densely populated historic centre, Siena showed a more balanced distribution, although it was penalised in the central areas. Latina, in contrast, appeared to be the most disadvantaged in terms of PCGS, suggesting a lack of integration of green infrastructure in urban planning. Analysis of actual accessibility indicates that a substantial proportion of the population in all six cities has access to urban parks within a 15-minute walk. Despite its complex topography, Siena recorded the shortest average travel time to parks, suggesting effective strategic positioning. Although Latina has the highest number of parks, its lower coverage in terms of population indicates that quantity does not equate to optimal accessibility, suggesting issues with the distribution or size of individual parks. Grosseto, with its larger average park sizes and high coverage, demonstrated an effective balance between park size and strategic positioning.

In conclusion, this research reinforces the idea that urban green spaces are important for physical and mental health, especially for vulnerable groups. The methodologies employed provide policymakers and urban planners with tools to assess existing green infrastructure and inform future development strategies. Understanding the nuances of green space distribution and accessibility in different urban contexts enables cities to progress towards a more equitable and health-friendly environment, in line with the evolving concept of health as a common goal influenced by environmental and social factors. Future research could build on these methodologies by incorporating socio-demographic data at a more detailed level, enabling the identification of specific populations with limited access to green spaces and the development of more targeted interventions.

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