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What transition for cities?

Scientific debate, research, approaches and good practices

This Special Issue intended to wonder about the possible transformations for cities towards the sustainability transition. Hence, contributions coming from scholars as well as from technicians have been collected around three main topics: methodologies for prefiguring possible sustainable transitions; urban policies and drivers of the transition; possible projects and applications for sustainable transition. Reflections and suggestions elaborated underline the awareness that the transition process, above all, needs cooperation among decisions, information sharing, and social behaviour changes.

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EDITORIAL PREFACE
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What transition for cities?

Scientific debate, research, approaches and good practices

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This Special Issue of TeMA - Journal of Land Use, Mobility and Environment proposes to delve into the concept of transition applied to urban and territorial systems with the aim of verifying the state of the art in scientific as well as in technical sector, also considering the effects of Covid-19pandemic crisis (Angiello, 2021).
What is urgent is the need to change both social behaviors and the use of primary resources (water, energy and soil) which is claimed by technicians and scholars as the only solution to face environmental challenges affecting nowadays cities. These challenges and the linked risks are so relevant that an in-depth change in the operative actions as well as in the theoretical approaches has become mandatory, in order to avoid negative and disruptive effects.
The current historical phase is very different from the previous ones, because of the availability of innovative technologies, enormous possibilities of connection, information production and exchange, the lack of well-defined limits among activities and sectors that Bauman (2011, pp 8-11) defined liquid modernity based on the belief that "change is the only permanent thing and that uncertainty is the only certainty". Dealing with the issue of complexity that characterises systems in which we live in requires to consider two aspects, at least, that need to be observed simoultaneously. On one hand, to study the evolution of the city as a complex system; on the other, to observe the rapid transformations that affect all sectors (social, productive, economic, cultural) to be able to drive them towards sustainable targets.
Some scholars defined this historical period as characterized by a critical transition, that has multiple dimensions (climatic, energetic, sanitary, social, economic), namely a systemic transition.
In this sense, it is needed the awareness that the systemic vision - even though it requires extreme changes in the theoretical and in decisional processes - is the most appropriate approach able to make scholars, researchers and expert able to reach adequate solutions to face the current issues (climate changes, overpopulation, social inequalities, etc.). Cities, indeed, has gained a central and strategical role both as crisis-producers and as crisis-solver; within this paradox urban and regional planning has responsibilities due to its intrinsic nature to be a science whose target is the collective well-being.

The systemic approach to the study of cities as complex entities is not recent but goes back to the General Systems Theory (GST) (von Bertlanffy, 1968) developed in the early nineteen century (Prigogine & Stegers (1984; Bertuglia & Vaio, 2005; Bai et al., 2016; Fistola et al., 2020; Gargiulo & Papa, 2021).
One of the main characteristics of complex systems is the non-linearity of the relationships between the elements. It is this characteristic that arose from Covid-19 pandemic crisis. This means that the processes within the system can be triggered by random factors, whose outcome may not be predictable, and therefore, ungovernable. Hence, the effects can be amplified, and they can multiply themselves as it happens in the theory of Lorenz (1972), expressed by the so-called "butterfly effect".
The current crisis conditions, on contrary, seem to be much closer to the adaptive capacity of complex systems, expressed by Levin (1988). This concept implies the fact that complex systems can have relationships between elements that are not always compatible. Thus, the behaviors between elements are so interconnected that they can modify both their own dynamics and those with other components of the system. This characteristic, on one hand, accentuates the condition of uncertainty, on the other, it does not prevent the search for practicable solutions that can be compatible with the complexity of the whole system.
Decision-making processes and social behaviors, therefore, must adapt to the evolutionary speediness of the system, with the awareness that there is not a single solution but a range of possible scenarios which are dynamic themselves. The concept of resilience, which, at present, is widely applied to urban sciences (Gaglione & Ayiine-Etigo, 2021), refers to the ability of a dynamic system to resist disturbances avoiding their catastrophic effects (dynamic stability) (Hunderson, 2000). At the same time, the concept of sustainability, since the Nineties, has been developed as a theoretical reference both in scientific debate and in the practices of urban and regional planning. By assigning different weights to its dimensions (environmental, economic, and social) according to the context, several other aspects have been added to sustainability that, if have enlarged its field of application (safety, risk prevention, adaptation to climate change, energy saving, load capacity, aging population), they have also generated criticisms and conflicting interpretations.
In the context of these considerations, the choice to concentrate the attention to the topic of transition of urban and territorial systems has been related to the target of indagating the interest coming from the scientific fields dealing with cities and its planning and urban evolution.
Generally speaking, and referring to physic approach, the concept of transition refers to a passage of state from a first condition "a" to a second and different condition "b"; this passage occurs in conditions of instability and originates continuous changes. In this sense, transition could be understood as the non-permanent phase that necessarily occurs to move from a state of crisis towards state in a new balance.
Referring to complex systems, such as the city and the territory are, the transition process also occurs through an exchange of energy released between one phase and another. The dispersion of such energy must be limited to guarantee the existence of the system itself. A further reflection arises within the purpose of this special issue of TeMA Journal of Land Use, Mobility and Environment the concept of transition refers to the need to distinguish the evolutionary process of the dynamic and complex system "city" from the typical transition process.
In other words, it is possible to refer to two different processes. The first one refers to an endogenous process, that is the evolutionary natural change of the system as it is dynamic and complex (evolutionary change). The second refers to an exogenous process (i.e. the transition) that leads to modification in the system moving along a designed trajectory. Both the processes arise because of the occurrence of crisis situations but are substantially different. While in the first case the change can be sudden and unpredictable, in the second case, the change can be gradual and result from a design of possible trajectories for transformation.
In this sense, urban planning assumes responsibility and the contribution of urban planners can be strategical in pursuing states of balance that can assure good levels of livability to the urban community.

This also responds to the principles of sustainability as they have been recently expressed by the International United Nations in 2030 Agenda for Sustainable Development (ONU, 2015) that it is possible to individuate as the collective moment of awareness of the need for change.
This awareness, for instance and as it concerns Europe, was induced into the Green Deal adopted by the European Commission in order to be the first climate-neutral continent (EC, 2019). In this context, the ecological transition refers to the transition from "unsustainable consumption models" towards "green" methods and lifestyles.
Within the scientific literature, *urban transition* is meant as a multidimensional and cooperative process, characterized by uncertainty; while the *urban green transition* represents an opportunity to solve "urban diseases", such as traffic jams, the dramatic increase in house prices, overpopulation (Jinpeng et al., 2017).
Actually, the search for an urban model representative of a city that is well balanced between man and nature, thus as the solution to the "urban illness" goes back to the utopian urbanism of the nineteen century (Owen, Fourier, Soria y Mata, Howard, Garnier), to contrast the industrial city model. The concept of sustainable city as a product of the paradigm of sustainable development as it has been defined in the report "Our Common Future" (Brundtland, 1987) and all its consecutive declinations, has in fact re-proposed – in a contemporary key – the objective of seeking the improvement of urban efficiency through the study of the (dynamic) relationship between different urban functions. Taking it to extreme and trying to identify the main stages that can describe the trajectory of the city's transition process towards more sustainable dimensions, five phases can be identified.

1. The "green" (ecological) phase

The first phase that can be identified as "green" refers to the shift from the ideal city, forerunner of the present sustainable city, –whose origins could be individuated in the Garden City of Howard (1898) or the later Ville Radieuse of Le Corbusier (1930) – up to the more articulated notion of "Green Urbanism". Lehmann (2011) (fig. 1), in proposing the principles of Green Urbanism, identifies two fundamental and very significant steps in the evolutionary history of the city, which summarize the emerging elements characterizing the most current urban model.
The first step can be linked to the spread of the use of the car which corresponded to a model of "dispersed city" (the de-compacted "functional city" of the 20th century or the focus of the urban sprawl theory in the same period). The second step is characterized by the awareness of climate change which imposes a more environmentally friendly urban model for which it is needed the re-conceptualization of the cities, of their infrastructures' systems, to make them "compact" (the "dense city" theory spread in the later years to contrast the urban sprawl). Hence, the whole ongoing debate around the definition of an urban model that could withstand the challenges that, in fact, urban evolution itself has activated (climate change, depletion of primary resources, social inequalities, etc.).

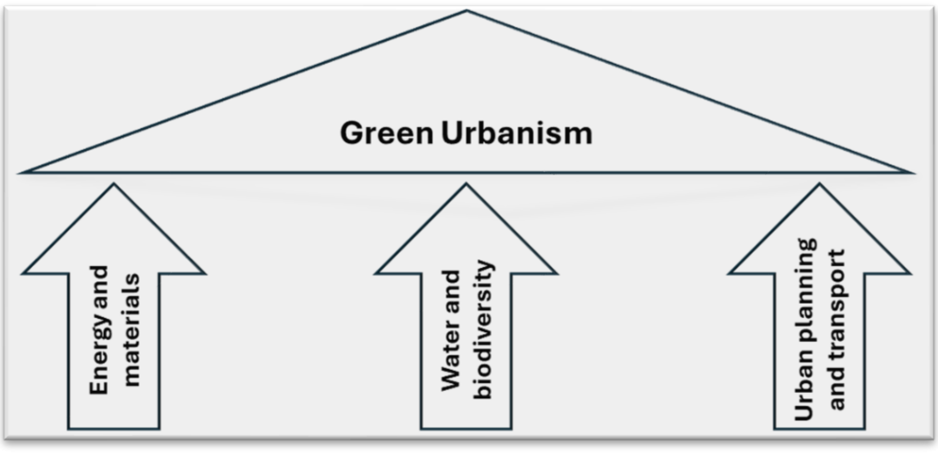

Fig. 1 The three pillars of Green Urbanism according to Lehmann (2011)

2. The phase of the Urban Ecology (UE) and eco-towns

The concept of urban ecology dates to about thirty years of studies and research which have involved the field of theories and above all those of practices and urban design. Wu (2014) delves into the aspects relating to both the sociological sector and the urban planning one, referring to the scientific research in the last ninety years (fig. 2). In his research he also clarifies the relationship between ecology and sustainability, specifying how the latter concerns a broader field of research while (also considering the several definitions coined in the last ten years) the former refers to the study of space-temporal patterns, environmental impacts, and sustainability of urbanization with emphasis on biodiversity, ecosystem processes, and ecosystem services. Socioeconomic processes and urban planning practices contributed to identification of urban ecology as a practice and a theory.

In the 2000s, within the debate about the city as an ecosystem, the concept of "ecosystem services" assumed a central role also in the scientific debate originating a specific research line. In a nutshell, also referring to Millenium Ecosystem Assessment[1] (2005) this concept refers to "the benefits people obtain from ecosystems" which include: (1) "provisioning services" (e.g., food and water), (2) "regulating services" (e.g., purification of air and water, regulation of climate, floods, diseases, hazard, and noise), (3) "cultural services" (e.g., recreational, spiritual, religious and other nonmaterial benefits), and (4) "supporting services" (e.g., soil formation, primary production, and nutrient cycling). As supporting services are really ecosystem processes or functions, ecosystem services hereafter refers only to provisioning, regulating, and cultural services.

In this framework, the notion of "green infrastructures" (GI) begins to concentrate attention within the debate about the sustainability of cities. The topic of "green infrastructure" is considered as a strategic approach to the subject of conservation of cities, fundamental for sustainability. It differs from the approach to open space planning because it proposes a system of multifunctional networks able to reduce impacts on the environmental and socio-anthropic urban systems. According to the United States Environmental Protection Agency "green infrastructure is an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. Green Infrastructure management approaches and technologies infiltrate, transpire, capture and reuse stormwater to maintain or restore natural hydrology". These technologies (green roofs, rain gardens, permeable floors, etc.) contribute to the reduction of pollution, of the energy demand, to the mitigation of the urban heat island effect. In the evolution of the concept and its application, GI becomes an important milestone for building the eco-town. Particularly, GI refers to a strategically planned and managed network of green spaces and other environmental features vital to the sustainability of any urban area. GI should be designed and managed as a multi-functional resource capable of providing the landscape, ecological services and quality of life benefits that are required by the communities it serves and needed to underpin sustainability. Its design and management should also protect and enhance the character and distinctiveness of an area regarding habitats and landscape types. The report of the Town and Country Planning Association in 2008 (The essential role of green infrastructure: eco-towns green infrastructure worksheet) indicates nine principles to create the GI in eco-town according to a specific strategy[2].

In the same period, in England, an experiment was started with the "Eco-towns" project, with an allocation by the government of around 200 million pounds for the construction of four small urban settlements, each with 2500

[1] The Millennium Ecosystem Assessment (MEA) is an international research project aimed at identifying the state of global ecosystems; evaluating the impacts of changes on human well-being and providing actions for the sustainable use of ecosystems. Started in 2001, it concluded in 2005 and involved over 1,360 experts from all over the world. The findings provided both a scientific assessment of the global ecosystems, and options for restoring, conserving or enhancing sustainable use of ecosystems. Retrived https://www.isprambiente.gov.it/it/attivita/biodiversita/documenti/millennium-ecosystem-assessment https://www.millenniumassessment.org/documents/document.356.aspx.pdf.

[2] The English eco-town initiative was launched by the UK Labour government in 2007 to address the twin challenges of growing urbanization and climate change. The experimentation, with the "Eco-towns" project, was started in England in 2008, with an allocation by the government of around 200 million pounds for the construction of four small urban settlements, each with 2500 homes built with use of energy saving technologies, to be completed by 2016. Project has not been finished also due to the change of government.

homes built using of energy saving technologies, to be completed by 2016. The project has sparked controversy and dissent also due to the change that affected the government leadership which cut funding by 50%. However, it can represent an example of "urban transition" towards modes of urban settlement different from the previous ones.

3. The Low Carbon City (LCC) phase

Initially, the concept referred to "low carbon economy", coined for the first time in 2003 (DTI, 2003) when the British Government published the "Energy White Paper" entitled "Our Future Energy: Creating a Low-Carbon Economy". A little later, in 2007, this concept was joined by "Low-carbon Society" that refers to a condition without which an economy based on low consumption cannot be achieved in the absence of behaviors and lifestyles that care of consumption of resources and energy. The low carbon city model, thus, is based on the idea of reducing polluting emissions through a city model in which citizens adopt virtuous behaviors which in turn have repercussions on the economic system. This topic has become central in the scientific context (fig. 3) evolving toward the concept of Smart Energy City.

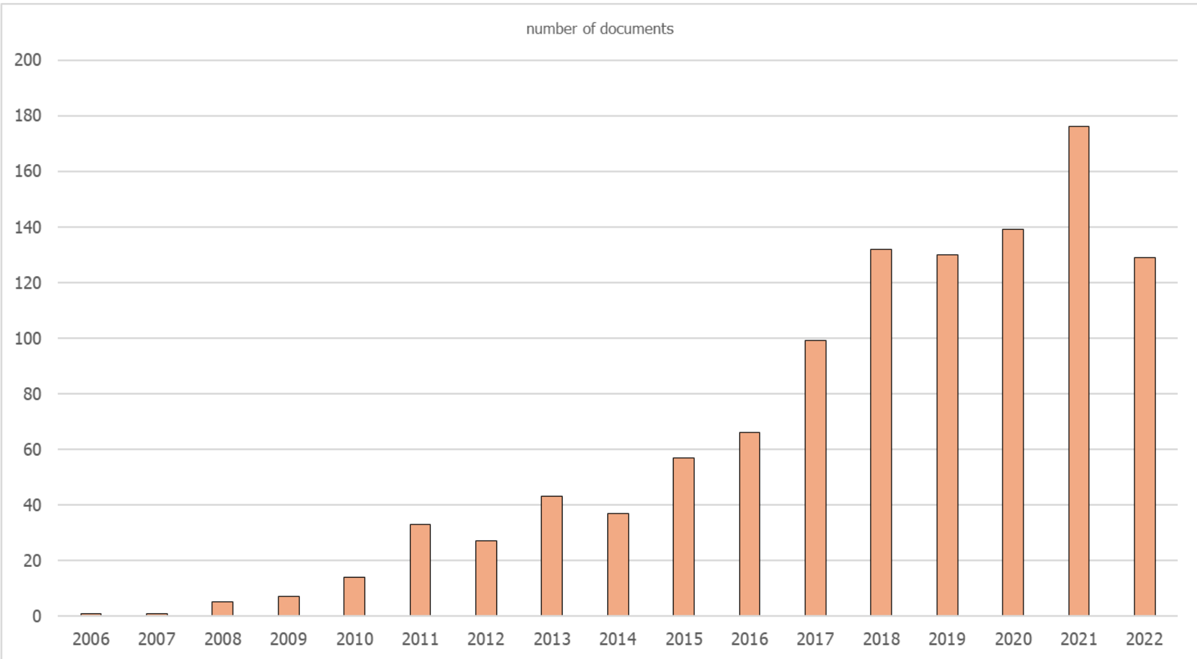

Fig. 3 Number of articles published in the period 2006-2022 on the topic of the low carbon economy (Scopus database accessed on 19th February 2023)

4. The phase of the Circular city (CC)

Based on the concept of circular economy (CE), CC imposed itself on the political and scientific scene as a possible model of sustainability based on the reuse, thus, on the reduction of consumption (Rios et al. 2022). The European Union defined the circular economy in 2019 as "an economy in which the value of products, materials and resources is maintained for as long as possible and waste production is reduced to a minimum" (Eurostat, 2019).
Many definitions have been proposed since then (Geissdoerfer, Savaget, Bocken e Hultink, 2017; Kirchherr, Reike e Hekkert, 2017; Korhonen, Honkasalo e Seppälä, 2018; Prieto-Sandoval, Jaca, & Ormazabal, 2018) without reaching a unique.
Geissdoerfer et al. (2017) underlined that the key aspects of CE typically include waste design, maintenance, repair, reuse, remanufacturing, reconditioning and recycling.

They define CE as "a regenerative system in which resource inputs, waste, emissions and energy losses are minimized by slowing, closing and restricting cycles of matter and energy". According to the researchers at Circular Cities Hub (2017), established at the Bartlett School of Planning of University College London, a circular city is based on systems integration, flexibility, intelligence, cooperative behavior, localization, recycling, and renewable resources. Within a circular city, they further write, "resources can be cycled between urban activities" and "within city regions," and "cities can be designed so that land and infrastructure can be re-used/recycled over time." Referring to the principles of '3R- reduce, reuse and recycle' and the process of 'resources- waste- renewable resources', circular city weighs the benefits against the costs, and then relieves the pressure of energy shortage and the burden on the environment.

In a nutshell, the concept of a circular city refers to the interpretation of the city as an organic system in which there is an influx of resources and an outflow of waste. This process is commonly described as urban metabolism. Therefore, metabolic rate is the key indicator that can evaluate the recycling capacity of a city. Urban metabolism can be divided into linear and circular modes. The linear one, to which most cities belong, depends on large quantities of resources and produces large quantities of waste; the circular one does not consider urban problems in isolation, but the interrelationships between the elements of the city system.

The ability to recycle resources defines the system's ability to influence environmental pollution and therefore to produce ecological damage. However, waste management and the ability to recycle it is only one aspect of reducing the polluting impact of cities. Transferring this aspect within the global governance process would help to change the entire process, allowing to move from a post-consumption phase to a pre-consumption phase, therefore to develop types of technologies to avoid or reduce initial waste. Furthermore, if we consider the urban territory as a finite and non-reproducible resource, the rational use of the territory and the containment of its consumption represent fundamental principles of the planning process of a circular city.

4. The phase of the smart city (SC)

The smart city phase, which exploded at the beginning of the 2000s and throughout the following twenty years, can now be said to be almost consolidated if not even overcome. It was clarified that this concept cannot be exclusively limited to the use of new technologies but must be based on the synergy of the elements that make up the city system, favoring a citizen-centered vision, according to which the intelligence of the city is closely related to social dimension. In this vision, quality of life and efficiency objectives become priorities in the urban development strategy towards dimensions that also associate safety, wellbeing, health and inequality overcoming with sustainability.

Referring to the considerations expressed, with this Special Issue we intended to draw the attention of technicians and scholars to the theme of urban transition which from many quarters seems to prefer the "ecological dimension" to pursue sustainability objectives. The eleven contributions received, while maintaining the underlying theme of the main theme, propose differentiated perspectives of sustainable transition which can be divided into three groups:

1. Methodologies and cognitive tools for urban transition
2. Urban policies and driver elements of the urban transition
3. Possible projects and applications for urban transition

The contributions of the first group propose analysis methodologies oriented to the knowledge of the changes affecting cities, they try to identify adaptation solutions suitable for these changes. In particular, the aspects relating to the vulnerability of cities to the effects of climate change (Palermo et al.), the need to develop adequate tools to support informed decision-making processes (Stufano Melone & Camarda), to define territorial planning tools capable of integrating the transition through the construction of a system of clear rules (Lazzarini et al.).

The contributions of the second group focus on the analysis of the effects deriving from climate change, highlighting the urgency of integrating adaptation and mitigation actions within the process of defining land use policies at different scales. Aspects relating to the framework of European "green" policies are explored in depth (Isola et al.), as well as the need for integration between urban planning and environmental assessment tools and the search for appropriate methods and tools to improve the adaptation and resilience capacity of urban systems to the need to define approaches based on a holistic and systemic vision for the knowledge of urban phenomena at different scales (Pultrone; Gisotti & Masiani; Ingaramo et al.).

The contributions of the third group allow for the building of a first cognitive framework related to research projects and/or urban planning practices aimed at identifying interventions to improve the conditions of urban sustainability, with particular attention to "fragile" territories (lagoon areas, internal areas, coastal areas).

Aspects related to the feasibility of creating zero energy emission urban districts as well as the definition of actions for the protection of urban ecosystems are always explored in depth with a view to tracing practicable and sustainable trajectories of change (Magni et al.; Caprari & Malavolta; Altay & Zencirkiran).

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Re-generate resilience to deal with climate change

A data-driven pathway for a liveable, efficient and safe city

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Abstract

Cities are vulnerable to the effects of the climate. Building resilience to contain the risks for inhabitants, businesses and infrastructures deriving from the impact of climate change represents a challenge for local planners and public decision-makers. To win it, it is necessary to include the most suitable adaptation actions to contain the conditions of vulnerability in the local urban regeneration processes. To this end, the authors have increased and applied a methodology for defining and mapping climatic vulnerability, with a particular focus on the built environment. The main element of integration and updating concerns the use of Copernicus satellite remote sensing data. The application to the case study demonstrates the adequacy of such data for the research needs and the relative utility in terms of spatial resolution of the results. The vulnerability map into a more accurate definition scale helps the planner to integrate the common regeneration goals with more specific climatic resilience goals. In fact, basing on the results obtained for the case study, the authors define adaptive design solutions aimed at regenerating local resilience in terms of liveability, efficiency and safety.

Keywords

Climate change; Urban regeneration; Resilience.

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1. Introduction

Climate change is a long-term phenomenon mainly linked to global warming. It causes significant changes in temperature, humidity and precipitation (Forino et al., 2015). The phenomenon is attributable, directly and indirectly, to human activity (Battiston, 2020), which varies according to population size, economic activities, lifestyles, energy, and land use. Increasing urbanisation and complex patterns of urban economic goods, infrastructure and services make cities particularly vulnerable and less resilient to climate change (Guida, 2021; Balletto et al., 2022; Gaglione, 2022).

In general, resilience and vulnerability support risk description. These concepts are mutually interdependent and inversely related. Resilient systems are able to evolve, as a result of the perturbation, in a state different from that preceding the manifestation of the disorder, ensuring the maintenance of essential functions and the restoration of the structures that distinguish them. A vulnerable system has lost resilience, becoming exposed to the risk of a negative impact that could previously be absorbed. Therefore, the risk is positively correlated to urban vulnerability concept (Beltramino et al., 2022) and negatively to resilience concept.

Strengthening the comprehensive evaluation of resilience is conducive to identifying high-risk areas in cities, guiding regional risk prevention, and providing a scientific basis for differentiated strategies for urban resilience governance (Feng et al., 2021). The containment of the conditions of vulnerability starts from the analysis of the characteristics and the extent of the expected impacts that allows to identify the areas of greatest risk, deepen where and how the phenomena are repeated more frequently, and to define possible scenarios including policies and strategies to increase the resilience of the places, according to the sustainable development objectives. With regard to climatic risk, it is necessary to plan new urban models to obtain social, economic and environmental responses. This planning model allows the urban environment and its users to resist (Bonan, 2020) in the long term, to the external environmental stresses induced by the climatic variations whose course is known, but foreseeable only in part (Sandrini, 2020). According to the Intergovernmental Panel on Climate Change (IPCC) the Mediterranean basin is one of the main hotspots of climate change, or one of the most responsive areas to this phenomenon (Pietrapertosa et al., 2019). Therefore, in this context the use of "climate planning" is crucial in order to reduce the impact of climatic impacts to the scale of buildings and open spaces and to pursue sustainable development conditions in urban areas. The local government level is the most appropriate framework for testing climatic mitigation and adaptation strategies. Cities emerge, in fact, as driving forces for adaptation and resilience to climate change, representing the ideal context to implement low-carbon policies and strategic planning processes shared with citizens and stakeholders (Pietrapertosa et al., 2019).

Many approaches and tools have been developed to measure climatic resilience in cities (Mehryar et al., 2022), many of which, across Europe, are already investing in infrastructure to reduce vulnerability to rising sea levels, adapt to rising temperatures and control air pollution (Pee & Pan, 2022). This effort, of a predominantly autonomous nature, aims to fill the widespread lack of efficiency of political frameworks, also recognized by literature (Pietrapertosa et al., 2019), which should have defined national and regional guidelines to accompany local climate action. With reference to the Italian national context, although the European climate regulation (EU 2021/1119), there is no national legal obligation to adopt the Local Climate Plans. There are no national laws that oblige municipalities to develop any type of plan or strategy aimed at reducing greenhouse gases or adapting cities to climate change, with the exception of the Municipal Energy Plan (Law 10/1991, Art. 5) for cities with more than 50,000 inhabitants and the Urban Plan for Sustainable Mobility (Decree 257/2016, art. 3) for municipalities and their associations with more than 100,000 inhabitants (Pietrapertosa et al., 2019). The recognition of this regulatory gap clearly shows the need to define operational decision support tools that foreshadow or verify the effectiveness of urban regeneration processes (Strippoli, 2020) in terms of reducing vulnerability and increasing resilience.

Therefore, the research intends to cover this gap by proposing the methodological framework described below[1]. In literature, the study of climate change and its impact on urban life is increasingly recognized as a serious, worldwide concern (Waly et al., 2021). From a policy intervention vantage point, addressing the drivers of vulnerability provides a reliable approach to reduce the current vulnerability level and manage potential climate change-induced risks of a system (Yimam & Holvoet, 2023).

The literature findings underscore the importance of evaluating the susceptibility of local areas to climate change and emphasize the need for tailored local initiatives and policies to reduce vulnerability and enhance adaptability in communities (Hossain et al., 2023). In this scenario, urban-planning instruments require a strategic view that enables the integration of climate change variables, aimed at reducing vulnerability and strengthen the resilience of cities (Shao et al., 2021). As stated by D'Ambrosio (2018), the issue of modelling vulnerability to climatic phenomena has long been addressed through statistical matrix methods and approaches and the return of vulnerability levels is mainly related to the assessment of the socio-economic component (Kocur-Bera & Czyża, 2023; Li et al., 2023). Therefore, the research work aims to integrate the socio-economic parameters widely considered in the literature, with a more precise knowledge of the physical-environmental aspects that characterize the territory. The authors define an experimental methodology for direct assessment of climatic vulnerability, and consequently indirect of resilience, with a particular focus on the built environment, including through the use of satellite remote sensing data. These aspects are the main originality of the research. The paper proposes the definition of an innovative tool to support the planning of regeneration interventions promoting adaptation action to the effects induced by climate change in urban contexts. It traces a data-driven path based on the characteristics of settlement and environmental systems to plan liveable, efficient and safe cities.

Based on the introduced contents, the paper is structured as follow. Section 2 presents the methodological framework that feeds the tool to support the planning of climate-resilient regeneration interventions, paining attention to the use of satellite data. Section 3 introduce a frame of the theoretical assumptions underlying climatic adaptive design choices. Section 4 demonstrates the usefulness of the proposed methodology for planning and design of possible regeneration interventions geared to adaptation to climate change in the municipality of Catanzaro (Calabria Region, Italy). In particular, the lines of intervention defined following the identification of specific objectives of regeneration and resilience aim to propose design in areas and spaces already built, increasing the level of quality of living, with regard to environmental and socio-economic aspects, and their resilience to climate change. Section 5 discusses these findings in order to draw useful generalizable conclusions.

2. Methodological framework

Recently, the availability of data, time series, and statistical analysis techniques have allowed a rapid development of risk analysis in various fields and scientific disciplines (Azzimonti et al., 2018), including urban and territorial planning, according to different perspectives and approaches (Fasolino et al., 2019). In order to reduce the risks induced by climate change, the planner must identify the most appropriate adaptation measures on the basis of a prevailing assessment of the areas of greatest vulnerability and least resilience that need adaptation actions (Guida & Pennino, 2022; Ceci et al., 2023).

Adaptation is essential to ensure comfortable and safe places for settled communities (Privitera et al., 2013). To this end, the authors considered as a starting point the experimental methodology for defining domains of local vulnerability to climate change defined in Francini et al. (2020). They update and increase the methodology framework through the use of satellite data, in order to ensure more effective results.

[1] This activity refers to the research project admitted to funding under the University's competitive call - Rectoral Decree 1101/2022 of 29/07/2022.

Subsequently, they define a framework of measures against climate change by analysing some project proposals eligible for funding in Italy from funds of the National Recovery and Resilience Plan. The interest on such projects recognizes the importance turned to the control of the climatic risks from the PNRR with particular reference to the first two environmental objectives of the verification of conformity to the principle DNSH.

Therefore, an in-depth literature study has been carried out on the identified measures in order to verify their importance in terms of liveability, efficiency and safety identified by the authors as relevant resilience parameters.

2.1 Climatic vulnerability assessment

The methodology is based on the additive estimation of three dimensions that define climatic vulnerability in the literature (Pachauri et al., 2014).

In climate change studies (Tessema et al., 2021), the vulnerability of a system is a function of the following parameters:

- climatic exposure, which is the degree to which a system is exposed to significant climatic variations. This component summarizes the information useful for the construction of the climatic profile of the context of interest through the knowledge and monitoring of the 18 meteorological parameters explained in Tab.1;
- sensitivity, the degree to which a system is affected by climate-related stimuli. This component takes into account the physical and environmental conditions of the territory and the physiological and socio-economic status of the settled population such as to make it capable of being affected by climate change according to the 6 parameters reported in Tab.1;
- adaptive capacity, that is, the degree of a system to adapt to climate change. This component aims to measure the skills and resources available to the population in order to have easy access to tools that can facilitate the interpretation of climate-related information through the 6 parameters summarized in Tab.1.

Climatic exposure		**Sensitivity**	**Adaptive capacity**
1. Frost days (FD0) 2. Tropical nights (TR20) 3. Maximum value of daily minimum temperature (TNx) 4. Minimum value of daily minimum temperature (TNn) 5. Cold nights (TN10p) 6. Warm nights (TN90p) 7. Summer days (SU25) 8. Maximum value of daily maximum temperature (TXx) 9. Minimum value of daily maximum temperature (TXn)	10. Cold days (TX10p) 11. Warm days (TX90p) 12. Warm spell duration indicator (WSDI) 13. Maximum 1-day precipitation amount (RX1day) 14. Maximum 5-day precipitation amount (Rx5day) 15. Number of heavy precipitation days (R10) 16. Number of heavy precipitation days (R20) 17. Very wet days (R95p) 18. Simple daily intensity index (SDII)	1. Degree of waterproofing (Env-1) 2. Density of tree cover (Env-2) 3. Moisture class (Env-3) 4. Landslide and hydraulic risk (Env-4) 5. Elderly population (Soc-1) 6. Young population (Soc-2)	1. Impact of households with potential economic difficulties (Kno-1) 2. Education level and literacy rate (Kno-2) 3. Internet connection (Kno-3) 4. Climate action planning (Kno-4) 5. Peripherality from services (Res-1) 6. Conservation of residential buildings (Res-2)

Tab.1 Parameters of climatic exposure, sensitivity, and adaptive capacity

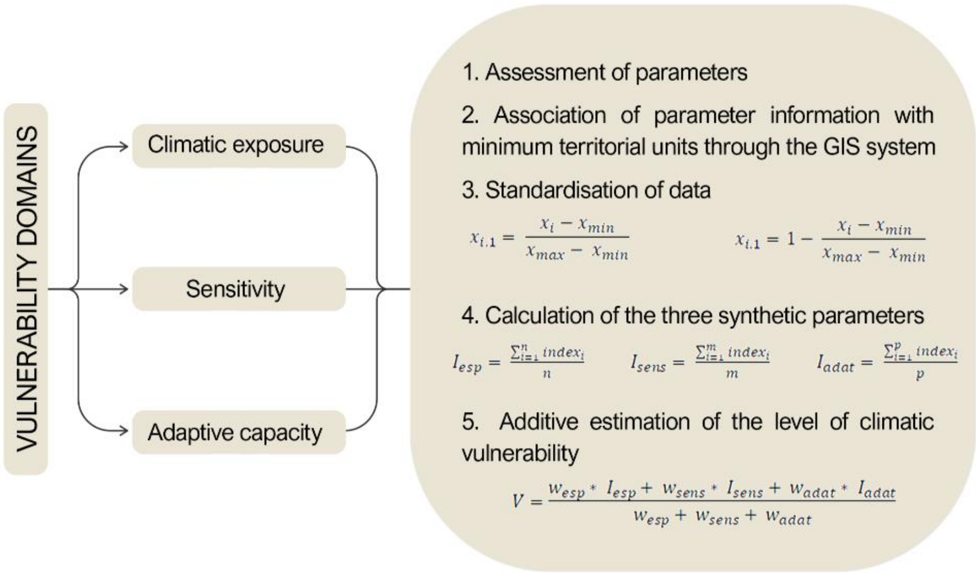

Fig.1 Methodological flowchart

The methodology is replicable in other urban areas. It attributes a set of parameters available on a local scale to each component. It is characterized by the steps shown in Fig.1.

The innovation element concerns the use of satellite data provided by the Copernicus[2] programme for the sensitivity component, namely the degree of waterproofing, the density of the tree cover and the humidity class. They allow to take into account a situation of extreme vulnerability to climate change represented by highly impermeable areas (buildings and roads), with a reduced percentage of vegetation and humidity. In particular, Copernicus waterproofing products capture the percentage and change of soil waterproofing. Waterproof areas are characterized by the replacement of the original semi-natural and natural soil cover or water surface with an artificial, often waterproof, cover. These artificial surfaces are usually maintained for long periods. Waterproofing captures the spatial distribution of artificially sealed areas, including the level of soil waterproofing per unit surface. The sealed ground level (degree of impermeability 1-100%) is produced using a semi-automatic classification, based on calibrated NDVI. In particular, the reference in this study is the high-resolution land cover characteristics for the year 2018, the last available update year.

The layer Impervious Built-up is a thematic product that shows binary information of building (class 1) and no building (class 0) within the waterproofing profile derived from the IMD 2018 for the period 2018 for the EEA-39 area. The production of the high-resolution built-up level has been coordinated by the European Environment Agency under the EU Copernicus programme.

As regards the density of tree cover, reference is made to the characteristics of the high-resolution land cover for the reference year 2018. The relevant TCD raster product provides information on proportional crown coverage per pixel at a spatial resolution of 10 m and ranges from 0% (all areas not covered by trees) 100%, where the density of the tree cover is defined as the vertical projection of the crown of the trees on a horizontal Earth surface. Finally, the combined product Water and Humidity is a thematic product that shows the presence of water and wet surfaces in the period from 2009 to 2018.

These layers are based on multitemporal and multiseasonal high-resolution optical satellite images. In addition, these layers are also based on radar information (Sentinel-1 data) with a geometric resolution of 10 m on a pan-European basis.

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[2] Copernicus data shall comply with Commission Regulation (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the interoperability of spatial data sets and services. Copernicus data shall not be subject to Regulation No 1089/2010.

(a) (b)

Fig.2 Maximum spatial resolution of the minimum reference unit (a) census section (b) square mesh net 10 m side

For the definition of this product is used a multitude of optical images and SAR that, covering a prolonged time series of 7 years, aim to capture as much as possible intra-dynamic annual within a given area and lead to a composite image per season (each season covered by 3 months) and per year during the observation period. The reference product is called Water and Wetness (WAW) and is characterised by the following defined classes of (1) permanent water, (2) temporary water, (3) permanent humidity and (4) temporary humidity. This product shows the presence of water and indicates the degree of humidity in a physical sense, assessed independently of the actual plant cover and is therefore not limited to a specific class of land use and its frequencies. The main advantage of using satellite data is that the data sampling scale is more accurate (Fig.2). In fact, in the first version of the methodology the minimum reference unit was represented by the census sections whose dimensions are variable according to the resident population defined by the National Institute of Statistics, as shown in Fig.2(a). Copernicus products selected by the authors in order to increase the above methodology are made available at a spatial resolution of 10 meters. The use of such data allows to increase the number of information points and to obtain a more detailed and uniform representation of the territory as represented in Fig.2(b). Having used indicators sampled at different levels (census section and spatial resolution of 10 meters), the final map was developed taking into account the spatial resolution of 10 meters after resampling the data referring to the census sections to the same scale. Increasing the quality of the result of the application of the methodology, that is the indirect assessment of resilience through vulnerability parameters, the relative potentialities in relation to the definition of adaptive project interventions increase.

3. Best practices in adaptive design to climate change

Adaptation planning has moved from a one-dimensional approach to an integrative approach that interacts with the concept of vulnerability and resilience (Ngoc Le, 2021).
As acknowledged by Fisher et al. (2022), one of the most challenging aspects of adapting to urban climate change continues to be the act of translating knowledge about vulnerability into action for resilience.
To this end, the authors have defined a summary of the main measures taken against climate change by analysing the projects eligible for funding under the Integrated Urban Plans (called PUI) and the National Innovative Programme for the Quality of Living (called PINQuA) funded by the Italian National Recovery and Resilience Plan. The best practices emerged are detailed in measures and actions. They appear closely related to the contents that characterize the wide recent scientific literature with reference to the principles of liveability, efficiency and safety of urban regeneration interventions (Tab.2). Recognizing the specificities of the best practices identified and summarized in Tab.2, it is clear that public spaces are a key system for testing the most appropriate strategies for reducing climate impacts.

In particular, with reference to these three principles, the following should be highlighted:

- urban liveability frameworks developed from a public health perspective seek to identify the tangible aspects of urban policy and infrastructure that shape residents' health and the results of urban sustainability (Lowe et al., 2015);
- an efficient system is important for resilience as it makes possible the cross-scale of synergies between the components of the territory, ensuring a certain degree of stability (Feliciotti et al., 2017);
- safety refers to the promotion of safe processes and relationships between inhabitants, prevention and reduction of risk exposure (López-Contreras et al., 2021; Tira, 2021).

As part of this study, the areas of project intervention are represented, therefore, by public spaces and are identified, based on the results of the mapping methodology described in the previous section, as the most vulnerable areas. In the next section we will demonstrate the usefulness of the framework briefly described here, in order to define possible project interventions.

Measure	Actions	Liveability	Efficiency	Safety
Increased vegetation in abandoned and degraded areas	Planting of trees and greening with the use of native species. The green areas represent dominant elements for the creation of spaces for the community, for the conservation and enhancement of the present vegetation system	Diz-Mellado et al. (2020); Alderton et al. (2021); Wang et al. (2023)	Baraldi et al. (2019); Badach et al. (2020); Han et al. (2020)	Campagnano et al. (2020); Fisher et al. (2021); Lis & Iwankowski (2021)
Improving the sustainable mobility system	Measures to limit the environmental impact of public transport and infrastructure by reducing land consumption and encouraging public transport services	Jones (2020); Brovarone et al. (2021); Trecozzi et al. (2022)	Cruz & Sarmento (2020); Holden et al. (2020)	Ozaki et al. (2022); Spadaro et al. (2022)
Construction of blue infrastructure	Development of areas characterized by dominant natural elements through the implementation of works of accommodation and mitigation of hydraulic risk, as well as containment of heat waves	Acierno & Coppola (2022); Sepe (2022)	Hamel & Tan (2022); Rosa et al. (2022)	Buldakova (2022); Palliwoda et al. (2022)
Containment of impermeable surfaces in buildings and public spaces	Interventions to increase permeability in built-up areas such as commercial and industrial areas through demineralisation processes of paved surfaces using Nature-Based Solutions	Liu et al. (2020); Sivestrini (2021); Escaffre et al. (2022)	Ruiz-Pérez et al. (2022); Twohig et al. (2022)	Ciriminna et al. (2022); Li & Bortolot (2022)
Energy efficiency of residential buildings	Realization of thermal coat systems, replacement of fixtures, realization of solar screens and modernization of lighting systems	Skalicky & Čerpes (2019); Okoye et al. (2020)	Athmani et al. (2023); Aslam et al. (2021)	Krarti & Aldubyan (2021); Mostafavi et al. (2021)
Production of energy from renewable sources	Implementation of interventions for the production of energy from solar radiation, wind, biomass, tides, sea currents and precipitation	Allam et al. (2020); Aboulnaga et al. (2022)	Akram et al. (2020); Wang et al. (2022)	Wen et al. (2020); Chien et al. (2021)

Tab.2 Overview of the main measures to combat climate change

4. Application and Results

4.1 The Municipality of Catanzaro's climatic vulnerability map

The proposed methodology has been applied to the Municipality of Catanzaro (Fig.3), capital of the Calabria Region (Italy). Catanzaro covers an area of about 112 square kilometres, following the North-South orientation, which goes from the mountain area of Sila to the Ionian coast of the region.

The first settlement developed on three hills but its expansion has advanced over the years developing towards the coast. Today, the territory is divided into 19 districts, divided in turn into suburbs and districts.

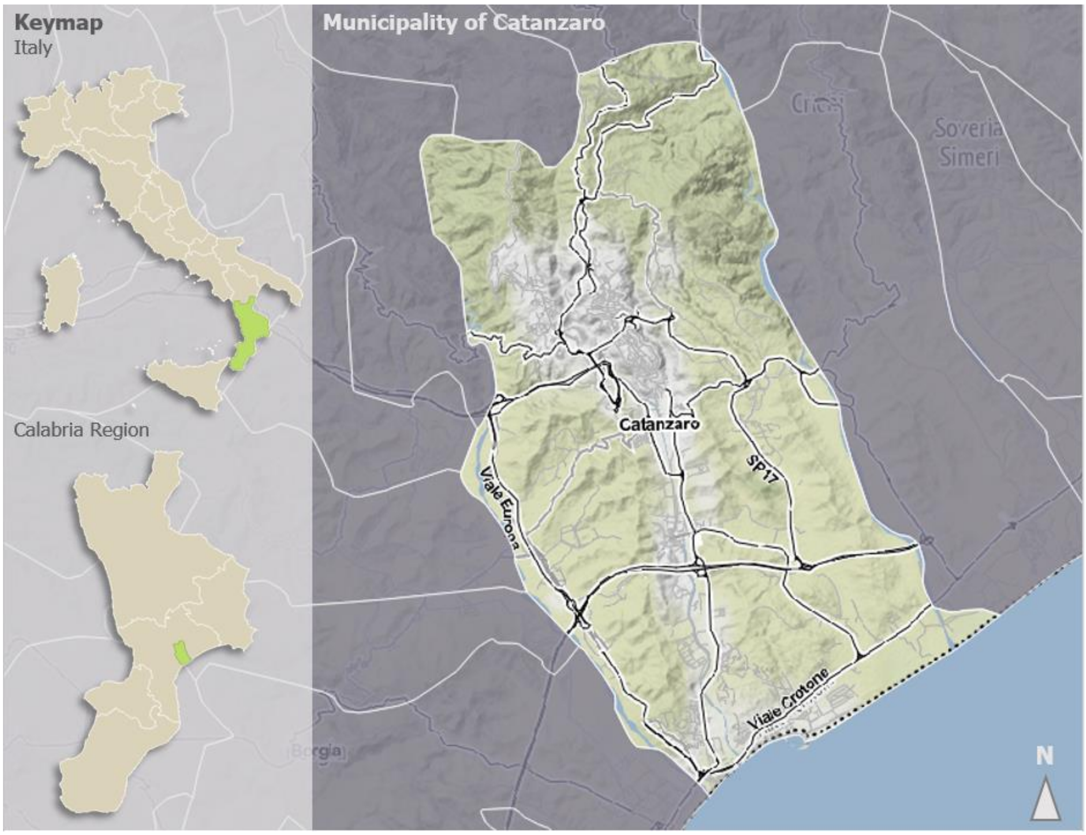

Fig.3 Municipality of Catanzaro's localization

The Municipality is equipped with a thermopluviometric station active in telemetry (cod. 1850) of the Functional Multi-risk Centre of the Regional Agency for the Protection of the Environment of Calabria (called ARPACal) useful for the acquisition of data useful for the sampling of climate exposure parameters (Tab.3). In particular, the data are derived from the historical series of minimum and maximum temperatures and daily rains in the climatological period of the last 10 years, that is between 2012 and 2021. The synthetic parameter of the climate exposure component was then calculated, according to the methodology described in the previous section, obtaining a value of 0.54. They depend on the characteristics of environmental and social capital (Fig.4). The relevant parameters derived from the information provided by the Copernicus satellite data and the Hydrogeological Order Plan.

Climatic exposure	Unit of measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
FD0	Days	0	0	2	0	0	4	0	2	0	1
TR20	Days	93	67	62	74	59	71	73	90	86	80
TNx	°C	28.6	25.8	24.8	26.3	25.1	27.9	24.7	25.5	25.6	29.2
TNn	°C	0.2	1.2	-2	1.5	0.1	-4.4	1.2	-1.1	2.9	-0.1
TN10p	%	9.8	9.6	9.8	9.8	9.8	9.8	9.8	9.6	8.7	9.3
TN90p	%	9.6	9.8	9.3	9.3	9.8	9.6	9.8	9.6	10.1	9.8
SU25	Days	121	112	106	99	109	111	117	123	109	116
TXx	°C	37.8	38.8	36	36.7	33.8	36.9	33	35.8	34.8	39.9
TXn	°C	5.8	6.6	7.1	6.2	3.5	2.5	6.9	5.8	6.2	2.3
TX10p	%	9.6	9.8	9.3	9.8	8.7	9.8	9.3	9.3	9.8	9.8
TX90p	%	9.6	9.6	9.8	9.8	9.3	9.8	9.8	9.6	9.8	9.8
WSDI	Days	22	9	13	6	0	20	14	10	8	26
RX1day	mm	104.2	140.4	79.6	73.6	80.6	201	101.2	58.6	109.8	70.2
Rx5day	mm	179.8	215.6	188.6	142.8	98.8	249	229.6	124.8	158.8	92.4
R10	mm/Day	12.4	13.9	10.9	16.6	12.2	11.7	15.0	12.2	9.8	10.3
R20	Days	35	37	28	34	36	20	43	43	20	37
R95p	Days	16	19	15	22	15	8	24	24	7	13
SDII	mm	634.4	731.4	557.8	744.8	567	542.6	853.8	525.8	463.6	487.8

Tab.3 Evaluation of climatic exposure parameters on the data recorded by the rain thermometer 1850 ARPACal

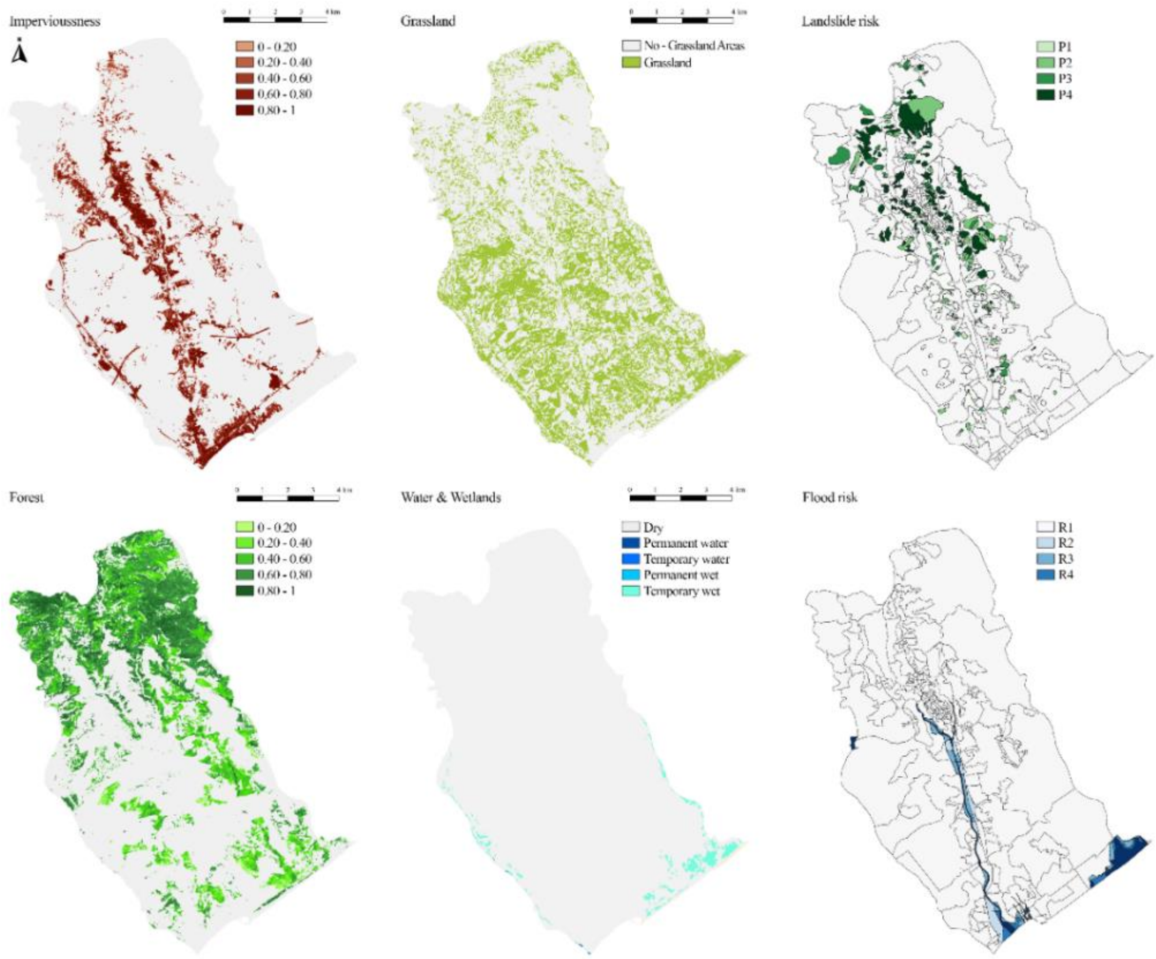

Fig.4 Mapping of some sensitivity parameters related to environmental capital

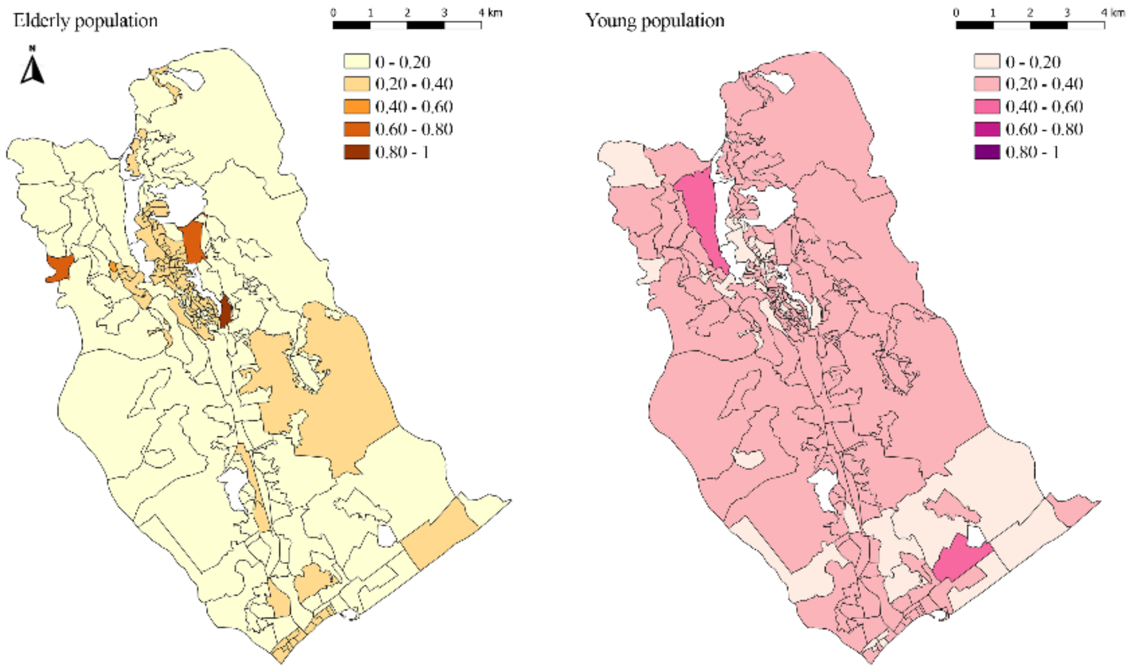

Fig.5 Mapping of some sensitivity parameters related to social capital

The elements belonging to the share capital are taken from the data of the National Institute of Statistics and have allowed to define the parameters relating to the elderly and young population (Fig.5). The two parameters influence the development of the climatic vulnerability map because they have a physiological and socio-economic status that makes them susceptible to climate change. Fig.4 shows the results obtained in GIS.The parameters relating to adaptive capacity assume unique value in the municipal context, with the exception of the state of conservation of buildings.

The category of knowledge allows to observe if the inhabitants have skills or have easy access to tools that can facilitate the interpretation of the information. A higher level of education allows society to be more resilient as it is able to cope with dangerous events. With the category of resources, we analyse what the territory offers at the level of services and properties. For the parameter of the state of preservation of residential buildings, depicted in Fig.6, the presence of buildings in good or excellent condition contributes to reducing urban vulnerability.

Sampled parameters of the three components of climatic vulnerability, the transfer of information in the GIS environment allows the different data levels to be presented together in the same map. Based on the data collected and the parameters obtained, the mapping relative to the Municipality of Catanzaro is the one shown in Fig.7 and allows you to visualize through colour bands the different levels of vulnerabilities.

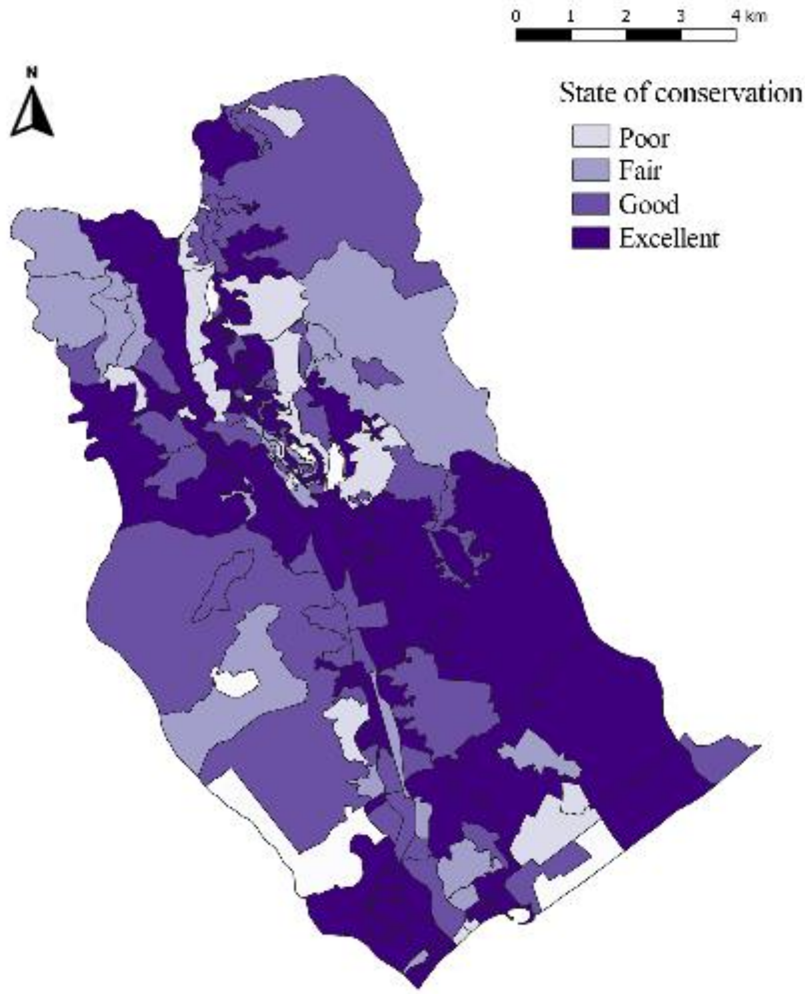

Fig.6 Conservation status of residential buildings

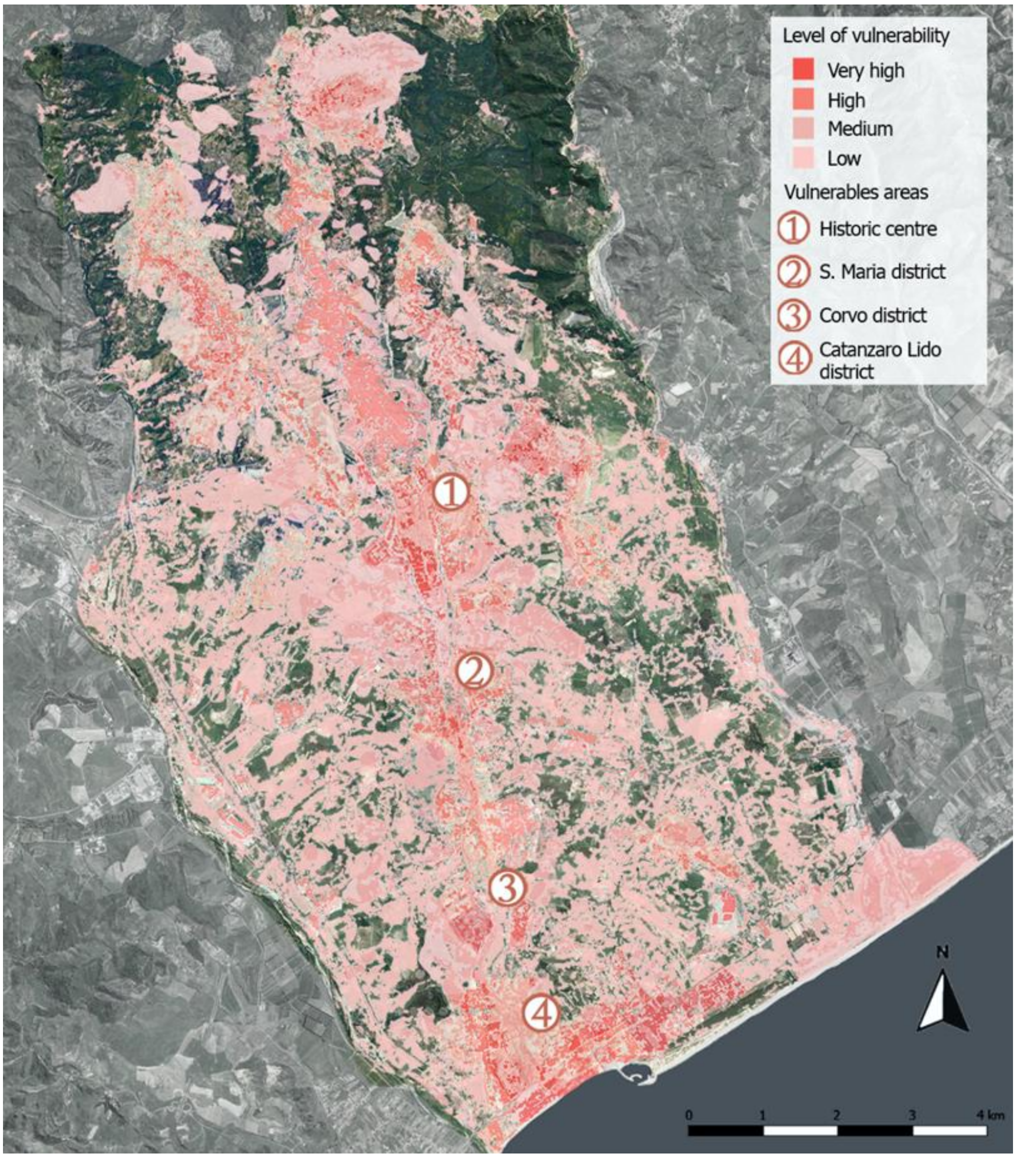

Fig.7 Municipality of Catanzaro's climatic vulnerability map

4.2 A context-based adaptation strategy for urban regeneration project

The elaboration of the climatic vulnerability map is a fundamental element because it is the starting point to integrate the appropriate adaptation measures in the urban regeneration processes of the Catanzaro context. By proposing possible design solutions, the authors intend to demonstrate the importance of supporting these processes through data-driven methodologies to achieve better results. In this specific case, the vulnerability map is useful to identify the priority areas of intervention and address the project interventions for the regeneration of areas and public spaces already built, increasing environmental quality and improving resilience to climate change. In fact, the definition of the Mapping of local climatic vulnerability has made it possible to identify the most vulnerable areas on the territory of Catanzaro that is those that are most likely to be at risk because they are less resilient, where to test some of the measures presented in section 2.2. In particular, in the analysed context it is possible to observe an average level of vulnerability spread throughout the territory and four areas with a particularly high level. These areas are located in the historic centre and in the districts of Santa Maria, Corvo and Catanzaro Lido.

The focus was on the two areas located further south, namely the districts of Corvo and Catanzaro Lido, which, due to the settlement characteristics described below, make it possible to demonstrate the urgency of integrating the most appropriate mitigation measures into urban regeneration processes.

The choice of the Corvo district is justified by the particular socio-economic condition that characterizes it.
The district, in fact, houses a large settlement of public housing, characterized by the absence of infrastructure and services. The history of this district begins with an unfavourable situation that led to greater degradation when, in the eighties, such residences were assigned to Roma citizens, because of the eviction of their huge camp located in another district of the city of Catanzaro, creating a difficult coexistence with the population already present. These situations of degradation and marginalization continue to the present day, determining the permanence of a complex social situation.
The coastal area of Catanzaro Lido, which is older than the Corvo district, is located on the southern outskirts of the town of Catanzaro. With the establishment of the university complex in the nearby Germaneto district, the area has undergone a huge demographic increase, to the detriment of the ancient area of the city. This sudden increase has led the city to face a greater demand for housing supply and a consequent uneven development. This problem still persists today and is the cause of considerable criticalities such as the presence of unmanageable traffic especially in the daytime peak and weekend night hours that lead the neighbourhood to be frequented by many young people due to the presence of numerous locals.
The main regeneration objectives for the two districts under study are:

- define integrated interventions that combine architectural recovery with the introduction of new urban activities and functions;
- restore the "sense of place" especially in spaces that have become marginal solving the lack of identity of a community;
- define a unitary development strategy that guarantees quality standards, low costs, minimum environmental impact and energy savings;
- contain the consumption of new soil.

Alongside the regeneration objectives are the resilience objectives aimed at increasing the ability of the system to cope with risks while preserving its essential functions and its adaptability and transformation capabilities. By narrowing the field to climatic risks, the main targets of resilience aim to:

- understand the vulnerability that characterizes the territory, recognizing how "understanding how shock and stress increase risks is the first step towards building resilience" (Urban Land Institute, 2018);
- making the territory socially resilient by strengthening employment and housing opportunities;
- redefine how and where to build through understanding the function and geography of systems;
- maximising co-benefits, improving quality of life and potential economic development.

The objectives of regeneration and resilience described are intended to stimulate the resilience of the city in assuming a management of public space that is able to respond to the new needs of the people living in them, revitalising the social fabric in disadvantaged areas and offering a new model of living for the weakest sections of the urban population. The actions that identify individual projects or proposals for specific action are the result of a planning process that, starting from the general objectives of regeneration and resilience, leads to the identification of the lines of project intervention, which define the specific objectives to be pursued in the proposed regeneration of the districts of Corvo and Catanzaro Lido.
In particular, the adopted strategy is articulated in three lines of participation that, echoing the principles of reference anticipated in section 2.2, describe the characteristics that are intended to attribute to the two areas: liveability, efficiency and safety. The goal of the line of action "liveable neighbourhood" is to improve the quality of life, or strengthen the conditions of use of the neighbourhood through the implementation of elements that can encourage its development and contribute, in general, to the definition of a smarter city.

The specific objectives of this action line are:

- redevelopment of the habitat of neighbourhoods with the inclusion of high-efficiency urban furniture;
- redevelopment of public squares and spaces through the reduction of paved surfaces;
- promotion of public green spaces by creating green areas and urban gardens;
- promotion of interventions in sports facilities using efficient systems and materials according to the principles of sustainability;
- promotion of alternative housing solutions with the promotion of social housing and student housing.

The intervention line "efficient neighbourhood" intends to spread services to the person at the scale of the neighbourhood such as the construction of gardens and meeting areas and the implementation of shops in the premises not used. In addition, there are initiatives and projects that involve citizens who, through the collaboration of professionals, can contribute to achieving shared regeneration goals.

This line of action concerns the overcoming of the mono-functional character of the "dormitory district" of the Corvo area and the criticality of the Lido area relating to mobility. The specific objectives of the action line are:

- increase of specific services for residences and promote meetings with citizens to discuss issues;
- encouraging the use of public transport and the provision of bike sharing and cycle paths;
- improvement of waste collection activity thus avoiding the accumulation of garbage in residential areas.

With reference to the last line of intervention, the adjective "safe" alludes to actions that contain the effects of extreme weather events that have characterized especially the neighbourhood of Lido and, as a result, helping to make it an environmentally safe neighbourhood.

The actions are aimed primarily at areas near the Fiumarella stream and the Alli river where, in the past, sudden heavy rainfall has created severe hardship to the population.

Fig.The specific objectives of this strand are:

- maintenance of watercourses by cleaning and removing vegetation that invades the riverbed;
- control of the built with the promotion of expansion policies that do not allow the inclusion of infrastructure in areas close to the waterways;
- introduction of monitoring networks with the activation of flood pre-announcement measures;
- implementation of blue infrastructure as works of accommodation and mitigation of hydraulic risk.

The planning activity, in particular, involves two areas belonging to the Corvo district and one belonging to the Catanzaro Lido district and insists on uncovered areas with the aim of creating useful services for the community (Fig.8).

Fig.8 Plans and renderings of the interventions

For the first district, the realization of a public space through the de-waterproofing of the soil is proposed. The aim of the intervention is to make the place accessible to the citizens of the neighbourhood, thinking of older people, through the promotion of activities useful to make them part of a large community. The second project focuses on the theme of sustainable mobility through the creation of a cycle path with the use of ecological materials and the promotion of the practice of recycling through the installation of recycling incentives. For the Catanzaro district, Lido proposes, instead, near a school building, the construction of an urban garden used both by citizens living in that area, and by the school for educational activities. The aims of the creation of an urban garden are many and include environmental education, food, and the preservation of agricultural biodiversity. The projects, although briefly described, aim to support, in particular, three of the measures already illustrated, namely: increased vegetation in abandoned and degraded areas; improvement of the sustainable mobility system; containment of impermeable surfaces in buildings and public spaces.

5. Discussion and conclusion

Public responses to impacts associated with climate change at the local level are mostly shaped by prevailing socio-cultural knowledge systems, supported by resilience thinking in the face of change and adversity (Iñiguez-Gallardo & Tzanopoulos, 2023). According to the same authors, climate change mitigation and adaptation planning and action must be informed and implemented within specific contexts. Communities depend on local policy tools to identify threats, determine goals, and implement strategies. As a result, many cities around the world have developed climatic adaptation plans to reduce climatic impacts in recent decades (Tu & Yu, 2023). To this end, nature-based solutions (Mazzeo & Polverino, 2023) enhance the potential for climate change mitigation and adaptation in cities. Among the environmental benefits of these measures, increasing biodiversity, increasing carbon storage, reducing extreme temperatures and controlling rainfall (Epelde et al., 2022). The evidence presented by this study indicates a possible path for the improvement of urban resilience oriented to the realization of a liveable, efficient and safe city with respect to climate change. The main idea behind this study is that to ensure greater synergy between the processes of urban regeneration and containment of climatic risks it is necessary to base planning choices on a quantitative and spatial analysis of climatic vulnerability local. To support this position, the authors have updated and applied an experimental methodology of climatic vulnerability mapping to the Municipality of Catanzaro. In particular, the update of the methodology has allowed to introduce a reflection on the usefulness of using satellite data in order to obtain better results in terms of spatial resolution of the output mapping. The application of the methodology has proved to be a useful opportunity to quantify and localize the main issues of the context of interest, enabling you to plan climatic adaptive design strategies and interventions consistent with the characteristics of the analysed context and in line with the best practices and principles known to the specialist literature in the field.

In the planning phase of the interventions, in order to define a set of transformation actions, the objectives of regeneration and resilience have been defined. Tackling these objectives synergically presupposes the development of innovative design methods, which must be able to manage the complexity of information and orient urban regeneration strategies in a multiscale perspective. In the proposed case, the defined interventions attempt to respond to the so-called "housing issue", understood not only by referring to socio-economic aspects, but also by analysing issues such as degradation, habitability and sustainability of public spaces. The actions that identify individual projects or proposals for specific action are the result of a planning process that, starting from the study of the state of the art and the general objectives of regeneration and resilience explained, leads to the identification of the lines of project intervention, which define, in turn, the specific objectives that are intended to pursue in the districts of Corvo and Lido and the Municipality of Catanzaro.

The strategy adopted attributes to these districts three lines of action representative of the principles attributed to the two areas are liveability, efficiency and safety. Although the proposed methodology is not yet able to fall into the totality of climatic issues, or to consider the entire management of building and urban processes, the results described provide a first cognitive and experimental input in relation to the definition of climatic adaptive design interventions for the study area. They are useful to guide innovative processes of planning and design. In this regard, future research developments consist of deepening these issues in depth with a focus on the link between infrastructures and communities for the climate resilience of urban, but also rural and coastal areas, also through the activation of a research group between the authors' Department and the Italian Institute of Atmospheric Sciences and Climate, National Research Council (ISAC/CNR). In general, the results presented show that urban planning is the preferred area for understanding the level of local vulnerability, assessing expected impacts and identifying priorities for action. In this regard, according to Fisher et al. (2022), a common problem is the difficulty that planning staff may encounter in tracing the specialist information that can be used to develop policies and strategies as part of a comprehensive and comprehensive programme of interventions and projects that ensure climatic resilience. It emerges, therefore, the need to activate collaborations and support activities of local authorities to encourage the interaction between competing skills and institutional subjects in order to determine shared paths in the definition of urban development processes based on the effective translation of knowledge about vulnerability into action for resilience.

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Image Sources

Figg.1 - 8: Authors' elaboration

Author's profile

Annunziata Palermo, associate professor in Urban and Territorial Planning at the University of Calabria. Her research's interest concern: the strategic planning of integrated territorial systems, the sustainable regeneration of "marginal" and disused areas, the multirisk analysis methodologies for the prevention and safety of urban resilience, the multilevel governance in cohesion policies.

Lucia Chieffallo, post-doc research fellow at the University of Calabria. Her research focuses on the study of interrelationships between services, infrastructures and settled communities with the aim of individuating possible solutions for sustainable and resilient planning in urban and territorial areas.

Sara Virgilio, PhD student at the University of Calabria. Her research is aimed at defining data driven tools to support urban and territorial planning with a focus on intervention monitoring systems.

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Spatial-cognition ontology models in policymaking: dealing with urban landmarks in literary narratives

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Abstract

Urban complexity is expressed through multiple and multiform directions and dimensions. With the aim of operationally managing such complexity, scholars have recently started uneasy research toward the construction of system architectures to support informed and aware policymaking. In particular, agent-based modelling efforts have been developed using the so-called applied ontologies. These models appear promising towards supporting complex relational and cognitive interactions in processes of urban decisions. Increasing simulation and experimentation activities are now oriented towards the support of ontology-based spatial planning processes in the real world. In the current planning context, where natural discourses and narrations are embedded in participatory plans, useful answers can also be provided by the narrations of some literary works, in the aforementioned sense. The work we have carried out explores the spatial representations included in those narratives, trying to develop ontological analyzes based on complex structuring characters and features of the represented urban spaces. The work is based on multi-agent experiments carried out with university students, who have extracted some passages from literary works dealing with urban environments. In particular, the paper analyzes some narratives focused on the urban square (or 'piazza'), with the aim of drawing out an ontology of it including aspects of literary semantics.

Keywords

Knowledge Management; Decision Support; Urban Planning; Ontology; Literary Works.

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1. Introduction

A city is an open and very dynamic multi-agent system: new properties always emerge from such complex dynamism (Portugali, 2011; Papa et al., 2021). Human agents characteristically contribute to complexity in terms of relations and behaviours, which are explicit or tacit, stable or uncertain but fundamental in city evolution (Simon, 1991; Borri et al., 2013). Multi-agent models, supporting complex cognitive exchanges and decision-making, today appear as possible system architectures and technology becomes a determining factor in characterizing a smart city as such (Geertman et al., 2015; Pereira et al., 2016).
Today, this concept of smart city represents a multi-agent entity (an 'agency') connected autonomously but intimately intelligently. This multifaceted conversion of complex knowledge into planning and dynamic decision-making has been recently tackled by an ontology-based approach, as a formalization model behind smart city management architectures (De Nicola & Villani, 2021; Stufano et al., 2018; Borgo et al., 2021).
In spatial planning, a traditional social inspiration often involves aspects of storytelling and narrations (Goldstein, 2015). In this direction, different literary genres have always grappled with the representation of spaces: prose, poetry, novels. We explore these spatial representations with the aim of using the knowledge encapsulated in literature works for developing and empowering an ontological analysis for the city (Caglioni & Rabino, 2007: Falquet et al., 2011).
This is carried out in a future perspective of building an ontology for the city that could be useful to operationally support planning and decision-making as well as designing activities in urban regeneration or development processes.
We have taken a starting analytical step from a multi-agent experimentation carried out with university students, in which literary works have been selected and analyzed with the aim of singling out representations and salient aspects of urban environments - according to the judgment of each student (Stufano Melone et al., 2019). In particular, the present research work focuses on one of the main city landmarks - the urban square (Lynch, 1960) towards a future perspective of building a planning-oriented ontology of it.
This was carried out by comparing a taxonomy of literary semantics with a more traditional taxonomy coming from urban planning manuals.
The rationale was to investigate actual differences in catching spatial-cognition complexities from a technical vs. a literary reference perspective - thus implying that they are both useful in their different aspects (Dodi, 1972; Moughlin et al., 1999; Tagliaventi, 2007) and at the same time useful in a joint use. Beyond the present introduction, chapter 2 deals with the substantial background framework of the research, whereas chapter 3 briefly discusses possible roles of ontologies in city planning. Chapter 4 then introduces and discusses relevant parts of the experimentation, leading to the conclusion chapter with brief final remarks and follow-up perspectives.

2. Research background: how and why we looked at literary works

In this chapter, we offer a brief recap of our specific experimental research path, so as to better locate and frame the research layout.
The aim is to set up a clear description of this experimental work, toward the ontology-building future perspective. In our previous research we focused on the concept of the sense of place, a sort of look at the genius loci in a structured and analytical way.
The relevant objective was to build a knowledge system that was as rich as possible, in order to offer the possibility of supporting planning and organization decisions for the territory, the city, the environment that could cross a wide range of aspects while not neglecting the collective and individual experience that stratifies and characterizes (or vice versa is characterized by) a specific place (Stufano et al., 2017).
We have developed a taxonomy of levels that tries to highlight the composition of the place at the agent level, space level, artifact level and cognitive/social level (Stufano Melone et al., 2019).

Along this path, a first result was therefore a list of ordered levels, shown in fig.1, of an informative nature. A strong contextual aspect is inherent in the way we live in places, as human beings. At the current stage of research, we have reported a description (often implicit) of a place that includes at least what we can consider some relevant elements in it (Stufano et al., 2017).

Anyway it is important to point out that relevant literature explored the support of ontological analysis and applied ontology for the city, as well as land management and planning, often in different and at times alternative directions. As a matter of facts, some literature looked at just compiling taxonomy aspects (Meijer et al. 2014), others spent efforts trying to use a more organized and aware approach toward the complexity concept and its huge potentials (Ballatore, 2012; Calafiore et al., 2017; Acierno et al., 2017).

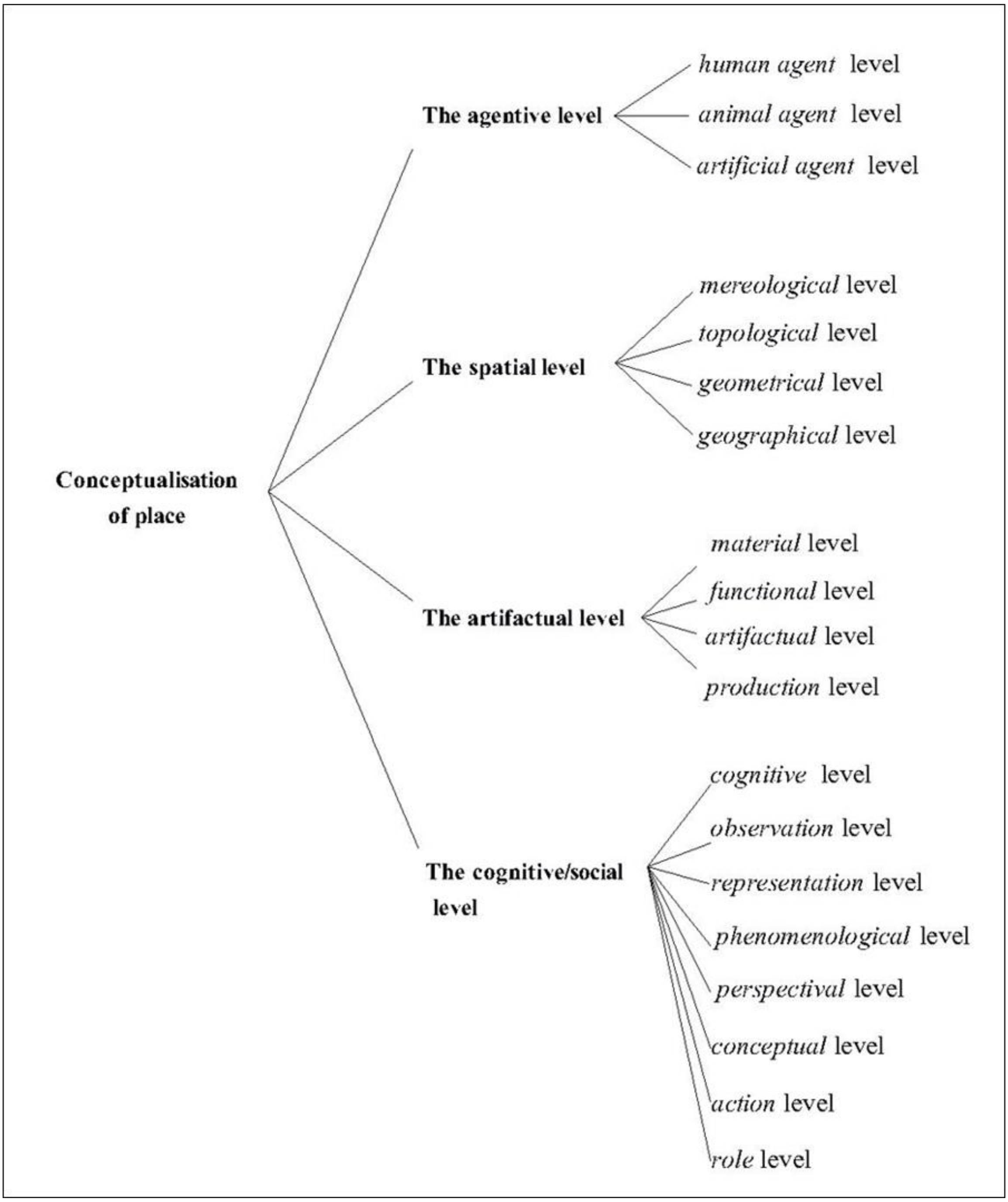

Figure 1 Conceptualization of place in terms of ontological levels (updated from Stufano Melone et al., 2019)

2.1 Narrative literature as a source of knowledge about the city

We said that the work is oriented toward a future perspective of building an ontology for the city. an ontology that could be an effective, inclusive and disambiguated knowledge support for decisions in planning processes (in the writing, monitoring and applying phases of a plan).

We know that in order to populate an ontology, it is necessary to collect knowledge (that is, in this specific field, to arouse elements and relationships related to the city system and its elements), also using known different techniques to achieve this goal (Asim, et al., 2018).

Previously we worked by eliciting knowledge from questionnaires answered by citizens involved in the participation of a planning process.

One of the most interesting processes concerned the city of Taranto, southern Italy, where we were part of a team charged of drawing the Master plan for the city (Stufano Melone et al., 2019). We reached a huge amount of knowledge about the 'places of the habits' or landmarks. Yet we became aware of how this was a limited part of what could be said about the city, as that type of 'narration' often appeared as somehow misled by strong impetus of rage or revendications.

It was not a question of right or wrong answers, but the primitive readability of the concepts risked being undermined. For sure questionnaires for eliciting a kind of knowledge translatable in our ontological-base system prototype should have to be built in a different manner and with a different frame of interaction. We thus started to explore alternative knowledge sources. In this light, literary products (i.e., romance, poetry, and narrative works in general) looked potentially helpful in integrating the conceptualization about the city in a wider sense.

The choice to look at literature texts arose while working with the protocols grabbed from the participants to a university class experimentation, and at the same time from the awareness that in literary creations nuances, aspects, relationships capturing precious moments and/or events are rather usual – whereas they slip away from the common narration of a citizen responding to a formal questionnaire in a planning process(Khakee et al., 2002). Aspects of conception, reflection and description about space often emerge in novels and poems. They can lead to interesting insights relating to a specific city or, as mentioned previously, relating to general aspects about the urban layout and about the relations of agents developing in manifold dynamics.

The tendency to enclose artistic, communicative or scientific expressions in watertight compartments, apparently distant from each other, can entail significant risks. In fact, it can lead to an incalculable impoverishment of the potential that a transversal synergy could offer to the various practices relating to different disciplines and disciplinary sectors. Books such as novels, poems, essays, or new form such as blogs are repositories of knowledge, they are often overlooked when dealing with practices related to actions such as planning, which are traditionally seen to be more linked to 'hard' disciplines – like economics, management, political science (Schon, 1983).

We reported the first explicit reflections in this direction in a preliminary work (Stufano Melone et al., 2019). Below we recall the very first two excerpts reported from two Italian works (fig.2 and fig.3), centered on the narratives of spatial environments. That first work can be considered an initial reflection proposal of our research group, about the integration of narrative texts in the context of knowledge elicitation aimed at planning and organization actions.

The two excerpts are very different from each other.

The first (fig.2) is the work of a contemporary author, Michela Murgia, recently passed away. It is taken from the novel Accabadora (Murgia, 2011) set in the early 1950s between Soreni, a small fictitious village in Sardinia, and the city of Turin.

Maria […] went out alone into the streets whenever she could, cautious but fascinated by the great city. Signora Gentili had told her the strange story of the rectangular street plan of Turin which seemed to have been designed in advance to fit the areas the streets were intended to lead to, on the principle that the citizens had had first to decide where they wanted to go, and only then to start planning and building their houses, squares and apartment blocks; the apparent illogicality of this led Maria to describe it in her first letters home to her sisters as an amusing novelty. This planning down to the last millimetre offended her good sense, convinced as she was that the only meaningful way to plan streets was the way it was in Soreni, where they seemed to have emerged from the houses like a seamstress's discarded scraps, clippings, and misshapen remnants, taken piecemeal from the spaces accidentally left over after the irregular emergence of the houses, which seemed to prop one another up like elderly drunks after a party given by their patron. Marta Gentili explained to Maria that the real reason for the geometrical plan of the streets of Turin had been security, since a royal capital must not offer rebels or enemies convenient places to hide, but this merely reinforced her view that to construct anything so deliberately on the basis of straight lines could only be an admission of weakness: who would ever take the trouble to design such straight streets unless they were trembling with fear?

Fig. 2 Excerpt from Murgia (2011), p.57 (original English edition)

We quickly cross the whole modern city: too westernized, too «Milanese», for our desire for the East. We end up in a long, wide, calm square. It is familiar - to me a provincial citizen - as if I had really crossed it, many years ago, a day of school walk «in a row».
We enter, through alleys, the old city; alive and at the same time remote, full of childhood.
An irregular square, strange, wonderful. On the one hand small houses in various movement and colors, a bit like a scene (in the ground remains of vegetables are scattered, after the market); and, opposite, the austere, simple, clear, bulk of a stone castle. Swabian castle (or Norman: names that make you dream). On the first ramp children run playing, shouting.
The Duomo, with its majesty, looms over another small, cheerful village square.

Fig.3 Excerpt from Romano (1960), p.118 (unofficial authors' translation)

The second excerpt (fig.3), written by Lalla Romano, a 20th century author and taken from some travel reports and published for the first time in 1960, reports the impressions of the author on her trip to Greece, passing through Bari (to which the excerpt is dedicated) (Romano, 1960).

Both passages are descriptions and reflections. The first concerns places imagined back in time with respect to the author's time,. The second narrates the author's impressions as a traveler who meets the urban reality of the city of Bari, Italy, contemporary but unknown to her. It is a southern Italian city, at the time full of an unknown and intriguing life for the author who perhaps prejudicially was looking for exotic aspects in southern Italy in the 1960s. The analysis of these passages provides a type of knowledge that is subjective, concerns the senses, perceptions and personal understanding of subtle aspects such as the intersections of lights or perfumes. These are elements that are part of what humans may consider their vision of a city, or more generally of a place (Stufano Melone et al., 2019).

2.2 From literary text to ontological analysis: some reflections

Let's start from the two excerpts shown in fig.2 and fig.3, focusing on what the excerpts actually tell. In both texts, interesting categories of perception and reflection on the urban layout emerge. The first text reports the reflections of someone not used to the right-angle layout of the streets, a reflection that may seem bizarre, in the eyes of those who live in western cities, or work with urban planning and/or design materials.

The right-angled layout is almost an automatism in both urban perception and conception, starting from Hippodamus of Miletus (5th century B.C.) passing through the Roman castra, reaching Ildefonso Cerdà (1867) and beyond. This makes us reflect on how our choices are based on social and cultural habits and/or automatisms and brings us back to reflections such as those left by Camillo Sitte (1889), in relation to the preciousness of the 'spontaneous' urban spaces of the European medieval city.

In Murgia's story, the objects that make the Soreni village (i.e. the buildings, that are mainly dwellings) actually create the map: there is not a functional distribution, decided and drawn down according to a pre-established scheme,to position the objects.

Certainly, such reflections enrich the knowledge base and allow for a wider, more aware and creative reflection and decision-making activities (Hofstadter, 1995; Stufano Melone & Rabino, 2014; Stufano Melone, 2019).

Yet they can be essentially prodromal to an ontological analysis, which is aimed at the disambiguation of knowledge and at the highlighting of objects, attributes and relationships in both static and dynamic aspects. Streets and houses, for example, clearly pertain to an ontological level of artefacts: however, they also pertain to a spatial and cognitive/social level. In this case it is possible to refer to the explanatory layout shown in fig.4.

In the second text, instead, everything is more centered on perception and cognition, on cognitive aspects, expectations, memories, sensations. They appear to be aroused by the place and by the naming of the large square, the narrow streets, the cathedral, the Swabian castle - both as a landmark and as an object of the imagination. Objects and relationships remain described according to strictly subjective attributes (Fig.5).

Course of the roads → Artefactual level → functional level → connection, distribution
Houses and streets
→ Spatial level → geometrical level → square angles, uncertain geometry
→ topological level → continuity of the empty space
→ geographical level → two different places, a town in the north and a village in an island
→ Cognitive/Social level → observation level → perception through sight
→ representation level → the conceptualization of a subjective map

Figure 4 Reflexions prodromal to an ontological analysis about the excerpt in fig.2

Crossing of the street → Artefactual level → functional level → distribution
street, castle, cathedral
→ material level → stones, colors
→ Spatial level → geometrical level → curbed streets, large square
→ topological level → a continuous space
→ geographical level → a city in the south-east
→ Cognitive/Social level → observation level → looking for east
→ representation level → imagination nostalgia

Fig.5 Reflexions prodromal to an ontological analysis about the excerpt in fig.3

3. Ontologies and urban landmarks in city planning

Our knowledge of the city greatly builds communication made of words - mainly natural language. Implicit meanings and semantics often do not reach the level required by inherent activities. Such complex richness and dynamics have always been a challenge for planners having only limited modelling methodologies and techniques to manage a great variety of information and points of view.

Formal ontology aims at bringing together different views, sharing disambiguated meanings, involving different agents of a process, with their behaviours (Masolo et al., 2003; Guarino et al., 2009). Our knowledge of places is a 'subjective knowledge', coming from intentions and experiences in individual and relational knowledge. It becomes a kind of representation of places, varying from agent to agent and even during an agent's life. In such sense, it is significant to refer to knowledge elicited from natural-language works.

Ontological analysis helps our reading of the knowledge domain, clarifying and organizing places, in terms of objects, properties and processes (Borgo et al., 2021).

The approach used here aims at supporting spatial planning and managing decisions in such integrated-knowledge perspective. With this aim, this paper draws its materials from a collective exercise carried out with the students of the Urban planning course at the Polytechnic University of Bari.

It was carried out by administering an interactive questionnaire with Google forms, through which each student was asked to select from their usual readings three literary passages that dealt with the city. Of course, we obtained a huge amount of material whose topics were the wider possible aspects, locations, landmarks of a city. Therefore, we tried to limit and contextually focus the analysis, by referring to the concept of square (or "piazza"). This assumption is in fact in line with well-known literature (Lynch, 1960) and refers to an element genetically embedded in a city. The purpose of the work was to explore the potential of structuring an ontology starting from the experimentation on Italian literary works.

Therefore, let’s now dwell a few lines to argue and focus our attention on the important "square" landmark.

Squares are urban spaces of variable shape, of more or less precious architectures, and more or less large, surrounded by blocks of buildings, often located at the crossroads of several streets.

The square is a collective urban space, in some sense it can be considered the primary node of the shape of the city. The urban system is made up of closed spaces and open spaces.

They are public places and private places: full (built) and empty (streets, greenery, squares), since the time of Agorà (in Greek ἀγορά, from ἀγείρω = to gather, i.e. a term used in Ancient Greece to indicate the main square of the polis, the city, where to meet and debate).

They are components of the urban tissue. Historically, in fact, the square can be defined as a space of public use and of significant architectural and urban planning quality, the barycenter of a specific urban area (Feraboli, 2007).

It is important to underline the social role of the square or system of squares. It is typically a heart of European cities and often by itself a chosen place to represent the centrality of the presence of civil and religious public institutions, as it is frequently delimited by the main city monuments with significant historical memories and privileged public function. From a cultural, historical and scientific point of view, the squares produced within the urban culture of the West constitute the formal space of the settled community, the spatial nucleus where the intersection of civil history, cultural movements, artistic tendencies, where material culture takes place, collective imagination, symbolic projections, consolidated rituals, popular traditions and behavioral habits (Dardi, 1987; Madanipour, 2003). In the object (organism) ‘piazza’ we can typically grasp the deep interweaving that links the civil history and the urban history of a city.

In the context of the European urban landscape, the squares of Italy typically represent an episode of richness and complexity, almost a cultural model. For example, just from the study of these ‘piazze’ Camillo Sitte built his theory of civic and urban art, at the end of 19th century (Sitte, 1889).

The great lesson of the Viennese historian lies precisely in the attention he reveals to the art of space, i.e., to squares as a masterpiece of urban art. Cities, anthropized places in general, feed themselves with, and live on, the life and awareness of those who inhabit them, who shape the character of them with their own cultural and social identification.

Conversely, from this point of view, unlived places embody an error that is not simply a planning one but a conceptual one, an error of political strategy.

Choices made in unlived places hardly include creative openings towards life situations to be developed: rather, they are rigid choices able to generate unexpected and unexpectedly aberrant life dynamics (Scandurra, 2001; Borges et al., 2014). In our case we are reporting literary texts that belong to the category of essays, specifically about architecture and urban issues, evidencing how critical and even political reflections in an essay can shape knowledge bases underlying planning decisions.

4. A literary-based experimentation

Having clarified the research reasons of focusing on the 'piazza' concept, we will now look in more detail at the actual experimentation. Out of 480 literary excerpts selected by 160 students, after eliminating double citations (i.e., many students citing same readings), as well as uncontextualized or undescribed squares, finally seven passages appeared adequate. They were four from novels/essays and three from poems. Relational graphic maps were drawn out to highlight the conceptual elements in each case.

An example is shown in fig.7, where the analyzed poem of the experimentation is Piazza Sarzano, a square in the city of Genoa, by Dino Campana (1989) (represented in fig.6). Aiming at a final ontological formalization of the square reported in the poetic/narrative literature, we started to explore ways of creating an effective taxonomic description of it. First of all, following a more consolidated approach to architectural research, we tried to analyze primitive elements and relationships that were mainly physical and spatial in nature.

Fig. 6 Piazza Sarzano (Sarzano square), Genova (© Google maps)

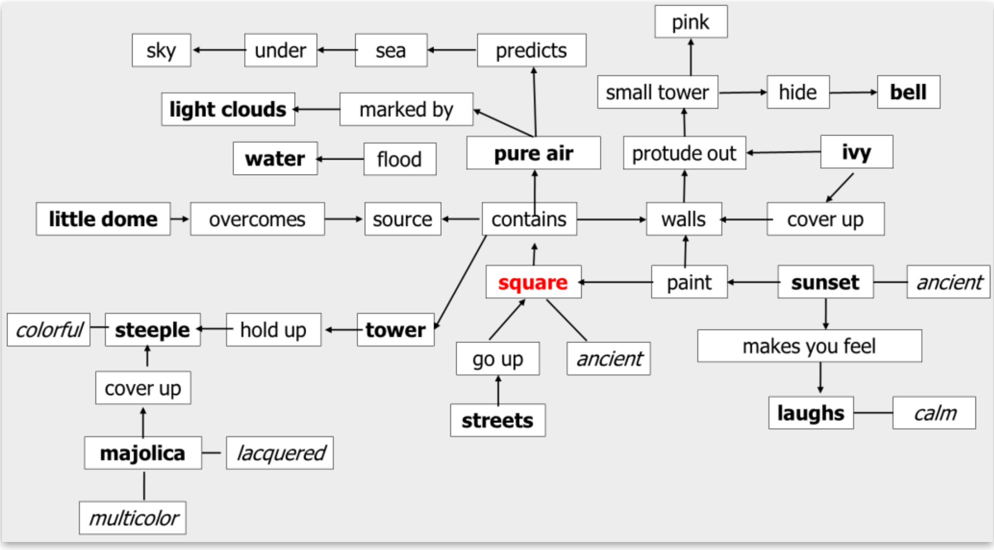

Figure 7 Example of a relational map of the 'literary' square (original language maintained to ensure consistency of meaning and of syntactic links: bold=nouns, locutions; italic=adjectives; other=verbs)

In this sense it is possible to trace some interesting analytical studies carried out on the constitution and spatial organization of monumental artefacts and historic buildings, occasionally or permanently frequented by residential or tourist agents (Cantale et al., 2021).

A good number of these studies refer, in particular, to conceptual models such as the CIDOC-CRM and the European data model (EDM). Specifically, the CIDOC-CRM ontology is related to the ISO 21127:2006 international official standard for controlled exchange of information in cultural heritage since 2006 (Doerr, 2003). EDM, instead, is an ontology useful to collect and connect cultural heritage information in order to support knowledge organization systems such as vocabularies and classification schemes (Isaac, 2013). Our first effort at ontological structuring partly followed this path, because it seemed to appear more responsive to the structure of the square as an artefact. From the analysis of the related database, a visible result emerged through the use of the Protege application software - a classification extract of which is shown in fig.8.

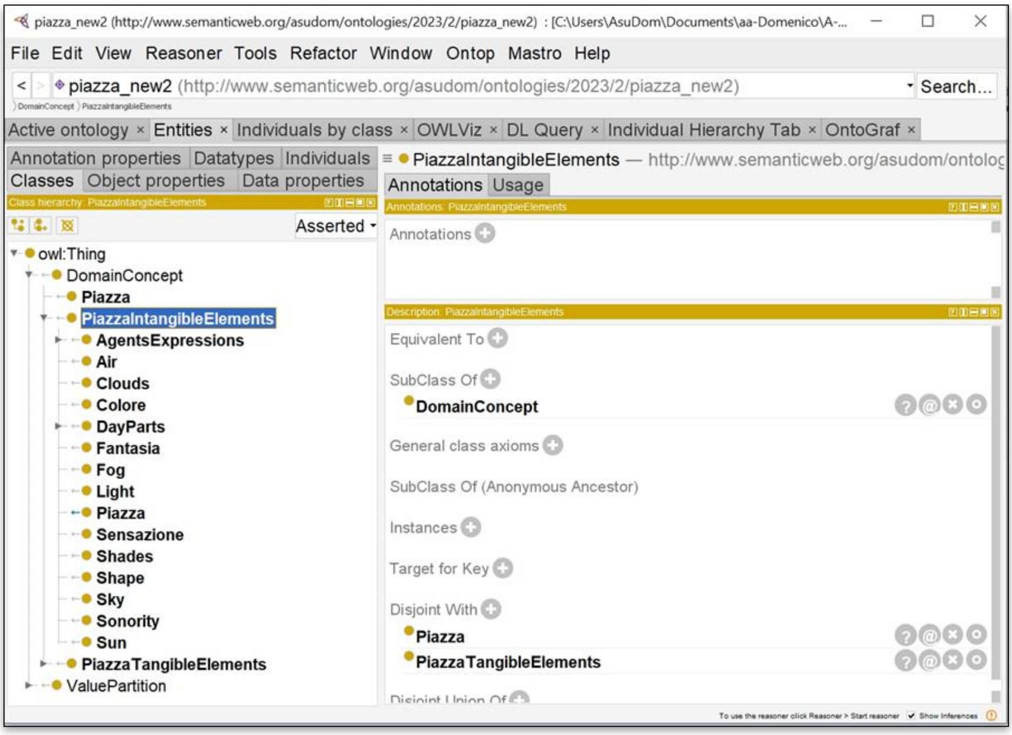

Fig. 8 Excerpt of the CIDOC-inspired ontology using Protégé software–Cidoc

In terms of mapping representation, the overall result is schematized in fig.9., showing the huge number of elements involved in the description and variously related, that take part in the building of the ontology. The classification is actually quite simple, defined through the use of tangible vs. intangible elements.

The tangible elements are basically referable to the elements mentioned in the texts of a physical type, such as water, clock, bricks, floor, window, bell, etc. In this group of classes, and related inherent and relational properties, a substantial coherence with the CIDOC system can be observed, even in the particular condition of open and extended space rather than of closed and confined monumental element. In fact, the conceptual model prepared by CIDOC makes essential reference to tangible aspects in the artistic, historical and archaeological fields. It also takes into account the cultural environments of location, thus partially including also the intangible heritage - especially in terms of traditions and cultural aspects (Biagetti 2016). However, the literary representation also transfers a large number of typically intangible elements in a very rich way, consistently with the multisensory and profoundly interpretative attitude of the writer.

Among the classes of non-tangible elements we find physical elements, such as air, fog, clouds, but also a significant presence of abstract, ethereal, behavioural, emotional elements. Some of these are visible, such as shadow or light, but others such as sensation are perceivable in other ways. Some are objectively shared characteristics, such as color, others are purely individual, agent-based, such as behaviors, expressions, crying, laughter, etc.

Especially regarding the elements we have called intangibles, therefore, the CIDOC system seems not very representative and coherent with the complex essence of a square. Furthermore, another aspect that seems little adherent to the deep expression of the text is the dynamic dimension of elements evoked by the writer. In fact, although this initial attempt at ontological modeling includes temporal variables, they are not structured through their dynamism - which in many cases is instead essential to represent the element. For example, the chromatic variation of parts of a square can constitute a structural characteristic of the square itself: it is an intrinsically dynamic intangible character, but limited both in configuration and in time, hard to be described by the static formalism of the CIDOC system. Ultimately, the square contains concrete, abstract, but also temporally concrete and temporally abstract elements, whose special structure can be a distinctive element of this socio-spatial, urban and environmental landmark. In this framework, a model -perhaps even only partially-reticent with respect to these complex aspects runs the risk of not including the management of that 'rich' knowledge (Meyer, 2001) useful for supporting the planning and/or organizational creativity and effectiveness beyond the operational skills formally acquired by professionals and decision-makers (Schön, 1983).

Following this reflection, we decided to go beyond this ontological modeling approach, more traditionally consistent with architectural and heritage aspects, albeit typically codified. We have therefore tried to use ontological models that structurally include temporal dynamics within them, as well as maintaining an operation-oriented approach, rather than just a descriptive one. We therefore used DOLCE ontology lite version, as a structure, being notoriously conceived as an ontological framework particularly suited for intangible and dynamic concept issues and properties (Borgo & Masolo 2010). An excerpt of the taxonomy of the square that includes all 7 maps of the literary works is shown in fig.10.

The taxonomy thus structured allows to maintain and highlight the representative complexity of the concept of square in terms of subclasses (as ‘classes’ are already formally defined on the ontological root of DOLCE).

The comparison between the ontology built on the poem and the one built on the manual reveals a different richness in concepts and focus. Literary taxonomy (LT) contains 121 subclasses. 63 subclasses appear as endurant, i.e. as something having no conceptually distinguishable temporal parts and thus existing in its entirety at each instant of its existence (e.g., being F at time t and nonF at time t+n) (Cresswell, 1986). Other 51 subclasses appear as perdurant, i.e. entities extended in time by temporal parts, that are partially present over time but may be not necessarily present along the entire time (e.g., one phase of a whole which is present now may not be present in the future) (Guarino et al., 2002).

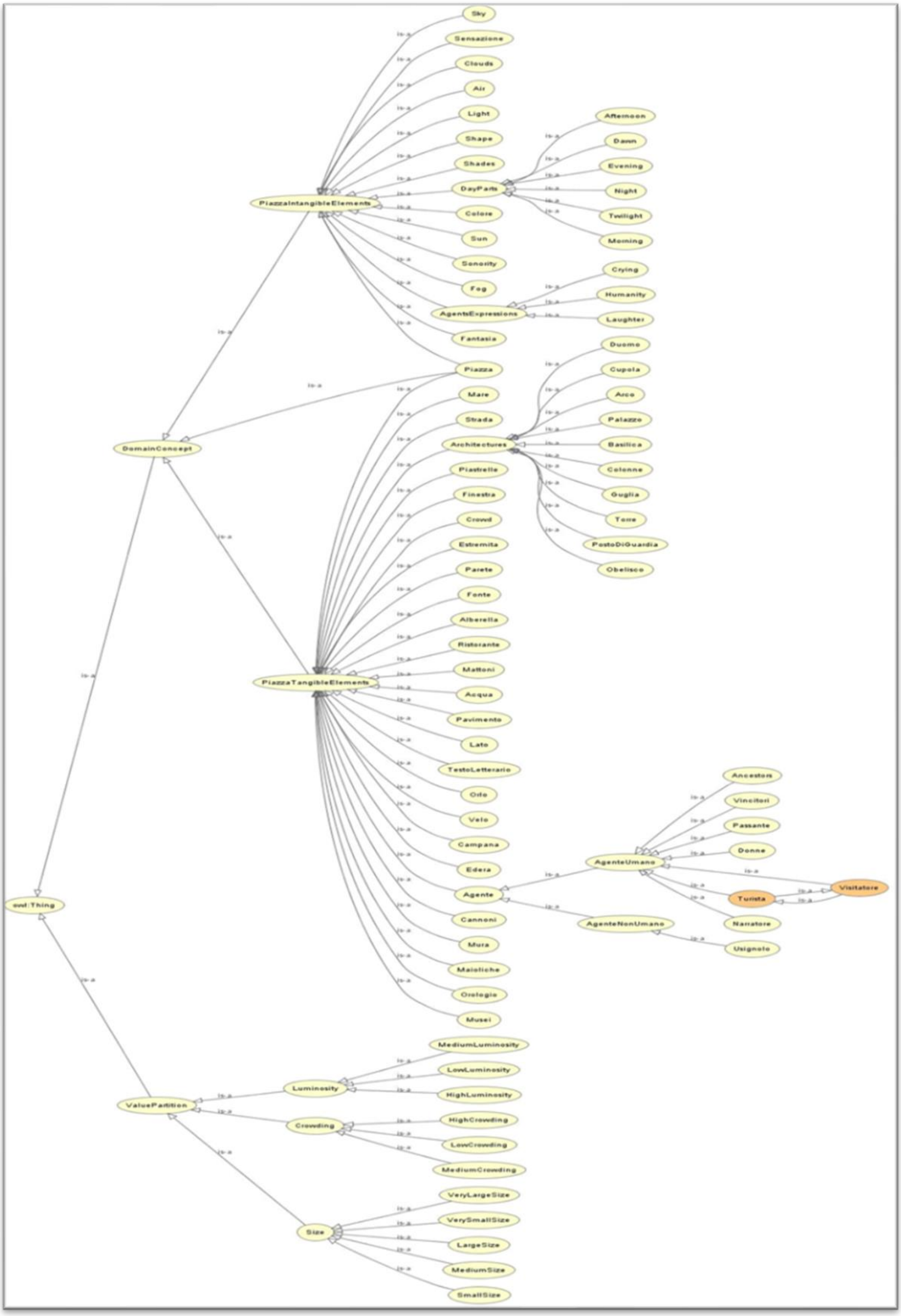

Fig. 9 OntoMap drawn from the CIDOC-inspired ontology using Protégé software (potential disaggregation highlighted with different color selection)

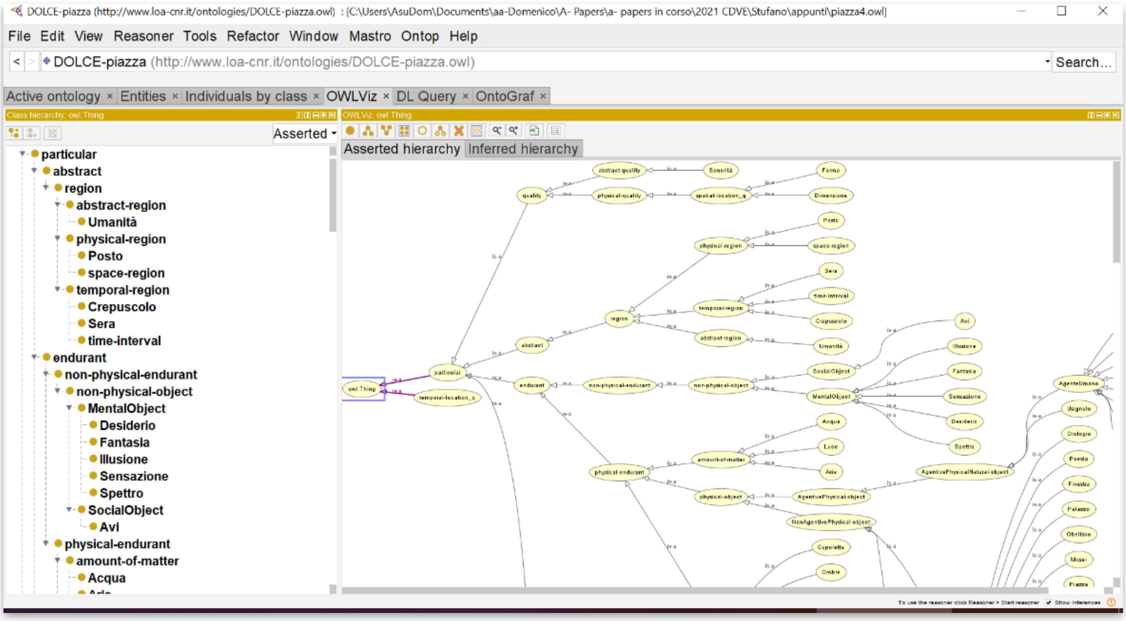

Fig. 10 Excerpt of the taxonomy of the square including maps of the literary works (Protégé)

The rather numerous amount of endurant and perdurant suggests that in LT the elements of dynamism of the square (particularly perdurant) are fundamental to characterize its conceptualization. This seems to be in line with the role played by the square in the spatial and social organization of the city (Madanipour, 2003).

In this regard, a comparative analysis was carried out with texts from traditional urban architecture and planning manuals (Dodi, 1972; Moughtin et al., 1999; Tagliaventi, 2007). An excerpt of the 'traditional' square taxonomy (TT) is given in fig.11.

Along this representation, TT contains only 23 subclasses, with 17 endurant (essentially physical elements) and only one perdurant ("observing") subclasses. Comparing LT and TT, an imbalance between endurant and perdurant seems evident, so at least suggesting that the role of time is very limitedly considered in TT, while it seems a great value in LT. A physical and static vision emerges in TT, basically excluding 'piazza' from the flow of life of a city. This circumstance is also confirmed by the absence of agentive components in TT (in LT they are 10) and of temporal regions in TT (in LT they are 2). Concerning mental objects, as part of the non-physical nature of endurants, there are 5 in LT (individual perceptions, sensations, active motions), while they are 2 in TT with a focus on generalizing a subjective interpretation rather than on individual aspects of perception. This suggests an underestimation of the intrinsic complexity of the urban 'piazza' in TT.

The disproportion clearly reflects intrinsic characters, where the sober TT derives from an articulation coming from non-descriptive but design needs, in which much is typically left to the sensitivity of the designer and many elements of abstract characterization are considered implicit and embedded in the effect of the final composition. Yet LT has the merit of making a large part of those tacit elements explicit, limiting the interpretation of the planner or designer to a more intimately creative or 'artistic' part towards the achievement of more aware and informed decisions, suitably reducing operational discretions without constraining them (Stufano Melone, 2019). In general, since a large part of the subclasses of TT are possibly articulated within LT, a single integrated ontology can be drawn in some cases. Once the ontology is complete (with properties, instances, data, etc.) many examples could be cited in an implementation-oriented perspective. For example, a design task of a square stimulating sense of security in socialization during twilight ('sense', 'security', 'socializing' and 'twilight' are in fact represented classes) could be supported by an ad-hoc query made on the square ontology. A useful design support would be guaranteed especially referring to LT, since the use of TT alone would in any case imply a high degree of interpretative discretion on the part of the designer, which might not guarantee an adequate response to actual needs in a complex operational context.

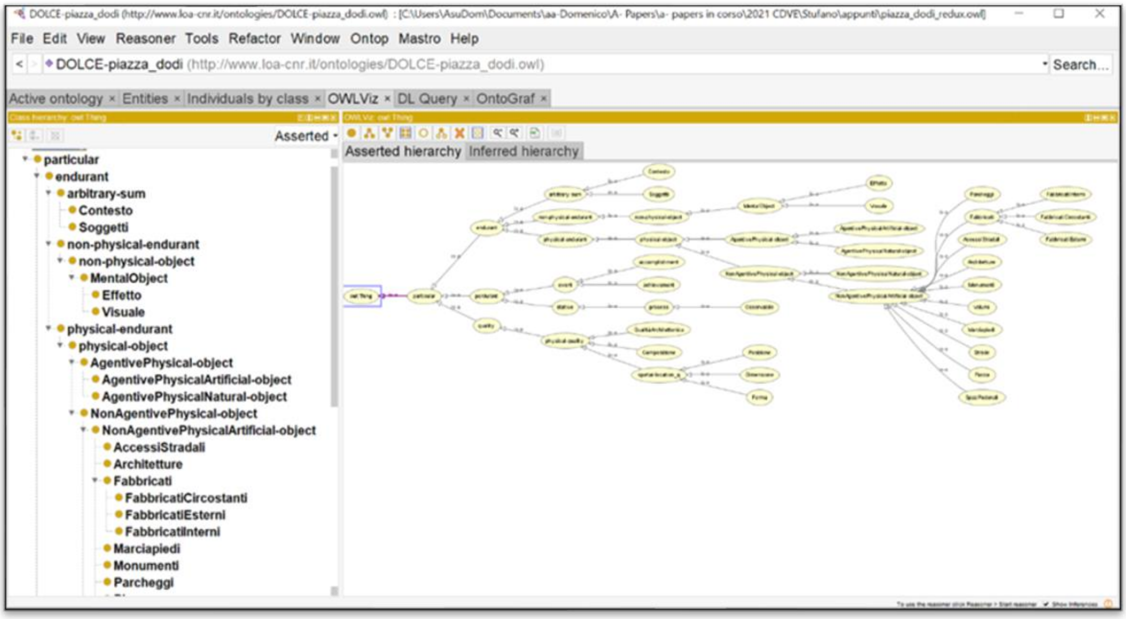

Fig. 11 Taxonomy of the square taken from manuals, on DOLCE lite ontology (Italian excerpt from Protégé 5.5.0)

5. Conclusions

Our previous and still ongoing research activities refer to the management of diffused multiagent and multisource knowledge. The present work tried to explore the usefulness of building ontologies (in perspective) based on literary narratives, using various conceptualizations of the urban square within an experimental approach. The ontological analysis of the literary square has shown a fair possibility of building a coherent taxonomy, rather rich in concrete, abstract, situational, dynamic and agentive elements, to interestingly represent the square role in the city complexity.

Based on the results, it is likely that such an approach could be extended to other landmarks or important elements of the city, so figuring out a perspective of extension of the approach to the city as a whole. Dealing with the elicitation of 'wicked' (Rittel & Webber, 1973) knowledge elements that are not always easy to draw, decision-support models and systems (DSS) can appropriately benefit from ontologically integrating literary narratives. In a context such as the urban one, where social and environmental complexity is pervasive, the possibility of developing complex models becomes precious. Although a complex system is made up of parts whose interconnections are as relevant as the parts themselves, the construction of partial but intrinsically complex models is itself clearly valuable. The possibility of creating ontological models of an urban element, which includes a material and immaterial multiplicity of characters and relationships, shows up as a guarantee of complexity, albeit partialised. Indeed, partialised models require relevant successive efforts towards an integrated urban ontology, possibly guaranteeing unitary visions of the analyzed context. And this is oriented towards supporting progressively aware and systemically effective urban decisions and policies. However, the ontological approach does allow processes of horizontal scalability and interoperability within its own methodological roots. In this sense, modeling approaches applied and/or applicable in real cases have also been developed (Falquet et al., 2011; Husain, 2011).

As a follow up, the ontological construction of the square will be completed including properties, instances, formal relationships, thus enabling an ontology-based DSS (Decision Support System) functionality. Subsequently, an attempt will be made to extend the ontological structure to other urban parts, up to targeting the entire city system if possible. This longer-term, ambitious perspective is in line with the current debate about urban digital twins (UDT) models, whose current complexity limitations can be challenged by exploring ontological approaches.

Authors' contributions

Within a common research work, jointly conceived and carried out by the two authors, chapters 2,3 have been written by Maria Rosaria Stufano Melone, whereas chapters 1,4,5 have been written by Domenico Camarda

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Image Sources

Figg.1, 7, 8, 10, and 11Stufano Melone et al. (2017) and (2021)

Fig.2: Murgia (2011)

Fig.3: authors' translation from Romano (1960)

Figg.4, 5 and 9: original content

Fig.6: collage from Google maps images

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Urban planning for biodiversity

An assessment of green plans in Northern Italy

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Abstract

In the recent debate on the urban planning-biodiversity nexus, much attention is being given to the identification of goals, targets, and indicators from the global, European, and national levels and the application of these at the local scale through targeted policies and specific actions. This article attempts to identify a theoretical framework for the integration of biodiversity in spatial planning processes at different scales, through mainstreaming the ecological transition, rightsizing the strategies and policies for biodiversity recovery, and overcoming the different challenges found in local contexts. Furthermore, a sample of green plans and strategies from the Italian context is analyzed across a deducted analytical framework including four dimensions: biodiversity goals, targets, commitment to implementation, and public participation. Results from the analysis emphasize that the focus of the green plans is generally oriented to the conservation of existing biodiverse urban areas rather than radically igniting new possibilities in spaces where biodiversity can be restored, or it is already present but not perceived by local communities. Lastly, the article highlights four gaps characterizing the biodiversity-planning nexus in its theoretical and operational implications.

Keywords

Urban biodiversity; Green plans; Monitoring; Public participation.

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1. Introduction

The latest research on the biodiversity and urban planning nexus calls special attention to the fundamental role of biodiversity on human well-being, healthy planetary systems, and economic prosperity for society. This has been strongly reaffirmed at the recent global UN Convention on Biodiversity during the 15th Conference of Parties (COP15) (CBD, 2022). While it is widely acknowledged that urbanization has several negative effects on biodiversity, at the same time rich nature can exist in cities. This includes several habitats for plants and animals, where also native and endangered species live. Cities have also the potential to play a critical role in biodiversity preservation and enhancement with initiatives that preserve habitats and species, improve landscape connectivity, mainstream urban green planning, and enhance residents' knowledge and stewardship of biodiversity (Rega-Brodsky et al., 2022). Nevertheless, despite advances in urban shared governance, biodiversity "in action" still encounters several obstacles at many scales. These include significant challenges at the policy and the operational levels as well as in the consolidation of the necessary stakeholders' engagement to address critical urban transitions. It is becoming apparent that complex processes are not manageable with traditional policy-making and incremental changes and, therefore, require some radical transformations (Bradley et al., 2022).

Nonetheless, the hurdles to integrating biodiversity-related actions within statutory planning, in general, and in strategic and thematic planning such as green plans and strategies, in specific, are many. Several authors point to the following aspects:

1) the spatial scales in which the specific biodiversity actions could be implemented consistently (Reckien et al., 2023; Uchida et al., 2021),
2) the difficulties in monitoring and evaluating the processes of biodiversity enhancement (Ronchi & Salata, 2022; Castaldo et al., 2021; Ruf et al., 2018),
3) the governance, financial and political willingness to pay for biodiversity co-benefits (Bulkeley et al, 2022), and lastly,
4) the challenges of citizen engagement and public participation in long-term urban regeneration processes, especially those related to natural capital and biodiversity (Pluchinotta et al., 2022).

The main objective of this research relates to the understanding of the role that biodiversity plays in urban plans in Italy, specifically looking at the degree to which a typology of thematic plans –the green plans– embeds objectives, actions, and indicators in favor of biodiversity conservation and enhancement in urban and peri-urban areas. The research questions that permeate the research are mainly two: How do green plans and strategies address the objectives of biodiversity preservation and enhancement? What attributes and indicators can be identified from the literature to assess the role of biodiversity in green plans?

The research is conducted as part of the National Biodiversity Future Center (NBFC), one of the five national research centers created and funded by the National Recovery and Resilience Plan (PNNR) which is dedicated to the topic of biodiversity conservation, monitoring, and enhancement in the Mediterranean context (https://www.nbfc.it/), and specifically of the Spoke 5 oriented to investigate the multiple challenges related to biodiversity in urban contexts.

The article is divided into four main sections: the theoretical framework based on a literature review, the methodology, the results, which also include the case-study analysis, and lastly a discussion and conclusion section. The research's main aim is a twofold analysis including:

- a literature review to identify the missing links (*fil rouge)* between the planning and policy guidelines considered at three scales (global, European and National) and the plans and regulations at the local level;
- an in-depth investigation of a sample of Green Plans and Strategies of provincial capital cities in Italy through a framework made of four main criteria of analysis, namely biodiversity goals, targets, commitment to implementation and public participation.

The originality of this research lies in the identification of specific indicators of performance against which an evaluation of the Green plans can be performed with respect to their role in leveraging urban biodiversity preservation and strengthening.

2. Literature Review

This section presents a literature review based on three different dimensions regarding the challenges to implement biodiversity actions: the global scale, the European scale, and the local scale. The main aim is to identify shortcomings that generally affect the commitment of the national governments to plan, implement and monitor urban biodiversity-related actions at the local scales of spatial planning. The literature review conducted in this section is constructed qualitatively through a snowballing technique practiced by the authors, in addition to several exchanges in the form of focus groups and public seminars on the urban biodiversity–planning nexus involving the experts of the Spoke 5 research group of NBFC.

2.1 Mainstreaming from the global level: towards ecological transition

The latest COP 15 adopted the "Kunming Montreal Global Biodiversity framework" (GBF) that consists of four goals related to the 2050 vision of biodiversity and the 23 targets to be achieved by 2030 within an overall framework for addressing biodiversity loss, restoring natural ecosystems and establishing sustainable relationships between humans and nature (CBD, 2022). Since then, the topic of ecological transition and increased biodiversity within the urban environment has become an important focus of attention, especially after the latest COVID-19 breakout. Furthermore, the role of nature has been associated with increasing social cohesion, health, and well-being in urban areas (Beute et al., 2020; Atiqul Haq et al., 2021).
Nonetheless, the actual biodiversity strategies put in place in several countries are not yet on the verge of meeting the needed co-benefits for significant improvements in well-being, especially with the lack of effective and measurable implementation of targets, which, consequently, requires coordination between different policy processes and high-level of political commitment across sectors/industries and adaptation measures (Cardona Santos et al., 2023; Salata and Yiannakou 2016). This integration of policies and their relative coordination requires a variety of scaling-out and scaling-up models for biodiversity-related actions at a larger scale, which makes their governance processes more complex and difficult to manage than those happening within municipal jurisdictions (Buijs et al. 2019).
From this perspective, the most evident shortcomings in implementing biodiversity-related actions on the global level fall on the challenges of mainstreaming the impacts and the propagation of co-benefits. This requires high levels of commitment from policy-makers and complex models of shared governance for ecosystem services in order to provide the enhancement and restoration of biodiversity over the long term.

2.2 Rightsizing at the European level: strategies and policies for biodiversity recovery and monitoring

The latest EU Biodiversity Strategy 2030 calls for a comprehensive strategy to put Europe's biodiversity on the path to recovery with 14 key commitments by 2030 (European Commission, 2020a). This strategy encompasses a variety of pledges to be taken by state members towards strengthening the legal framework for nature restoration, as well as proposing a dedicated EU Forest Strategy that roadmaps planting at least 3 billion additional trees by 2030.
On one hand, the emerging challenge from this amendment at the European level – besides stepping up the enforcement of EU environmental legislation – is building an integrated framework and a whole-society approach towards biodiversity, including businesses, governance, measurement of nature value, as well as, improving and raising awareness on the role of natural capital for human well-being.

This challenge also relates generally to the alignment of municipal, metropolitan and regional planning with the sustainable development goals (SDGs) and how they could possibly catalyze and promote concrete actions at local scales (Mahmoud et al., 2022; Rizzi, 2023).

On the other hand, one of the most known difficulties to scientists and researchers in the biodiversity field remains the possible monitoring methods and techniques to assess biodiversity performance against specific targets and standardized criteria (Kumar et al., 2021). Frequently, analysis of performance of specific biodiversity-related actions, such as nature-based solutions (NBS), are based on experimental approaches that take into consideration the challenges which these NBS were implemented for. In other words, specific urban regeneration projects do establish an agenda of detailed activities for which their planning phases aim to: enhance environmental resilience, increase social cohesion, enhance disaster risk reduction, or preparedness for natural hazards, etc. (Frantzeskaki et al., 2022). This agenda setting-process of renaturing, very often, does not consider the possible "spillovers" of biodiversity actions from the local scale to be considered at the larger scale of implementation, unless these are mandated by wider policy frameworks (Mahmoud, 2022; Neuman, 2019).

From this perspective, the most evident shortcomings fall on the effective planning of biodiversity-related actions that have a broader agenda based on larger and whole societal goals and targets that are not rightsized from the European level towards the national and/or subnational levels. Nonetheless, the challenges framing this agenda should be consistent with the monitoring and evaluation methods by which these actions could be observed.

2.3 Downscaling to the local level: challenges for the urban planning-biodiversity nexus

In urban settings, the implementation of biodiversity-related actions leading to ecological transition is seemingly correlated to spatial planning contexts and local scales in which the actual green and blue infrastructures are executed as concrete measures (Brunetta & Voghera, 2014; da Silva & Wheeler, 2017). Very often, at the local scales of municipality and neighborhood, those actions are not consistently planned with larger scale strategies and policies (e.g., regional, metropolitan). For instance, the metropolitan planning sector is responsible for considering the ripple effects of natural capital and ecosystem services, as associated with ecological corridors connecting urban and rural areas across different municipal jurisdictions (Lazzarini, 2021). However, the specific increase of public green – or blue – areas and the related species that become established should be considered for implementation at a local scale such as the district or the municipal scale. This discrepancy, or better, mismatch between the regional, metropolitan, and municipal plans and their actual biodiversity-related actions can cause a lack of consistency in the effective results of biodiversity performance. When local authorities at different scales do not dialogue, this is commonly referred to as siloed thinking in urban governance dynamics (Cordini et al., 2021) which often leads to a lack of alignment between the content of local plans, and the priorities and guidelines laid out in national strategies (Oke et al., 2021). For instance, in the Italian context, it is a contentious issue to determine whether and how the biodiversity-related priorities, set by national strategies such as the National Biodiversity Strategy 2030 (MASE, 2023), and regulations (e.g., Law 10/2013 and related implementation guidelines) are integrated into statutory or sectoral plans at metropolitan and municipal levels (Salata, 2023). Concerning these levels, a problem of consistency is frequently reported horizontally, especially between the sectoral plans (like the Green Plans investigated in this article) dealing with specific policy sectors (mobility, greenery, climate change, etc.), and the statutory municipal plans that are in charge of regulating the land-use transformations and localizing the new urban developments and the public infrastructures and services, including parks and green areas (Colavitti et al., 2013).

Lastly, one of the main challenges in implementing biodiversity-related actions, identified in the literature, is the difficulty in developing systemic public participation and stakeholder engagement in the governance of urban planning, regeneration, and transformation (Tozer et al., 2022; Xie et al., 2022; Bianconi et al. 2018). Several scholars call for "biodiversity as a meeting point" between humans and non-humans, whereas our *vis-à-vis* relationship with nature should be deliberated and discussed with local actors (Pascual et al., 2021). Hence, research on biodiversity-related actions at the local scales should provide a voice for "nature" to be recognized and heard throughout the process of sustainable urbanization and greening of cities (Mansur et al., 2022; Pereira & Baró, 2022).
Nonetheless, from several European Commission (Research and Innovation Actions) projects (European Commission, 2020b), a tentative stream is focused on helping local communities and citizens get engaged in long-term urban regeneration through co-creation and co-design – with aspects related to urban greening and NBS – in order to foster accountability on local policies towards enhancing biodiversity.
However, there are hurdles to overcome when engaging citizens in such co-created actions, such as the loss of interest and a reduced sense of belonging that may emerge in the long-term (Hartmann et al., 2018; Mahmoud & Morello, 2021; Kauark-Fontes et al., 2023). In addition, it can be hard to recreate the intangible immediacy of results at the 'right size' in multiple neighborhoods and to match local communities' commitment towards natural environment and biodiversity with that sense of local impact. This challenge is often considered a limitation to existing urban planning and policy mechanisms since the biodiversity-related actions and their socio-cultural impacts still lack a cohesive modeling and monitoring framework that puts all these aspects together while helping to downscale them in local communities.
At this level, the downscaling of biodiversity-related actions locally should be ultimately supported by citizen engagement and public participation encouraging shared responsibility and accountability on local policies over the long term. Nature and biodiversity actions are, by their nature, integrative and effective at breaking silos across different spatial scales of urban planning (Tulisi, 2017). To summarize, the embeddedness of biodiversity-related actions should be mainstreamed from the global level, rightsized at the European level, and downscaled to the local level (see Table 1). Table 1 puts together the three levels and the lens of analysis through which the case studies will be analyzed. The following section puts this framework of analysis into action by surveying eleven Green Plans and Strategies in Italy considered as case-studies, and identifies the indicators to connect the theoretical and the operational aspects. The objective is to investigate what role urban biodiversity plays in green planning at the local level, with an emphasis on exploring the biodiversity-related goals and quantitative targets, the commitment to implementation, and the public participation mechanisms employed for conserving and enhancing biodiversity.

Biodiversity related actions	**Relative guidelines and policy documents**	**Challenges to implementation from Literature**	**Analytical framework of analysis**	**State of the art and relative frameworks**
Mainstreaming from Global Level	IPCC, 2018 COP 15- CBD, 2022 SDGs 2030	• Social challenges • Health and wellbeing • Commitment to implementation	Biodiversity Goals	Nilon, et al (2017); Cardona Santos et al., (2023).
Rightsizing at European Level	EU Biodiversity strategy 2030, 2020	• Monitoring and evaluation • Financial challenges	Biodiversity Targets	Kumar et al., (2021)
Downscaling to Local Level	National Biodiversity Strategy 2030 (MASE, 2023) Law 10/2013	• Raising awareness and fostering accountability • Shared governance and breaking silos • Citizen engagement and public participation	Public Participation and Commitment to implementation	da Silva & Wheeler, 2017); Tozer et al., (2022); Xie et al., (2022); Mahmoud et al. (2021); Hartmann et al. (2018)

Tab.1 Theoretical Framework of analysis based on the literature with relative guidelines and policy documents

3. Methodology

As stated in the introduction, methodologically this contribution relies on a two-fold qualitative analysis, whose outcomes are the theoretical framework built through the literature review presented in section 2 and the operational framework analyzing a sample of Green Plans and Strategies adopted by provincial capital cities in Northern Italy. The decision to work on a specific typology of thematic plans is due to the fact that in Italy, the Green Plan represents the strategic policy instrument where typically the aspects related to the management and enhancement of urban green spaces are tackled. The Green Plan is a strategic sectoral plan elaborated and adopted by a municipal government whose objectives, strategies, and actions should be then integrated into statutory municipal plans (the so-called "Piani Regolatori Generali, PRG" as regulated by the National Planning Law n.1150/1942) (Colavitti et al., 2013). In particular, according to the Italian legislation (National Law 10/2013 and the related guidelines drafted by the Ministry of Environment in 2017), the Green Plan is defined as the instrument in charge of developing the strategic dimension of green space planning, and thus contains the analysis of the urban green system, as well as the strategic interventions for developing and enhancing the urban and peri-urban green spaces in the medium and long term (Comitato per lo Sviluppo del Verde Pubblico, 2017). As explicitly mentioned in the guidelines elaborated by the Committee for the Development of Urban Greenery, the Green Plans should «identify the areas of the municipality characterized by high biodiversity and landscape value and improve the overall conditions of the urban and peri-urban territory from the ecological and ecosystem point of view […], increasing the ecological connectivity» (Ibid., 2017: 15). Starting from the content of these guidelines, the research wants to recognize whether and how the objectives of biodiversity preservation and enhancement are embedded in the Green Plans.

To achieve this objective, eleven Green Plans were mapped after a survey conducted to identify the provincial capital cities in Italy having an adopted Green Plan or Strategy in their local policy framework (Figure 1).

The decision to work on the provincial capital cities of the 8 Northern Italian regions (Valle d'Aosta, Piemonte, Liguria, Emilia-Romagna, Lombardia, Trentino Alto Adige, Veneto, Friuli Venezia Giulia) matches with Task 3.1 of the NBFC research, which has at its core the objective to carry out a systematic screening of plans and policies in major Italian cities, and identify guidelines, recommendations, and advice for improving the capacity of planning and design and their tools and mechanisms to address urban biodiversity. While the POLIMI-DAStU research unit conducted the survey in Northern Italian regions (tab. 2), the other NBFC partners of Task 3.1 (Universities of Florence, University of Molise and University of Rome La Sapienza) have surveyed the Central and Southern regions. In this sense, more empirical work is be needed to investigate systematically the full sample of Green Plans mapped in the whole country and identify the related challenges and the potential areas of improvement.

City	Population	Municipal area	Population density	Year of adoption of the green plan
Torino	843,514 (2023)	130.01 km²	6,488.07 ab/km²	2021
Genova	560,455 (2023)	240.29 km²	2,332.41 ab/km²	2022
Sondrio	21,185 (2023)	20.88 km²	1,014.61 ab/km²	2007
Parma	197,945 (2023)	260.6 km²	759.57 ab/km²	2022
Reggio Emilia	170,819 (2023)	230.66 km²	740,57 ab/km²	2021
Ferrara	129,341 (2023)	405.16 km²	319.23 ab/km²	2019
Bologna	389,772 (2023)	140.86 km²	2,767.09 ab/km²	2022
Forlì	116,509 (2023)	228.2 km²	510.56 ab/km²	2021
Bolzano	105,939 (2023)	52.29 km²	2,025.99 ab/km²	2022
Padova	207,330 (2023)	93.03 km²	2,228.64 ab/km²	2022
Vicenza	110 133 (2023)	80.57 km²	1,366.92 ab/km²	2018

Tab.2 Demographic data about the provincial capital cities in Northern Italy having an adopted green plan

Fig.1 Localization of the green plans and strategies in Northern Italy

From the operational point of view, the survey has screened the official websites of the local governments to access and download the Green Plan documents.
In case of missing information, an e-mail was sent to municipal officers, to retrieve the planning documents. The data collected were then validated by using a national survey made in 2021 by the National Institute of Statistics (ISTAT) on the state of implementation of the already mentioned National Law 10/2013 that reported info about different topics, including the Green Plans and regulations.
After the survey, the main reports of the Green Plans *(relazione illustrativa)* were analyzed through a qualitative analysis taking into consideration four criteria:

- *Biodiversity goals*, meaning the presence in the plan of general and/or specific goals related to the protection, restoration, and management of urban biodiversity, animal and plant species, habitats, and natural capital resources in the urban environment;
- *Biodiversity targets*, which is to say the quantitative targets set by the plan for increasing urban biodiversity habitat area or species populations;
- *Commitment to implementation*, namely the instruments, devices, and actions present in the plan to monitor the implementation of urban biodiversity goals;
- *Public Participation*, meaning if the green plan mentions participatory approaches or mechanisms in relation to the identification of planning priorities and actions related to urban biodiversity and to their implementation.

The four criteria were identified after the previously stated literature review in section 2, aiming to define potential analytical frameworks for assessing the role of urban biodiversity in Green plans.
In particular, the three dimensions of biodiversity goals, targets, and commitment to implementation are considered by Nilon et al (2017), who proposed a model to investigate discursively the biodiversity-planning nexus in policy documents. T
he criterion of public participation was then added to the framework model as it represents a specific focus of the NBFC research examined by the authors (Mahmoud et al., 2021). The main report of each Green Plan was then investigated to determine the extent to which the four criteria are discursively tackled.
A scale of values from 1 to 5 reworked from the Priority Likert-type Scale was employed (Vagias, 2006).

In particular, the following guidance was used to apply the Likert scale to the analysis:

- Score 1: the criterion is not present or even mentioned in the plan.
- Score 2: the criterion is mentioned implicitly in the plan, meaning that an unexplicit reference to it is present.
- Score 3: the criterion is explicitly mentioned in the plan, although this has a marginal or lateral role in the plan.
- Score 4: the criterion has a major role in the plan, namely it is mentioned more than one time in the plan.
- Score 5: the criterion is the structuring principle of the plan; it is mentioned several times, and it has a central role in the corpus of the plan's strategies or objectives.

A performance indicator was then added based on the sum of the values attributed to the single criteria to compare the performances of Green plans against each other across the priority values given by the authors. The results of the analysis are shown in Table 3, graphically shown in Figure 2, and presented in the following section.

4. Results

The initial literature review showcases that there is a need for three levels of integration for biodiversity in urban planning mainly through:

1) mainstreaming of societal challenges and needs across the global scale of biodiversity strategies and policy recommendations,
2) rightsizing the actions at the subnational scales (regional, metropolitan, and intermunicipal) while monitoring their ripple effects at large scales, and lastly,
3) downsizing the actions at the local scales, namely the municipal, neighborhood and district scales, where the local communities could be directly involved in initiatives and projects oriented to improve or restore biodiversity within the built environment.

The survey highlighted a variety of approaches by which the Green Plans and strategies tackle the issues related to urban biodiversity according to the total scores below. Nevertheless, the main focus of the plans generally shifts to conserving existing biodiverse areas and to re-naturalizing high-value natural spaces, rather than radically igniting new possibilities in areas where biodiversity can be restored or is already present but not perceived by local communities.

	Turin Green Infrastructure Strategy	Genova Green Strategy	Sondrio Green Plan	Vicenza Green Plan	Parma Green Plan	Padova Green Plan	Bolzano Green Plan	Bologna Urban Climate Green Strategy	Reggio Emilia Green Plan	Ferrara Green Infrastructure Action Plan	Forlì Green Plan
Biodiversity goals	5	3	3	3	3	5	3	3	3	3	2
Biodiversity quantitative targets	1	1	1	1	3	3	2	3	1	1	3
Commitment to implementation	4	1	1	3	4	4	1	3	1	4	3
Public participation	3	1	1	3	3	4	3	4	1	3	3
Total score	13	6	6	10	13	16	9	13	6	11	11

Tab.3 Results of the survey regarding the role of the four criteria in the green plans

Regarding the criterion of biodiversity goals, the survey highlighted that just in the cases of the Green Plan of Padua and the Green Strategy of Turin the goal of biodiversity preservation and enhancement is interpreted as one of the structuring principles of the plan.

In the case of Padua, biodiversity is explicitly tackled by one of the five macro-strategies of the plan, which mentions the need to «propose and identify […] belts of connection between the ecological corridors and the urban areas where a biodiversity strategy should be implemented» (Comune di Padova, 2022: 407).

The biodiversity strategy is highlighted with reference to specific actions to be performed by the municipality, from the identification of the green areas with a biodiversity potential in the municipal territory, and their overlapping with the other green areas, road trees and the so-called "10,000 trees municipal strategy", to the identification of both the linear and transect elements that connect the various existing ecological corridors. The interesting point is that the strategy is then articulated in a set of several guidelines for specific species (pollinators, dragonflies, bats, etc.) with concrete and specific actions for preserving and managing the related habitats. In the case of Turin, biodiversity is developed in-depth in the section "ecosystem services" of the strategy where four strategic actions for incrementing the quality of ecological corridors and habitats and preserving biodiversity are pointed out: protection of high-value areas, completion of urban ecological corridors, re-naturalization of river areas, creation of widespread urban forestation (Comune di Torino, 2020).

In relation to the quantitative targets for increasing biodiversity habitats and species identified by the plans, 5 out of 11 plans (Parma, Padova, Bolzano, Bologna, and Forlì) employ and mention them, although none gives this criterion a central role in the green strategy.

In the case of Parma, the Green Plan includes a set of quantitative targets for increasing constructed habitats and ecological corridors for biodiversity purposes. It sets the commitment of the municipality to enlarge the horticulture areas of 16,500 sqm of public land, turning marginal and vacant lots into productive spaces available for urban agriculture, and identifies 12 new ecological corridors for a total of 58,6 km to be implemented in continuity with the existing cycling network and to be equipped with tree rows for diversifying the landscape and creating an environmental mitigation zone (Comune di Parma, 2022). The Green Plan of Padua introduces some quantitative targets for the increase of biodiversity habitat area, such as the rise of tree cover in the municipal area (from 1,8% to 5% with at least 20% of the tree species prone to adapt to climate change). Moreover, regarding the increase of tree biodiversity, the Plan provides that the abundance of a single species should not exceed the 6% and that the relative abundance of a single genus should be 10%. It also sets a long-term period of 20 years to achieve this target. Also in the Green Plan of Bolzano, a quantitative target dealing with the increase of biodiversity habitat area is introduced (665,000 sqm of new green areas, +92% than the current state), although this concerns green public spaces mentioned in general terms with no emphasis on biodiversity-related aspects, neither of commitment devices regarding the time or the funding sources needed to implement them. In the same vein, the Green Strategy of Bologna highlights the target of 1,300 trees per year to be planted in the city and of 30,000 sqm per year of new green areas to be created for strengthening the urban green system. As in the case of Padua, the Plan sets targets for the tree species composition of the new green areas so that the future green areas will host no more than the 10% of any tree species, no more than 20% of any genus, and no more than 30% of any family (Comune di Bologna, 2022).

The criterion of commitment to implementation is a critical aspect tackled by the majority (8 out of 11) of the Green plans under investigation (Turin, Milan, Vicenza, Parma, Padova, Bologna, Ferrara, and Forlì). The survey highlighted that the plans tackle this criterion following three main declinations:

- the presence of indicators to monitor the plan implementation.
- The mentions of specific economic sources needed to implement the plan objectives.
- The introduction of specific governance arrangements needed to implement the plan.

In the cases of Turin, Bologna, Parma, and Padua, the commitment to implementation is expressed in the presence of a set of indicators matching with different actions that deal with biodiversity preservation or enhancement (tab. 4). These refer to several aspects related to the increase of both habitat area (e.g., total green surface area, number of trees and their canopy cover, etc.), and biodiversity performances (e.g., number of animal species or percentage of tree species diversity reported in each portion of green area, as in the Plans of Parma and Padua).

The issue of financial sources needed to implement the plan actions is tackled by the Green Plan of Forlì where in a specific section the funding opportunities for implementing the objectives of the plan are highlighted.

For instance, synergies with the actions of the Rural Development Plan or other economic incentives to be activated by the Municipality for sustaining the initiative of agricultural entrepreneurs or citizens to realize the green interventions foreseen by the plan are mentioned (Comune di Forlì, 2020). A more pragmatic approach is taken by the Action Green Plan of Ferrara where each action included in the plan is developed with reference to the time and the estimated costs of implementation, and the potential funding sources to be activated (Comune di Ferrara, 2019).

Plan	Biodiversity-related actions	Indicator
Green Infrastructure Strategy of Turin (2020)	Protection and safeguarding of high natural value areas.	- n. of interventions / year
	Completion of urban ecological corridors through acquisitions and based on the local plan forecasts.	- sqm / year
	Re-naturalization of ecological corridors and river areas.	- sqm / year
	Widespread urban forestation in non-wooded publicly owned areas.	- no. trees in publicly owned areas / year
Bologna Urban Climate Green Assets Strategy (2022)	Forestry interventions in peri-urban areas	- n. of wooded areas and related surface
	Plantation in municipal and private systems of entomophilous plants and/or attractive to birds.	- % of tree species diversity planted - No. of projects/interventions with specific prescriptions
	Re-naturalization of the riverbanks to increase local biodiversity, through policies of reforestation both spontaneous and planned.	- n. of hectares of naturally evolving or re-naturalized areas within the riverbanks
	Design and maintenance of public green spaces according to the principles of urban ecology (e.g., maintaining and increasing spontaneous or low maintenance green areas).	- n. of hectares of green areas with low or zero maintenance.
	Plantation of species resistant to water deficiency.	- % of distribution of resistant species out of the total of the new plants
	Creation of productive urban landscapes and food forests in public spaces.	- sqm of food forests
Green Plan of Parma (2022)	Growth of total tree cover	- sqm of tree cover (ground projection of the canopy)
	Growth of the number of trees	- n. of trees presents within the municipal territory in the spaces planned for urban greenery
	Biodiversity improvement of the tree system	- % of abundance of tree species
		- % of abundance of tree species higher than 5%
Green Plan of Padua (2022)	Biodiversity improvement	- n. of animal species and their abundance detected in the territory.
		- Biodiversity index of the main parks of the city (n.)
		- Biodiversity of the tree system (n. of species higher than 6%)
		- n. of species/n. of trees x 100
		- n. of species higher than 5%
		- n. of species reported annually on the portal iNaturalist.

Tab.4 Indicators focusing on urban biodiversity in the green plans under investigation

The governance arrangements for implementing the plan objectives are a minor aspect of the plans investigated. Only the Green Plan of Vicenza gives this aspect a relevant role as it introduces a specific governance device, the framework agreement ("Accordo Quadro") for implementing the plan objectives.

In particular, this is interpreted as a device shaping the coordination between the different actors involved in the plan implementation, specifying their commitment and levels of engagement in the process (Comune di Vicenza, 2018). The criterion concerning public participation is tackled in 9 Plans out of 11 (all except Genova, Sondrio and Reggio Emilia). As in the previous case, this topic has several withholds and operationalizations in the documents analyzed. The more recurring one entails aspects of communication of the plan's contents and strategies related to urban biodiversity to the local community.

This is the case of the Green Plans of Parma and Forlì where the communication programs are explicitly addressed to inform citizens about the new green space management, and the related ecological and economic benefits that the low-maintenance green areas unfold (Comune di Parma, 2022; Comune di Forlì, 2020). Just in the case of Bolzano, the process and content dimension of participation is fully developed in the Green plan, with an emphasis both on the participatory tools employed (thematic focus groups with third sector representatives, citizens, and other stakeholders) and on the results achieved which concerns the demand for new green spaces manifested by citizens and the proposal to manage and maintain them collectively, through bottom up mechanisms and without the financial support of the municipality (LAND, 2021).

A reference to specific case studies where participatory approaches is employed to strengthen biodiversity is included in the Green Infrastructure Strategy of Turin and in the Action Plan of Ferrara. The first mentions the experience of Parco Michelotti, a former zoo area in the Po riverbank where an urban park was created after a consultation process involving local administration, volunteering associations and a local school (Comune di Torino, 2020).

The second includes a set of actions, each of which is spatialized in the municipal territory and developed with reference to the typology of stakeholders to be involved and the participatory mechanisms to activate for implementing those actions (Comune di Ferrara, 2019).

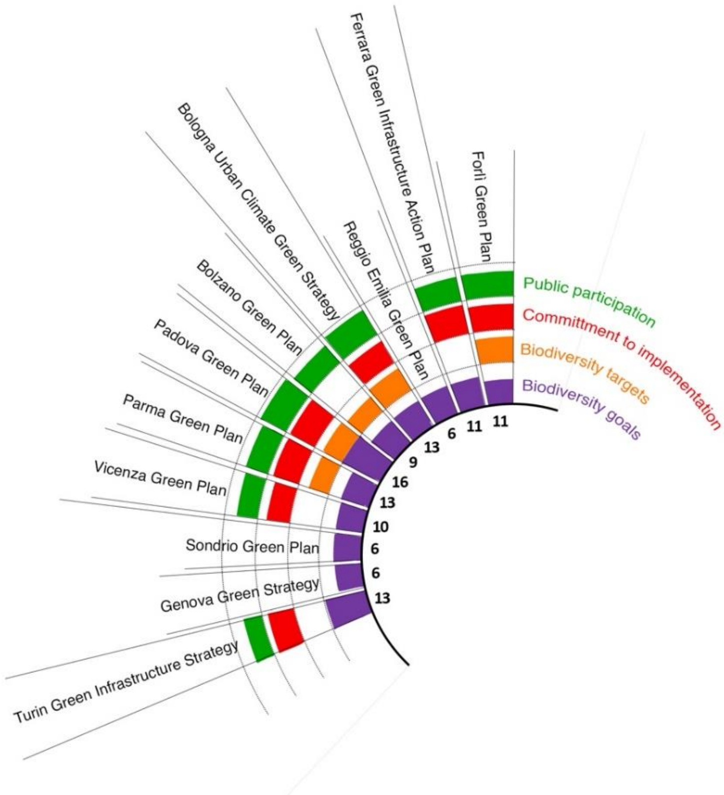

Fig.2 Graphical representations of the results of the survey on the eleven green plans investigated

5. Discussion and conclusions

The research has shown several shortcomings related to the policy and legal frameworks needed to institutionalize biodiversity in urban planning, especially after the increasing environmental pressures highlighted by the recent IPCC (2018) report. While it is increasingly acknowledged in the debate that statutory planning stands as a crucial policy field for promoting the ecological transition of cities (Bush, 2020), this contribution stems from the idea that also strategic policy tools like the Green Plans can make a relevant contribution to operationalize this transition. Four fundamental issues can be highlighted, based on the analysis carried out in this article. Each issue matches with a specific gap characterizing the biodiversity–planning nexus, in its theoretical and operational implications.

The first issue is merely at the theoretical level. As mentioned in section 2, a mismatch between the literature on human-nature health and wellbeing improvement and the possible relationship to biodiversity-related actions should be acknowledged. Henceforth, there is a need for a standardized and cohesive framework for monitoring social and environmental aspects altogether, using quantitative and qualitative methods. The scientific research on urban biodiversity puts a clear distinction between the *mainstreaming* process of planning and policies from the global level which are barely *rightsized* at the European level and met according to the national and subnational strategies and standards in many countries, and the *downscaling* process of translating them at the local scale.

The second issue is related and concerns the procedural level. It entails the lack of consistency which connotes the downscaling process of integrating the contents and priorities set from the national and subnational level in the local plans (Oke et al., 2021). In the case of the Green Plans, this aspect is particularly relevant as the Italian National Government, in the guidance documents drafted by the Ministry of Environment (Comitato per lo Sviluppo del Verde Pubblico, 2017), has introduced a set of guidelines regarding objectives, contents and implementation mechanisms to guide the elaboration of the Green plans. Despite this, the analysis has pointed out that these guidelines have a low degree of cogency and were followed only partially by the Green plans under investigation. This demonstrates that an approach to differentiation rather than standardization still prevails in the field of green strategic planning (Nilon et al., 2017). Another aspect emerging from the green plans analyzed is the recency of their adoption; most plans were elaborated and adopted in the period from 2018 to 2022. This makes notable the possibility to match their priorities and actions with the recent global frameworks such as the GBF of 2030 (IPCC, 2018) and their relative targets.

The third critical aspect concerns the impact level and the commitment to implementation. The results from the survey analysis emphasize the lack of distribution of the resources needed to catalyze the biodiversity net gain in urban areas. Indeed, the focus generally shifts to conserving existing biodiversity in urban areas rather than radically igniting new possibilities in areas where biodiversity is not high or perceived as important. Moreover, a mismatch between the quantitative targets and the possible monitoring indicators for increasing biodiversity habitats and species emerges in the Green Plans investigated. Emphasis is mostly placed on the indicators, with scarce or no attention oriented to the target thresholds to be met. In other terms, several Green Plans introduce a set of specific indicators for monitoring the achievement of biodiversity objectives, but they do not establish any quantitative target for these objectives, making their commitment to implementation weak. Also, the analysis highlighted that the Green Plans rarely specify the financial resources and the governance mechanisms needed to implement the objectives and actions identified, making the implementation hard to monitor. Only in the case of Ferrara, the Action Plan on Urban Green Infrastructures includes a specific mention of the time, costs, and potential funding sources to retrieve for implementing the actions, specifying a solid guidance for its execution.

The last issue regards the discourse level and involves the topic of human-nature relationships in the public participation processes underlying the Green Plans. Though the analysis has shown that participatory mechanisms and approaches related to biodiversity preservation and enhancement are topics frequently mentioned in the plans, these are mainly framed in traditional terms. For instance, participatory processes are employed to inform local inhabitants about the plan objectives and actions and/or consult and gather inputs for identifying specific priorities. In this case, a mismatch between theory and practice is present and this relates to what role nature plays in participatory planning processes. Despite the growing perspective in the debate that our relationship with nature should be openly discussed in public arenas and that the nature itself should be considered as an actor to be heard in policy-making processes (Pascual et al., 2021), the Green Plans still frame the human-nature relationship in univocal and often "opportunistic" terms. They thus interpret nature as a generator of benefits that humans can take advantage of for improving their capacity to adapt to climate change and resources shortage, rather than as a plural entity shaping patterns of interdependency and coexistence between human and non-human agents.

Alongside the results emerged so far, one shortcoming of the research concerns the sample of analysis which is limited to a specific typology of sectoral plans, the Green Plans and strategies, elaborated by provincial capital cities in a specific geographical context (Northern Italy). Thus, the article lacks a comprehensive focus on the different typologies of sectoral plans where the biodiversity objectives are potentially tackled (e.g., the Sustainable Energy and Climate Actions Plans) as well as on the statutory plans that, as already mentioned, have a direct impact on the increase or loss of biodiversity in cities. Following this shortcoming, a future development of the research would be to extend the sample of analysis in terms of the number and typology of plans. Here it is suggested that the analysis should cover other sectoral and statutory plans and focus on the whole National context. Widening geographically the sample would allow to describe the territorial distribution of plans across the whole Country and, more importantly, to identify the approaches by which different municipal administrations – through different sectoral and statutory plans – tackle the objectives of biodiversity preservation and enhancement and highlight the barriers and obstacles that characterize the integration of these objectives in the planning process. The large dimension of the sample would also require the construction of a more sophisticated framework of analysis, made of a set of indicators through which assessing the attributes related to urban biodiversity in a technically sound way.

Authors' contribution

L.L. and I.M. share first authorship rights, the order is purely alphabetical. Conceptualization: L.L., I.M. and M.C.P.; methodology: L.L. and I.M.; validation: L.L. and I.M.; investigation: L.L. and I.M.; writing—original draft preparation: L.L. and I.M.; writing—review and editing: L.L. and I.M.; visualization: L.L.; funding and supervision: M.C.P. All authors have read and agreed to the published version of the manuscript.

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Image Sources

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Integrating climate change adaptation into municipal masterplans through Strategic Environmental Assessment (SEA)

A case study concerning Sardinia.

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Abstract
Adaptation to climate change and the need to deal with its impacts pose in evidence how important it is to identify and implement new planning practices that integrate these profiles into land-use policy-making. Within this conceptual framework, the identification of a system of plan objectives and actions that characterize the integration of climate change adaptation into planning policies, with particular reference to the local scale, is of particular importance. In this study, a methodology for implementing this integration is proposed through the establishment of a logical framework for the construction of municipal masterplans through strategic environmental assessment, as a pathway in which plans are formed and developed, as part of the assessment process, through the identification of a strategic system of objectives and an operational system of planning actions based on the integration of climate change adaptation into the plan formation process.

Keywords
Climate change adaptation; Strategic environmental assessment; Spatial policies; Strategic planning.

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1. Introduction

The integration of climate change adaptation (CCA) into strategic environmental assessment (SEA) processes is a widely discussed and analyzed issue in the technical and scientific literature.
During the preparation of Directive No. 42/2001/EC, an analytical research report on the implementation of SEA in the decision-making processes of plans and programs, prepared by the Imperial College for the European Commission (Sheate et al., 2001), emphasizes how the effectiveness of land-use policies at different scales, national, regional and local, is fundamentally linked to the integration of CCA issues, highlighting several profiles of these issues. Of particular relevance, among the many cases analyzed, are the SEA of the land-use plan of the city of Weiz (Austria), in which it is emphasized that "The targets, goals and objectives used in the SEA process are clearly defined, for example, carbon dioxide threshold according to the goals of the 'Climate Alliance'" (Sheate et al., 2001, p. 9), the SEA of the National Environmental Policy Plan 3 of the Netherlands, which places CCA among the reference themes for identifying the structure and framework of administrative and technical competencies of the decision-making process (ibid., p. 85), and the Regional Economic Strategy of the Yorkshire Regional Development Agency, which explicitly includes climate change among the components of the strategic framework (ibid., p. 153).
A very significant document is the Advisory Note on Environmental Assessment and CCA (ENVIRONET, 2010), which identifies four fundamental moments in the implementation of spatial planning processes that involve the integration of SEA and CCA: (i.) the precise and circumstantial identification of the universe of stakeholders and environmental components that reasonably will be affected, during the plan process, by the impacts of CCAs; (ii.) the implementation of the SEA; (iii) the process of informing and educating local communities, affected by the plan and climate change, in the proactive participation in the definition and implementation of planning policies; and, (iv) the continuous updating of the plan's strategic framework through the ongoing SEA and monitoring. A significant moment in the discussion proposed in the Advisory Note concerns the problematic nature of the conceptual and technical relationships between SEA and CCA. Indeed, it should be acknowledged and kept well in mind how SEA does not so much provide a conceptual and technical framework for the development of scientific research related to the impacts of climate change, but, rather, poses, in problematic terms, the need to fill knowledge gaps (ENVIRONET, 2010), which need to be kept in mind, if not resolved, as SEA is tasked with constructing frameworks and assessing impacts in reasonably plausible terms, which would not be possible if the gaps gave the assessment process a character of dramatic indeterminacy.
SEA is effective in monitoring the implementation of plan processes, and, during this, the type and magnitude of climate change and, therefore, related adaptation measures, in relation to, for example, atmospheric precipitation, the genesis and likelihood of extreme weather events, the effects on water quality, and the generation of re-risk conditions, related to the hazard, vulnerability, and exposure associated with the impacts of climate change on natural resources and local societies.
An analytical discussion of this theoretical and technical conceptual vision is proposed by Wende et al. (2012), who examine, in comparative terms, SEA processes which integrate CCA approaches with reference to regional land-use plans from Saxony and East England.
A more comprehensive and general view of the relationship between SEA and CCA is, on the other hand, proposed and discussed by Gonzáles Del Campo et al. (2020) with reference to SEA processes that integrate, in the strategic device of the assessment, specific objectives that refer to Strategic Development Goal No. 13 of Agenda 2030 (Partidário & Verheem, 2019), "Take urgent action to combat climate change and its impacts."
The issue of integrating CCA into SEA processes is addressed, specifically, in the European Commission's document "Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment" (McGuinn et al., 2013), which takes up and develops the contents of ENVIRONET's Advisory Note (2010).

The issue is discussed, in systematic terms, in the fifth section of the paper, in which some basic conditions for the construction of SEA environmental reports (ERs) whose strategic device, i.e., whose hierarchical system of objectives, includes CCA-relatable goals, integrated into the plan strategy, are discussed.
Related to what is presented and discussed in this study, of particular relevance is what is indicated regarding the need to address, in a detailed and specific manner, in ERs, the issue of consistency between the strategic device of the plan and the systems of objectives regarding mitigation and CCA identified in national and local strategies and plans focused on these issues (McGuinn et al., 2013, p. 70).
In general, integrating the sustainability paradigm into public policy-making and implementation processes involves a careful assessment of economic and social equity issues in intra- and inter-generational terms (Francini et al., 2021). With regard, in particular, to spatial planning, this integration is not made operational through measures identifiable in deterministic terms, but, rather, through practices that involve an open and continuous dialectic with local societies, based on mediation in relation to the instances and expectations they express, as well as on the contributions of spatial sciences, to be used not only as foundational references of spatial analysis, but, also, as sources of collective learning (Gambino, 2005).
It is within this conceptual framework that the objective of this study is recognized and placed, which consists in the definition of a methodological approach for the integration of CCA in the ERs of the SEAs of the territorial plans of local governments that, in the Italian regulatory context, are identified as municipal masterplans (MMPs) (Isola et al., 2023a). It consists, therefore, in the implementation of a downscaling operation to the local level of strategies and plans concerning CCA, in force in the European and national contexts, that is, with reference to MMPs (Frigione & Pezzagno, 2023).
The starting point for the development of the downscaling process to municipal urban planning is the National Plan for Adaptation to Climate Change of Italy (NPCCA), whose strategic device declines the European Union Strategy for Adaptation to Climate Change (EUSCCA)[1] and the National Strategy for Adaptation to Climate Change of Italy (NSCCA)[2].
The EUSCCA has had two versions, the first dating back to 2013, the other to 2021 (see footnote 1).
The second is a critical restatement of the 2013 EUSCCA following an in-depth evaluative review of its implementation through the national CCA-related strategies and plans adopted and implemented by many EU countries[3]. The EUSCCA promotes, in this regard, the implementation of the conceptual and technical-operational framework of the EU Covenant of Mayors for Climate & Energy initiative[4], for whose local plans and actions the JRC has defined a specific approach in a three-part guideline manual, of which the first proposes a detailed itinerary for the definition of a municipal action plan aimed at CCA and mitigation, and energy savings, the second refers to emission census, and risk and vulnerability assessment, and the third to the identification of best practices and key actions concerning CCA and mitigation, as well as financial issues (JRC, 2018a; 2018b; 2018c). The NSCCA was defined, in 2015, on the basis of the 2013 EUSCCA, and, as far as it concerns the integration of CCA into local plans, it offers some very important pointers, in implementation of the technical device of the EUSCCA.

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1 The two reference documents of the European Commission concerning the EUSCCA are as follows: i) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "An EU Strategy on adaptation to climate change," COM(2013) 216 final; ii) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change," COM(2021) 82 final.

2 The reference document for the NSCCA is Decree No. 86 of the Director of the Directorate General for Climate and Energy of the Ministry of the Environment and Land and Sea of June 16, 2015, adopting and approving the NSCCA (Art. 1). The NSCAA is contained in the Annex to the Decree and is an integral part of it.

3 The evaluation document is the Commission Staff Working Document "Evaluation of the EU Strategy on adaptation to climate change," SWD(2018) 461 final.

4 An extensive and systematic information dossier on the initiative can be retrieved from the European Union website https://eu-mayors.ec.europa.eu/en/home. Accessed February 18, 2024.

In particular, the approach of the NSCCA individuates the reference areas for defining the situation of climate dynamics and climate change and, in relation to these, identifies impacts and vulnerabilities, with respect to which the objectives and actions of the NPCCA will be defined. These will form the foundational strategic device for the downscaling operation that is the objective of this study.

In the second section, the methodology used to carry out the downscaling is described, and the reasons for the choice of the four local contexts in relation to which the methodology is implemented are given, namely the cities of Capoterra, Selargius, Nuoro and Sassari. The ERs of the MMPs of the four cities are based on the declination, in the local spatial contexts, of the principle of sustainable development, in accordance with the provisions of Legislative Decree 152/2006 (Art. 3-quater, and Art. 4, paragraph 4, letter a), in line with the conceptual approach of the Brundtland Report (WCED, 1987). That scientific and technical framework highlights important issues, both theoretical and applicative, with reference to local government spatial planning practices. The concluding section highlights the prospects for the development of the research, also in relation to the problematic issues reported in the discussion of the results.

2. Methods and materials

This section is organized as follows. The first part is devoted to the analytical description of the methodology used for the integration of CCA into the ERs of the SEAs of MMPs. The second part presents the reasons for the choice of MMPs, related to four Sardinian cities, taken as a reference for the application of the methodological approach adopted.

2.1. Methodology

The NSCCA identifies reference areas for defining the situation of climate dynamics and climate change. In relation to these areas, it identifies impacts and vulnerabilities to which the objectives and actions of the NPCCA have been defined. The NPCCA has recently been adopted and is currently undergoing the SEA process, according to the Ministry of Environment and Energy Security's announcement[5].

The current version may, therefore, not be the one that will be approved as a result of any changes made following the completion of the SEA. For the purposes of this study, this version is assumed to be reasonably close to the final draft of the Plan, as its current structure has remained unchanged since the time of its first online publication in 2018. Since then, it also has been subject to the scrutiny of all interested public administrations, at the state, regional and local levels, registering a generalized consensus.

The NPCCA is, therefore, the operational extension of the NSCCA, of which it maintains the taxonomy of 18 reference sectors identified. The identification of plan objectives and actions is based on a context analysis, which deepens that of the NSCCA, based, as noted in the fourth chapter of the NSCCA, on the identification of impacts and vulnerabilities associated with each of the 18 reference sectors.

The methodology for the integration of the CCA into the ERs and, therefore, for the construction of the MMPs, consists of three phases, basically geared toward grafting the NPCCA's device of objectives into the systems of objectives of the MMPs. It should be noted that the application of the methodology proposed in this section, which refers to the adopted NPCCA, could be replicated with reference to any future drafts of the NPCCA, whose strategic framework, represented by the system of objectives of the updated version, would need to be incorporated.

[5] See, in this regard, the press release retrieved from: https://www.mase.gov.it/comunicati/pubblicato-sul-sito-del-mase-il-piano-di-adattamento-ai-cambiamenti-climatici. Accessed February 18, 2024. This bears "Climate Change Adaptation Plan published on MASE website," which gives notice that the NPCCA has been published for SEA purposes. The NPCCA can be retrieved from: https://www.mase.gov.it/pagina/piano-nazionale-di-adattamento-ai-cambiamenti-climatici. Accessed February 18, 2024.

Among the objectives of the NPCCA, systematized in Annex IV of the NPCCA, called "Database of Actions"[6], the first phase aims to identify those that can be associated with the processes of defining MMPs, having significant implications on land governance. Based on the objectives of CCA, and also taking into consideration the 18 NPCCA Reference Sectors[7] to which they refer, a selection of significant objectives relevant to land-use and urban planning is made, followed by an identification of the actions/measures referring to them.

The second stage is the construction of the system of specific objectives of the MMPs to which the ERs refer, that is, the construction of the logical frameworks (LFs) of the ERs of the MMPs, systems that are deduced directly from the ERs of the MMPs.

Finally, in the third phase, the objectives identified in the first phase are used in the drafting of the ERs for the construction of the MMPs as operational references to redefine the systems of the specific objectives and actions of the MMPs so that these systems integrate the CCA into the overall strategy of the MMPs.

The following sections describe the three steps in detail. Fig. 1 provides an overview of the methodological steps presented in Sections 2.1, 2.1.1, 2.1.2 and 2.1.3, and the relations between actions from the four Sardinian MMPs and good practices from other case studies, as discussed in Sections 4.1, 4.2 and 4.3.

2.1.1. Step 1: Targets of the NPCCA that can be associated with MMPs

The first phase is aimed at identifying and selecting NPCCA objectives and actions that are relevant to land-use and urban planning. All 18 areas of the NPCCA were considered. Of the 137 Objectives defined in the NPCCA, 74 Objectives were found to be relevant to the analysis of possible effects on spatial governance. Subsequently, by the same process, out of the 360 Adaptation Actions referred to the 137 Goals, 253 Actions were identified as relevant to land-use and urban planning.

Table 1 shows, as an example, the identification and selection of Objectives and Actions of the NPCCA with reference to the Sector "Hydrogeological instability." In the example, the actions are identified with reference to the NPCCA goal "Improving emergency management by administrations at all levels and increasing public participation." The table contains a summary description of each action, and an indication of the indicators that the NPCCA associates with the action.

2.1.2. Step 2: Targets of the NPCCA that can be associated with MMPs

The second phase consists in the construction of the system of the specific objectives of the MMPs to which the ERs refer, that is, the construction of the LFs of the ERs of the MMPs.

For the exemplification, which is proposed in the following third phase, reference is made to the Selargius MMP, which is a plan that has completed the process of adaptation to the Regional Landscape Plan (RLP)[8] and the Sectoral Plan for the hydrogeological framework (SPHF), and whose documentation is integrally available online in the institutional website of the Municipality of Selargius[9].

The environmental sustainability objectives, defined in the Selargius MMP as "General Objectives," and the Specific Objectives were extrapolated from the ER of the Selargius MMP, where they are clearly spelled out, while, as far as the plan actions are concerned, the set of actions in the ER was integrated with the actions reported in the Selargius MMP's elaboration No. 37 "Quadro Logico del MMP".

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6 Retrieved from: https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/PNACC_AllegatoIV_database_azioni.ods. Accessed February 18, 2024.

7 Aquaculture; Agriculture and food production; Desertification, land degradation and drought; Geological, hydrological and hydraulic instability; Ecosystems and biodiversity in inland and transitional waters; Marine environments: Biodiversity, Functioning and Ecosystem Services; Energy; Terrestrial Ecosystems; Forests; Hazardous Industries and Infrastructure; Urban Settlements; Cultural Heritage; Marine Fisheries; Water Resources; Health; Transport; Tourism; Coastal Zones.

8 Documents retrieved from: http://www.sardegnaterritorio.it/paesaggio/pianopaesaggistico2006.html. Accessed February 18, 2024.

9 Retrieved from: https://www.comune.selargius.ca.it/amministrazione_trasparente/index.php?i1=19&i2=60&i3=98. Accessed February 18, 2024.

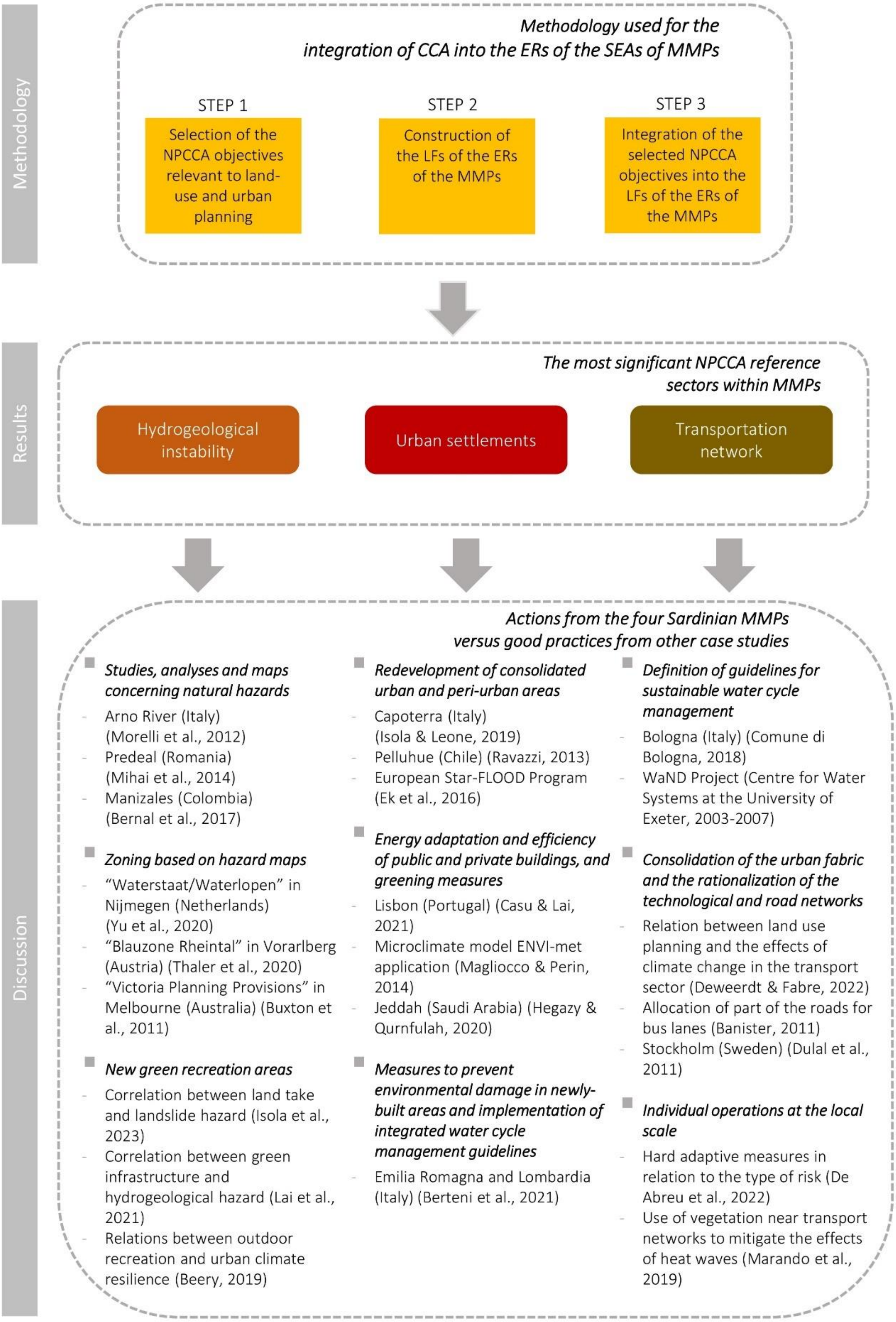

Fig. 1 Overview of the methodological approach and relations between actions from the four Sardinian MMPs and good practices from other case studies discussed in Sections 4.1, 4.2 and 4.3

SECTOR	Hydrogeological instability		
OBJECTIVES	Improving emergency management by administrations at all levels and increasing public participation		
ACTIONS / MEASURES	Improved forecasting systems-innovative methods of collecting information	Improved technical support, emergency management, and preparedness and training-guidelines for technical design	Improved technical support, emergency management, and preparedness and training-techniques for emergency management
DESCRIPTION	Analysis of innovative information collection and monitoring methods	Development of Guidelines for engineering design in non-stationary environment	Developing emergency management techniques based on interdisciplinary approach
INDICATORS	- Number of early warning systems updated to take into account climate change and adaptation. - Number of registered users of early warning systems and information services. - Increased number of administrations using scientific evidence to support decision and policy making. - Improved catalog of knowledge tools (decision support tools (DST), other tools, technologies, methodologies, etc.) to support adaptation	- Number of projects funded - Number of regions updating their reference standards	- Number of technical reports, publications, and scientific communications relevant to civil protection organization at the local level - Increase in the number of actors/organizations involved in international support networks relevant to adaptation - Increased regional and national coverage of the monitoring carried out

Tab. 1 Identification and selection of NPCCA Objectives and Actions that are relevant to spatial and urban planning

2.1.3. Step 3: Integration of NPCCA objectives into the LFs of the ERs of the MMPs

The integration of the NPCCA strategic framework into the LFs of the MMPs is exemplified in Tab. 2, which shows the structure of the assessment matrix. The matrix has been populated trough the following sub-steps:

- comparison of all specific objectives of the MMP (column [b]) with all the objectives of the NPCCA relevant to land-use and urban planning (column [a]), selected in the first stage, also in light of the plan actions referred to them. At the end of the series of comparisons, column [c] is populated, which, for each specific objective of the MMP, lists all NPCCA objectives with respect to which it is relevant.
- For each specific objective of the MMP, assessment of the level of integration of all NPCCA objectives for which relevance was found. Column [d] is thus populated, in which the specific objective is either kept unchanged in case it integrates all relevant NPCCA objectives, or is reformulated, in case the integration with one or more NPCCA objectives is only partial, so as to improve the level of integration.
- Comparison between the NPCCA objectives relevant to the specific objectives of the MMP and all MMP actions (column [e]) that, in the strategic framework referred to in the second step, are linked to those specific objectives. In this sub-step, column [f] is populated, making explicit the ways in which each action contributes to the achievement of the NPCCA objective to which it is linked through the specific objective, and, where appropriate, indicating any corrections or arrangements needed to raise the level of integration. Non-relevant actions are excluded from the assessment.

The final result of the assessment conducted through the LF approach is presented through a matrix in which there are NPCCA goals relevant to specific objectives of the MMP stated in the ER, and plan actions related to them. Tab. 3 shows an example related to the Selargius MMP.

[a]	[b]	[c]	[d]	[e]	[f]
Objective of the NPCCA	**Specific objectives of the MMP**	**Assessment of relevance between the NPCCA Objective and MMP objectives**	**Reframing the specific objectives of the MMP in terms of CCA**	**MMP actions related to the specific objectives and consistent with the NPCCA Objective**	**Evaluation of MMP actions in relation to the NPCCA objective**
…	…	…	…	…	…

Tab. 2 Evaluation matrix for the integration of NPCCA Objectives into the LF of MMPs' ERs

Column [d] in table 2 shows the new formulation of the specific objectives of the MMP's ER LF, which incorporates the NPCCA strategic framework, thus its regional declination in the CCA, as the specific objectives of the MMP have been reformulated to be consistent with those of the NPCCA. The MMP actions themselves are evaluated in relation to their consistency with the NPCCA Goals (last column of Tab. 2).

2.2. Choice of spatial context

Sardinia, an autonomous region of Italy located in the western Mediterranean area (as shown in Fig. 2, panel "A"), covers an area of approximately 24,000 square kilometers and is home to a population of 1,639,591 residents.

The choice of Sardinia as a case study for this study is due to its insular status, which simplifies the investigation of environmental issues on a regional scale. Additionally, the island's climate exhibits a remarkable consistency, featuring hot and dry Mediterranean summers and mild winters with moderate rainfall (Canu et al., 2015). The landscape is predominantly characterized by hills, with only a few plains, notably the Campidano plain (the prominent greenish area in Fig. 2, panel "B"), which is of significance for agricultural purposes. Several small coastal valleys are also present, but their agricultural potential is compromised by coastal urbanization pressures. Sardinia boasts several mountain ranges, none of which exceed 2,000 meters in height, contributing to the island's rugged terrain (Pungetti et al., 2008).

Regarding land cover, Sardinia is distinguished by its herbaceous vegetation associations, many of which are endemic, as well as by its scrubland, comprising Mediterranean maquis and garrigue (Cardil et al., 2014). Agriculture and pastures, including wooded grasslands resembling Spanish dehesas (Seddaiu et al., 2013), play a significant role.

These multifunctional agro-sylvo-pastoral systems consist of pastures featuring oak and cork oak trees. Urbanized areas constitute less than 3.8% of the region's land, a notably low figure compared to the Italian average, which was recently assessed at 7.6% (Munafò, 2019).

Objective of the NPCCA	Specific objectives of the MMP	Assessment of relevance between the NPCCA Objective and MMP objectives	Reframing the specific objectives of the MMP in terms of CCA	MMP actions related to the specific objectives and consistent with the NPCCA Objective	Evaluation of MMP actions in relation to the NPCCA objective
Encourage and support ecosystem service-based solutions aimed at preventing and mitigating the effects of extreme events attributable to climate change	Protect the qualitative and quantitative status of surface and subsurface water resources	Objectives of the NPCCA relevant to the objective of the MMP (previous column): i) improve land management and maintenance; ii) ensure the functionality of river ecosystems even in lean periods, environmental sustainability of water resource uses, and socioeconomic sustainability of related activities; iii) encourage and support ecosystem service-based solutions aimed at preventing and mitigating the effects of extreme events attributable to climate change; iv) improve the efficiency of the water supply system in periurban areas, suburbs, historic centers, and public spaces; v) increase soil permeability and hydraulic system efficiency in periurban areas, suburbs, historic centers and public spaces; vi) promote planning and design for hazard prevention and facilitating monitoring; vii) increase or change the velocity and volume of water runoff; viii) improve the efficiency of water infrastructure; ix) operationally define risk assessment procedures and enhance the resilience of integrated water services; x) implement testing of materials, structures, facilities, and technologies that are more resilient to increasing temperatures and rainfall variability; (xi) secure land in relation to hydrogeological risk.	Protect the qualitative and quantitative status of surface and groundwater resources while ensuring the permanence and functionality of associated ecosystems	Provision of precautionary measures in new residential expansion areas and guidelines for sustainable management of the water cycle: application of the principle of hydraulic invariance in new developments, with the construction of the lamination and rainwater collection tanks in individual lots	Collecting tanks and lamination basins distributed throughout the lots contribute to retention and thus mitigation of the effects of flood events

Tab. 3 Construction of the LF that integrates NPCCA objectives MMP specific objectives and plan actions – Example referred to the Selargius MMP

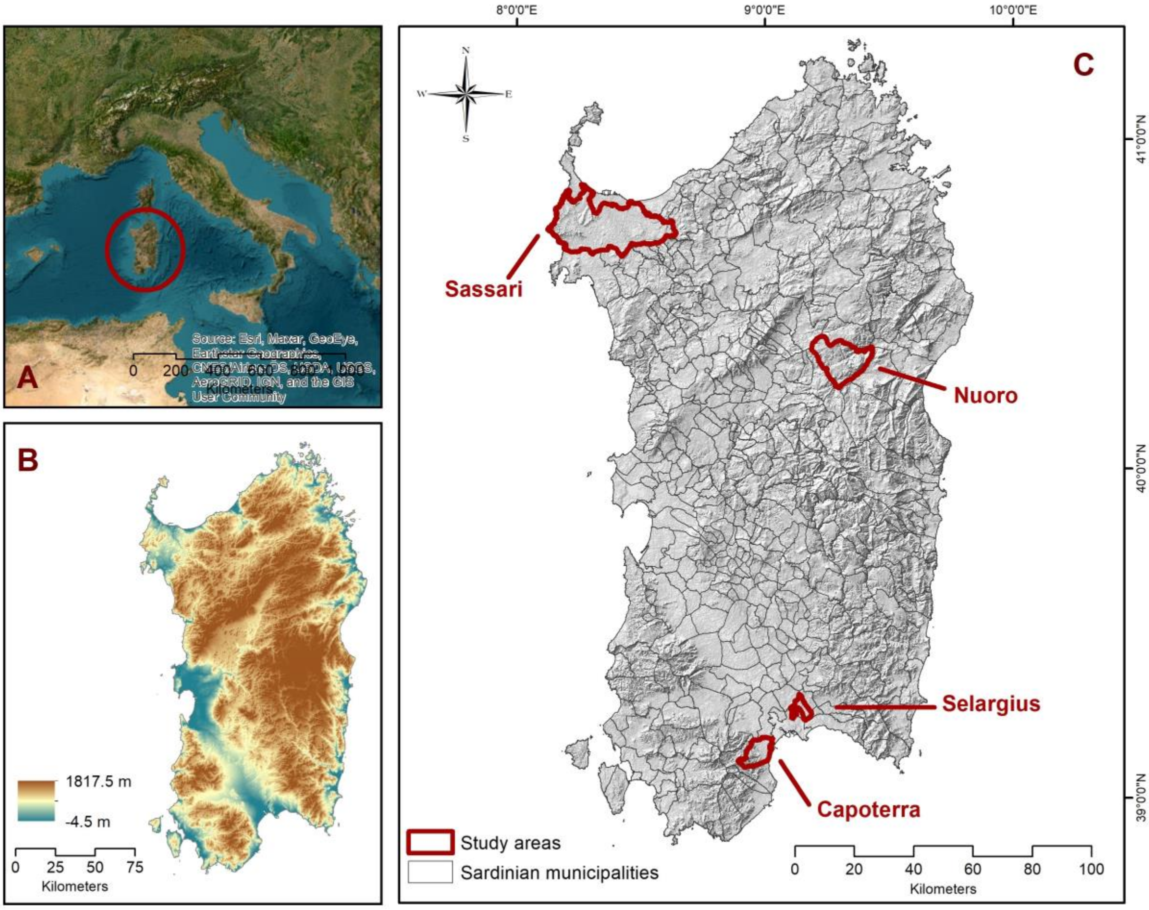

Fig.2 Sardinia within the Mediterranean Basin (A); Topographic map of Sardinia (B). The four municipalities selected as case studies (C)

The ongoing practice of spatial planning in the Region of Sardinia is based on the adaptation of MMPs to the RLP and the SPHF, which involve the implementation of SEA processes within which, in endoprocessual terms, the MMP is produced and, essentially, identified, with the development of the assessment, according to the LF approach described in Section 2.1, with particular reference to the integration of the CCA in the construction of the system of objectives and plan actions (Tab. 1 through 3).

The selection of MMPs for testing the methodology for implementing CCA in SEA processes was based on the following criteria:

- cities with approved MMPs in accordance with RLP and SPHF;
- cities with significant population for the Sardinian context;
- availability of plan and SEA documents on cities' institutional websites.

For the first criterion, the monitoring registry of municipal planning instruments freely available on the regional geoportal was used as a data source, which led to the identification of about thirty municipalities with approved MMP compliant with the SPHF and the RLP[10].

The subsequent population relevance criterion, using a threshold of 20,000 inhabitants, narrowed the number of municipalities from about thirty to fewer than ten.

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10 The thematic navigator can be retrieved from: https://www.sardegnageoportale.it/webgis2/sardegnamappe/?map=monitoraggio_strumenti_urbanistici. Accessed February 18, 2024. Data extrapolation from the attribute table of the shapefile "Monitoraggio strumenti urbanistici comunali, PUL, PP centri matrice e riperimetrazioni centri matrice" was carried out in December 2021.
The shapefile was retrieved from: https://webgis2.regione.sardegna.it/geonetwork/srv/ita/catalog.search#/metadata/R_SARDEG:4c48fe46-1014-4846-ae83-39c3be986b99. Accessed February 18, 2024.

Finally, based on the criterion of full availability of plan and SEA documents, the four selected case studies, namely the municipalities of Capoterra, Nuoro, Sassari, and Selargius, were identified from among the ten plans. Capoterra, with its approximately 24,000 residents and 68 km^2 of land area, and Selargius, with approximately 29,000 residents and 27 km^2 of land area, are two important urban centers in the Metropolitan City of Cagliari, whose municipal territories are adjacent to that of the Regional Capital City to the west and north, respectively. Nuoro, a provincial capital of Sardinia and the administrative landmark of the region's central mountainous areas, has a resident population of about 34,000 and an area of 192 km^2.

Sassari, the urban center capital of the Metropolitan City of Sassari, recently established under the provisions of the Regional Law No. 2021/7, is located in the northwest of Sardinia, in a predominantly flat territory with periurban belts characterized by an extensive presence of olive groves. Sassari has an area of 547 km^2 and a resident population of about 121,000.

For these four municipalities, whose locations are shown in figure 2, panel "C", the ERs of the SEAs and the MMPs documents, such as general report and technical implementation rules, are analyzed in order to define the respective LFs that contribute to the overall scheme in Tab. 3.

3. Results

The NPCCA reference sectors that stand out as the most significant within the MMPs of the four cities in Sardinia selected for the implementation of the methodology described in the second section of this study are hydrogeological instability, which is characterized by 31 specific objectives and 50 plan actions, urban settlements, with 29 specific objectives and 47 plan actions, and transportation, with 40 specific objectives and 62 plan actions. This section is divided into three parts and presents the results for each of these areas in relation to the definition of objectives and operational plan choices that integrate CCA into the LFs, i.e., strategic and implementation arrangements, of the MMPs.

3.1. Hydrogeological instability

The full set of actions and measures contained in the LFs of the ERs of the four analyzed MMPs that integrate climate considerations and contribute to addressing hydrogeological instability is provided in table 4 (third column), together with the objectives from which they descend within each LF (second column), and the NPPCA's goals that are pursued (directly or indirectly, to a larger or lesser extent) through the plans' objectives and action (first column). Three NPCCA's goals have been found to be pursued by the four the LFs of the ERs of the MMPs; two out of three aims at enhancing knowledge, either on areas that are prone to hydrogeological issues within the administrative boundaries, or on the conditions of buildings and infrastructure, while the third goal is action-oriented and paves the way for either revised planning choices or tangible actions.

The first objective, concerning improved knowledge on critical geological and hydraulic issues, is integrated within Sassari's and Selargius' LFs, which both contain an action providing for the identification of areas characterized by hydrogeological hazard and risk. Such action stems from a single objective in Sassari's LF and is connected to three objectives in Selargius LF.

The second objective, concerning improved knowledge on the conditions of buildings and infrastructure with a view to increasing their resilience, is integrated within three LFs of the ERs of the MMPs (Capoterra, Sassari, and Selargius). As for Selargius, a single action, providing for mitigating hydrogeological risks, hence focusing on the resilience part, stems from two LF objectives, while in the two other LFs a one-to-one relation between action and objective can be observed.

In Capoterra, the action focuses on the coastal areas, where a critical infrastructure, the road connecting the regional capital with Capoterra and the southwestern part of Sardinia, lies over a narrow strip of land, constrained between the coastline and a large wetland.

In Sassari, the action focuses on former mining sites, which also include abandoned buildings forming the old mining hamlets, as knowledge on their status is a precondition for their recovery and reuse for tourism purposes.

Finally, the last objective, concerning improved land management and maintenance, is integrated within all of the four analyzed LFs of the ERs of the MMPs, by means of one action (connected to a single objective) in both Capoterra and Sassari, of three actions (connected to four objectives) in Selargius, and of seven actions (connected to seven objectives) in Nuoro.

The broad goal of enhancing land management and maintenance is variously pursued in the four LFs, whose actions range from studies and analyses, to the identification of rules to be included within the municipal planning implementation code, to tangible interventions aimed at addressing specific problems within the town, as in the case of the conversion of the former railroad and of landscaping actions in Nuoro, or of the recovery and reuse of former mining hamlets in Sassari, or of measures to mitigate hydrogeological hazards in Selargius and to improve the coastal area in Capoterra.

3.2. Urban settlements

With reference to urban settlements, Tab. 5 in the Supplemental material shows that all four MMPs develop strategies aimed at defining objectives and actions aimed at mitigating climate change negative impacts, and at adapting urban environments.

The NPCCA's objective concerning the improvement of thermal comfort and quality of living involves establishing measures for heat control, storage, and dissipation. The objective is fully implemented into the LFs of the ERs of the four analyzed MMPs through: i. two specific objectives in the LF of the ER of the Capoterra MMP; ii. eight specific objectives in the LF of the ER of the Nuoro MMP; iii. eight specific objectives in the LF of the ER of the Selargius MMP; and, iv. two specific objectives in the LF of the ER of the Sassari MMP. In relation to these objectives, two types of plan actions have been identified to achieve the NPCCA's objective: the first aims at redeveloping and recovering the built characteristics of the urban consolidated fabric, while the second concerns the redevelopment of peripheral, periurban and rural spaces.

This redevelopment pursues the strategic distribution of greenery to mitigate impacts due to solar radiation and the heat island effect (Isola et al., 2023b).

As for Capoterra, four plan actions are of the first type, while three plan actions refer to the second type. Both clusters of actions are associated with the same LF objectives. In the case of Selargius, most of the plan actions are aimed at creating green areas and improving the conditions of existing ones.

The actions are associated with the objective "To pursue an environmental policy aimed at increasing the quantity and quality of green spaces present in the urban and suburban context and to encourage processes of reconfiguration and regeneration of the same through raising the building quality of public spaces and facilities." The actions of the LF of the ER of the Nuoro MMP are, in general, oriented toward the redevelopment of the landscape and built environment, with particular attention to the endowment of urban standards, the enhancement of the built urban fabric and the redevelopment of some of the most important sites of historical and cultural interest.

The LF of the ER of the Sassari MMP, on the other hand, defines a plan strategy that, with reference to the objective of the NPCCA, focuses on the partially unbuilt areas within the urban center, through the inclusion of a share of non-developable areas to make room for an urban network of green areas. These plan actions pursue the objective of reconnecting the most significant urban voids.

NPCCA goals	LF objectives	LF actions
To improve land management and maintenance.	NUORO – To regulate building expansion. NUORO – To restore areas currently hosting illegal buildings.	Analysis of the residential and service systems.
To improve land management and maintenance.	SELARGIUS – To ensure soil conservation and protection. SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality. SELARGIUS – To prevent new hydrogeological hazards.	Restrictive rules for Subareas C3.1 (residential) and G1.4 (services and facilities), classed as areas prone to high and very high geological hazard. Their implementation in terms of urban planning and construction is subject to the execution of hydraulic works of mitigation, regimentation and regularization of the current hydrogeological risk, so as to eliminate constraints arising from the current classification under the SPHF
To improve knowledge on critical geological and hydraulic issues in the area and their associated risks, and to produce updated databases based on land monitoring.	SASSARI – To prevent hydrogeological risks through appropriate land use regulations. SELARGIUS – To ensure soil conservation and protection. SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality. SELARGIUS – To prevent new hydrogeological hazards.	Identification of areas characterized by hydrogeological hazard and risk.
To improve land management and maintenance.	NUORO – To ensure the endowment of public services and facilities. NUORO – To enhance the area of the former powder mill in Prato Sardo.	Allocation of new areas for sports and recreation.
To improve land management and maintenance.	NUORO – To reclaim areas with illegal buildings. NUORO – To take action on the "Testimonzos" area in accordance with current regulations.	Preparation of a landscape-oriented redevelopment plan.
To improve knowledge of the conditions of the buildings and infrastructure to increase their resilience.	SELARGIUS – To ensure soil conservation and protection. SELARGIUS – To prevent new hydrogeological hazards.	Interventions aimed at mitigating hydrogeological risks.
To improve land management and maintenance.	SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality. SELARGIUS – To prevent new hydrogeological hazards. SELARGIUS – To ensure soil conservation and protection.	
To improve land management and maintenance.	SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality. SELARGIUS – To prevent new hydrogeological hazards. SELARGIUS – To ensure soil conservation and protection.	Precautionary measures in new residential expansion areas and guidelines for sustainable management of the water cycle: the principle of hydraulic invariance shall be applied in new development, and individual lots will be equipped with lamination and rainwater collection tanks.
To improve knowledge of the conditions of the buildings and infrastructure to increase their resilience.	SASSARI – To reactivate the Argentiera tourist system.	Functional-architectural recovery and securing of former mining areas
To improve land management and maintenance.	SASSARI – To reactivate the Argentiera tourist system.	
To improve land management and maintenance.	NUORO – To ensure the endowment of public services and facilities. NUORO – To enhance the area of the former powder mill in Prato Sardo.	Conversion of the former railroad into a bicycle and pedestrian pathway.
To improve land management and maintenance.	NUORO – To contain the built environment within an ideal perimeter. NUORO – To regulate building expansion. NUORO – To plan and develop a linear park that includes equipment and services of public interest.	Redesign of the zoning scheme.
To improve land management and maintenance.	NUORO – To ensure the endowment of public services and facilities. NUORO – To regulate building expansion.	Redevelopment of the railway station area by maintaining the existing destination while also providing for new volumes for residential, commercial, and office uses, as well as for a new "park and ride" area.
To improve knowledge of the conditions of the buildings and infrastructure to increase their resilience. To improve land management and maintenance.	CAPOTERRA – To protect and maintain environmental, historical and cultural components in order to recover historical memories and preserve landscape areas of particular importance, while also considering safety issues within the municipal areas, so as to promote its sustainable development by mitigating, or even reconsidering, incompatible urban planning expectations.	Improvement of the coastal area, mitigation of current erosion phenomena, conservation of the ecological systems (beach and wetland), environmental recovery of the wetland system for both productive and naturalistic purposes, reorganization of the coastal renaturalized landscape, environmental land rehabilitation for tourism purposes.
To improve land management and maintenance.	NUORO – To ensure the endowment of public services and facilities. NUORO – To enhance the area of the former powder mill in Prato Sardo.	New green recreation areas and landscaping.

Tab. 4 Goals related to hydrogeological instability contained in the NPPCA and integrated within the four analyzed logical frameworks (LF) of the MMP's environmental reports, LF's objectives and actions and measures that contribute to pursuing the NPCCA objectives

Regarding the NPCCA's objective concerning the improvement of the efficiency of the water supply system in periurban areas, suburbs, historic centers and public spaces, it is worth noting that the issue of water resource management is a nationwide problem. Regarding the LFs of the MMPs' ERs, the NPCCA goal is implemented into all of the four plans. In the case of Capoterra, six plan actions stem from a single LF objective alone related to the redevelopment and reorganization of consolidated urban hubs. As for Nuoro, ten plan actions referring to this NPCCA objective, and they derive from as many objectives of the LF of the MMP, largely aimed at enhancing the existing built and cultural heritage and ensuring the provision of new public services. The same aims are pursued in the LF of the Selargius MMP, in which thirteen plan actions implement the NPCCA objective and are associated with a set of specific objectives aimed at protecting the qualitative and quantitative state of water resources, preventing hydraulic and geological risk, and increasing the availability of quality green spaces in the urban, periurban and rural areas. The LF of the ER of the Sassari MMP targets two plan actions that relate to improving the efficiency of the water system; both refer to the need to define an urban ecological network and are linked to two different objectives of the LF.

The third and fourth objectives of the NPCCA aim to promote planning and design for risk prevention and to facilitate monitoring and increasing soil permeability and hydraulic system efficiency in periurban areas, suburbs, historic centers, and public open spaces. Both objectives aim to address these critical issues and are integrated into the LFs of the ERs of the analyzed MMPs. The third objective is present in three of the LFs of the ERs of the analyzed MMPs, with the exception of Sassari, while the fourth is implemented into all four plans. As far as Capoterra is concerned, six plan actions contribute to the achievement of the NPCCA's third objective, all referring to the same specific objective of the LF of the ER of the MMP, namely the redevelopment and reorganization of the consolidated urban poles, i.e., the urban consolidated fabric, the Poggio dei Pini hamlet and the coastal strip. Also referring to Capoterra, six plan actions are associated with the fourth objective of the NPCCA. Among them, some implement the LF objective focused on the protection and preservation of environmental, historical and cultural components, and the protection of areas of special landscape significance; others pursue the LF objective of spatial and environmental safety.

3.3. Transportation network

The LF, reported in Tab. 6 in the Supplemental material, provides: i. in the first column, the NPPCA's goals directly or indirectly pursued by objectives and actions of the LFs of the ERs of the analyzed MMPs; ii. in the second column, the objectives of the four LFs of the ERs of the MMPs with which the objectives of the NPPCA are associated; and, iii. in the third column, the actions that implement the LFs' objectives, integrate climate considerations, and contribute to addressing transportation network.

Four NPCCA's goals have been found to be pursued by the four LFs. Two objectives refer to prevention measures, such as promoting the securing of the territory against hydrogeological risk and the integrating climate change risks into planning and design processes. One objective refers to monitoring measures. Finally, the last objective refers to increasing knowledge in relation to materials, structures, plants and technologies that are more resilient to increasing temperatures and rainfall variability.

The first objective, which concerns the testing of materials, structures, plants and technologies more resilient to increasing temperatures and rainfall variability, is implemented into fifteen LF objectives: one from the Capoterra MMP's ER LF, eight from the Nuoro MMP's ER LF, five from the Selargius MMP's ER LF and one from the Sassari MMP's ER LF. With reference to the Capoterra LF, two actions, both connected to the LF objective, contribute to the achievement of the NPCCA objective in terms of transport network. In reference to the Nuoro LF, twelve actions are connected to the eight LF objectives. With the exception of five LF objectives that are connected to a single action, the objectives "To restore areas currently hosting illegal buildings" and "To ensure the endowment of public services and facilities" are implemented through two actions each, while the objective "To enhance the historic center as a part of the city to be preserved and handed down to future generations in the most appropriate manner" is connected to five actions that contribute to the achievement of the NPCCA objective in relation to the transport network. With reference to the Selargius LF, the five objectives are implemented through a single action that contributes to the achievement of the NPCCA objective in terms of transport network. The action, concerning interventions aimed at mitigating and reducing the hydrogeological risk, is connected to three different LF objectives. The only objective of the Sassari MMP's ER LF is linked to a single action that contributes to the achievement of the NPCCA objective in relation to the transport network. The second objective concerning the integration of climate change risks into planning and design is implemented into nineteen objectives: one from the Capoterra MMP's ER LF, nine from the Nuoro MMP's ER LF, three from the Sassari MMP's ER LF, and six from the Selargius MMP's ER LF. With reference to the Capoterra LF, six actions, linked to a single LF objective, contribute to the achievement of the NPCCA objective in relation to the transport network. In reference to the Nuoro LF, thirteen actions contribute to the achievement of the NPCCA objective. In particular, with the exception of five LF objectives each connected to a single action, the LF objective "To enhance the historic center as a part of the city to be preserved and handed down to future generations in the most appropriate manner" is connected to five actions. The LF objectives "To ensure the endowment of public services and facilities," "To restore areas currently hosting illegal buildings," and "To enhance the area of the former powder mill in Prato Sardo," are each connected to two actions contributing to the achievement of the NPCCA objective. In addition, three actions ("Preparation of a landscape-oriented redevelopment plan", "Conversion of the former railroad into a bicycle and pedestrian pathway", and "Conversion of existing areas into parking areas") refer each to two different LF objectives. With reference to the Sassari MMP's ER LF, three actions contribute to the achievement of the NPCCA objective in relation to the transport network. With the exception of one LF objective, the remaining two LF objectives "To encourage sustainable nature-based tourism" and "Protection and Conservation of Sites of Community Importance" relate to two actions. Furthermore, two out of three actions relate to two different LF objectives. With reference to the Selargius MMP's ER LF, three actions contribute to the achievement of the NPCCA objective. With the exception of one action ("Redevelopment of the Is Corrias areas, the boundary areas with the municipality of Quartucciu, the boundary areas with the municipality of Monserrato"), which is connected to a single LF objective, the other two actions are connected, respectively, to three LF objectives in the case of the action "Interventions aimed at mitigating hydrogeological risks" and two LF objectives in the case of the action "Identification of the "Road of Parks" and concentration of areas handed over to the Municipality of Selargius through supplementary agreements pursuant to Law 241/90 within the areas "San Lussorio", "Paluna" and "Santa Lucia"".

The third objective concerning the improvement of the effectiveness of monitoring, alerting and emergency intervention systems for transport services is implemented into a single LF objective related to the Capoterra MMP's ER LF. In addition, six actions, linked to the MMP objective, contribute to the achievement of the NPCCA objective.

The fourth objective concerning the securing of the territory in relation to hydrogeological risk is implemented into seven LF objectives: three of the LF of Nuoro, and four of the LF of Selargius. With reference to the Nuoro LF, three actions contribute to the achievement of the NPCCA objective. Apart from one action ("Functional reconversion of the Artillery Barracks into a university campus (Campus in the Green)") which is connected to a single LF objective, the other two actions are both connected to two LF objectives. With reference to the Selargius MMP's ER LF, four actions contribute to the achievement of the NPCCA objective. Except for one LF objective ("To protect the qualitative and quantitative status of surface and groundwater resources") which is connected to a single action, the remaining three LF objectives are connected to all four LF actions.

4. Conclusions

In the construction of MMPs which implement CCA into their LFs, SEA is connoted as a process in which planning and evaluation are progressively integrated, leading to the identification of a system of objectives and operations aimed at their pursuit, which constitute a strategy.

Within this strategy, the evaluation of the impacts of choices, i.e., of plan actions, is aimed at incrementally refining this system in such a way as to arrive at an overall result that is identified as the best strategy with reference to the implementation of local development processes that are configured as expressions of the best compromise, i.e., the most effective integration, between the instances aimed at nature conservation and the protection of archaeological, historical and landscape resources, social equity, economic development and, certainly, the CCA (Lai and Zoppi, 2023).

Information and participation, on the part of public administrations vis-à-vis local communities, are, likewise, fundamental characteristics for the effectiveness of the evaluation and planning process, as factors that favor, in a relevant way, the recognition of their demands (Zoppi and Lai, 2010).

The methodological approach proposed and applied in this study could serve as a valuable tool to support decision-making processes related to spatial planning, and it has the potential to be applied in various European Union member states. This adaptability is attributed to its alignment with national planning regulations based on legislation stemming from Directive 2001/42/CE. Within these regulatory frameworks, there is ample room for the incorporation of SEAs into the decision-making processes of MMPs, where they can seamlessly integrate questions and policies related to CCA.

The employed methodology may effectively help civil servants, practitioners, and local authorities in addressing the repercussions of changes in land cover and land use. From this perspective, the inclusion of CCA-related measures within MMPs' policies can serve as a foundation for steering local decision-making towards prevention or, at the very least, mitigation of damages caused by climate change impacts (Lai et al., 2020).

Looking ahead, promising avenues for future research become apparent. One crucial focus should be on the implementation of SEAs for MMPs that entail legal provisions encompassing CCA-related activities within MMP implementation codes. Furthermore, an important area to explore is the role of local communities in shaping and executing environmental hazard management policies aimed at mitigating climate change impacts (Lai et al., 2021). These initiatives should be built upon the gradual enhancement of scientific, technical, and cultural knowledge within local societies regarding climate change, climate change impacts and CCA (Magnaghi, 2019).

Within this conceptual framework, the evolving awareness within communities can be identified as a key driver of the qualitative enhancement of local spatial, environmental, and landscape assets. From this standpoint, policies related to CCA can be seamlessly integrated into planning practices undertaken by local governments, reflecting societies that fully grasp the significance of nature and natural resources in terms of enhancing quality of life (Magnaghi, 2020).

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Authors’ contributions

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Images and tables sources

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Transform*Active* Cities facing the ecological transition

Cha(lle)nges, Strategies and Practices in the EU Panorama

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Abstract
Climate change is the ultimate threat multiplier, since it worsens most of humanity's most pressing environmental, societal, and economic challenges. Anyway, growing urbanisation brings both opportunities and challenges related to the ongoing transition process, since cities are at the forefront of changes and challenges. Regeneration of urban areas is a significant priority, which needs to take into account environmental quality, social justice and sustainable development. Transforming cities and regions into vibrant, sustainable, and resilient living places has become a key global priority. In the light of the above, the article – in the context of ongoing research activities – focuses on the ecological transition in the EU panorama, highlighting the active and decisive role of cities, with reference to some significant case studies in the implementation of Green and Nature-based Solutions (NBS) through an integrated, forward-looking, and broad-based planning approach. It is structured in three main parts. The first part frames the topic in the international scientific context. The second one, in the EU panorama, highlights the fundamental role of NBS with reference to the methodological approach, and the latest and most innovative ongoing policies, strategies, and practices. The third and final part develops the discussion and the consequent conclusive remarks with possible future research directions.

Keywords
Climate Change; Ecological Transition; Nature-Based Solutions.

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1. Climate Change as a Threat Multiplier within the Global Dynamic Framework

As stated by the Acting Executive Secretary United Nations Framework Convention on Climate Change, Mr. Ibrahim Thiaw, at the Third Global Conference on Strengthening Synergies Between the Paris Agreement and the 2030 Agenda for Sustainable Development[1] (Tokyo, 20-21 July 2022), climate change is the ultimate threat multiplier, since it negatively impacts all UN Agenda 2030 Sustainable Development Goals (hereafter referred as SDGs) and worsens most of humanity's most pressing challenges such as poverty, hunger, drought, desertification, access to clean air, water energy (United Nations, 2022a).

According to the Intergovernmental Panel on Climate Change (IPCC, 2022), human influence has unequivocally warmed the atmosphere, ocean, and land, resulting in widespread and rapid changes in the atmosphere, oceans and biosphere. The scale of recent changes in the climate system as a whole and the current state of many aspects of the climate system are unprecedented for many centuries to many thousands of years (Antwi-Agyei, et al., 2017). Furthermore, the climate system is now in a situation where atmospheric concentrations of CO2 are higher than ever in at least 2 million years and concentrations of CH4 (methane) and N2O (nitrous oxide) are higher than ever in at least 800,000 years. We are facing a global challenge precisely because it is human influence on the climate system[2]. Also, according to the critical framework outlined by the World Economic Forum, the continued degradation of nature will add to stress on local residents, public health, businesses and ultimately the stability of society, while regional population growth will further impact the use of land and resources such as water and food. Beyond the sheer scale, complexity and interdependency of the needed changes, the climate transition will be disorderly because decades of inaction and hesitant implementation of transition measures on local and global levels have steered the planet onto a path that will be difficult to change (World Economic Forum, 2022 and 2023). Definitely, humanity's environmental challenges have grown in number and severity ever since the Stockholm Conference in 1972 and now represent a planetary emergency (UNEP, 2021). One of the main objectives of the transition is to seek to answer the question of how we can better understand the processes of structural social change to help achieve a sustainable future (Loorbach, 2009 and 2014). Because of this, the implementation both of the SDGs and of the Paris Agreement is an imperative and essential challenge for the benefit of all mankind (United Nations, 2022a)[3]. As a matter of fact, climate change and sustainable development pose significant intertwined challenges, and the adoption of the UN Framework Convention on Climate Change (UNFCCC), Paris Agreement and the 2030 Agenda and its 17 Sustainable Development Goals (SDGs) in 2015 represented major progress for multilateral efforts to address the world's most pressing problems (United Nations, 2022b).

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[1] The United Nations' 2030 Agenda for Sustainable Development, adopted in September 2015, is underpinned by 17 Sustainable Development Goals (SDGs) and 169 targets. National policymakers are facing the challenge of implementing this indivisible agenda and achieving progress across the economic, social and environmental dimensions of sustainable development worldwide. As the process moves towards implementation, there is a need to address the scope and systemic nature of the 2030 Agenda and the urgency of the challenges through a wide range of tools and science-based analysis to navigate that complexity and to realise the global shared ambition.

[2] Notably, each of the past four decades has been successively warmer than any decade preceding it since 1850, when global surface temperatures were 1.09°C higher in 2011-2020 than in 1850-1900, with increases greater on land than in the ocean. Temperatures have risen faster since 1970 than in any other 50-year period in at least the last 2,000 years. Furthermore, global average rainfall over land has likely increased since 1950, with the fastest rate of increase since the 1980s. The frequency and intensity of heavy precipitation events have increased since the 1950s over most land areas for which observational data is sufficient for trend analysis. Human influence is likely to have contributed to the pattern of observed precipitation changes since the mid-20th century. For more information, see https://www.ipcc.ch/report/ar6/wg3/. The IPCC Working Group III report provides, in fact, an updated global assessment of climate change mitigation progress and pledges and examines the sources of global emissions. It explains developments in emission reduction and mitigation efforts, assessing the impact of national climate pledges in relation to long-term emissions goals.

[3] The complete documentation of the Conference can be accessed via the dedicated Conference Website: https://www.un.org/en/climate-sdgs-conference-2022. The Third Global Conference on Strengthening Synergies between the Paris Agreement and the 2030 Agenda for Sustainable Development was held in Tokyo, Japan, 20-21 July 2022. It was co-convened by the UN Department of Economic and Social Affairs (UN DESA) and the Secretariat of the UN Framework Convention on Climate Change (UNFCCC).

The single biggest challenge to achieving sustainable development remains taking urgent action to combat climate change and its impacts (Fig. 1).

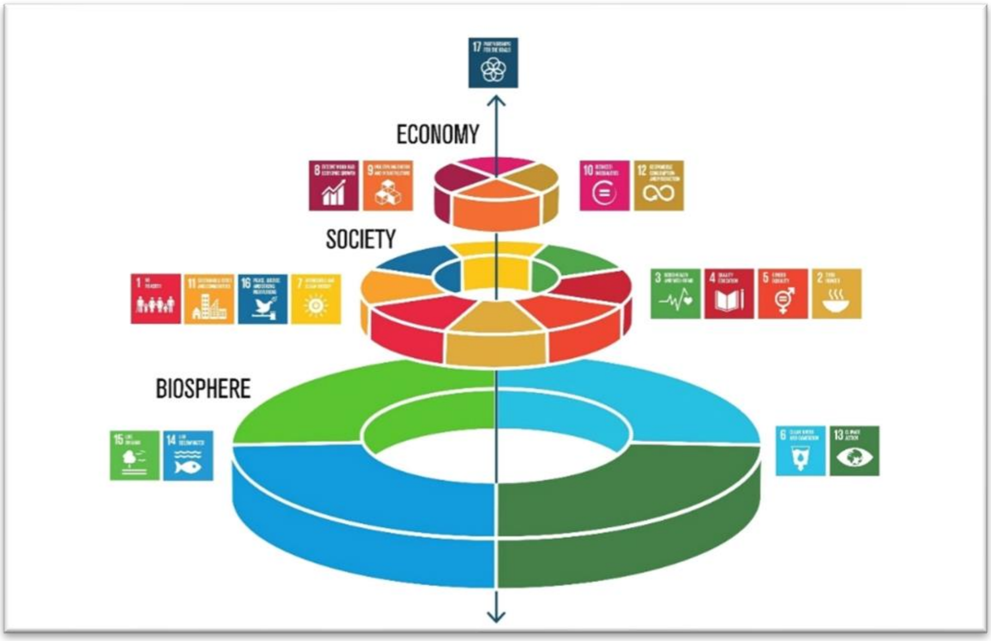

Fig. 1. The SDGs Cake, in addition to the reports concerning the global challenges and objectives, highlights the basic, priority and essential role of the planet with its resources and of nature with respect to other economic and social aspects

In this regard, a growing body of evidence demonstrates that climate action necessitates a multiple transition that addresses all dimensions of sustainability, including both social, economic, and environmental aspects. Furthermore, the territorialization of the SDGs while accelerating progress towards a climate resilient, net-zero future requires the active and collaborative engagement at national level, of line ministries as well as sub-national and local authorities in integrated planning and implementation (Cavalli & Pultrone, 2020; Dzebo, & Shawoo, 2023; Fuso Nerini et al., 2019). Meaningful engagement of youth, civil society, academia, the private sector, and local communities is also vital.

In essence, enhancing capabilities of various stakeholders to pursue synergistic implementation of climate and SDGs agendas is crucial. This includes enhancing capacities to identify synergistic opportunities and to overcoming technical, financial, planning, organizational, and behavioral barriers.

Another aspect of utmost importance to consider –to be placed at the center of the planning and implementation of integrated policies and programmes –is to achieve the *Just Transition*[4] without leaving no one behind. Indeed, climate action should prioritize the needs of marginalized, poor, and vulnerable communities, as well as those who will be most affected by transformational pathways (Galgóczi, 2022; Papa Francesco, 2015).

4 The foundations on which the *just transition* is developed are to move towards a zero-emission economy in a fair and inclusive way, guiding the process according to specific parameters that avoid the risk of creating new inequalities. As part of the European Green Deal, the environmental plan to achieve climate neutrality, the European Union has implemented a program specifically dedicated to just transition. In fact, a fund of 150 billion euros has been set up to be used by 2027 precisely to organize the energy transition in a balanced way. It is a new financial instrument sanctioned in the framework of the cohesion policy which aims to provide support to the territories facing severe socio-economic challenges arising from the transition to climate neutrality. For further information see: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en.

At the same time, there is a need to strengthen national and local development and climate strategies, including NDCs[5], building on existing integrated approaches, such as Circulating and Ecological Spheres and Decarbonization Leading Areas, aimed at advancing the SDGs and action for climate.
Indeed, the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change, referred to above, highlights, for the first time, the social and demand-side aspects of climate mitigation, draws attention to the deep links between climate mitigation and sustainable development, and to how climate action is intimately connected to facing the crisis of nature.
Not to be overlooked, the contributions of digital technology could contribute to efficiency improvements, cross-sectoral coordination, and decreasing resource use, implying several synergies with the SDGs, as well as trade-offs, for example, in relation to reduced employment, increasing energy demand and the increasing demand for services, possibly increasing GHG emissions (Büchele & Andrä, 2016; Ellen MacArthur Foundation, 2019; Ronchi, 2021; IPCC, 2022; Pultrone, 2023)[6].
There are many strategies, actions, and pathways available for building sustainable cities, working "with" and not "against" nature, as highlighted by United Nations Environment Programme (2021).
Numerous approaches and technologies that address critical human needs while conserving and restoring nature and ecosystem services have been developed, framed in the perspective of ecological justice and in a transformative framework to be rethought, based on the fair distribution of environmental goods and evils, on socio-ecological interconnection, on the action and capabilities of nature, and on participation in decision-making processes (Pineda-Pinto et al., 2021). They include: engaging in sustainable urban planning; encouraging densification for compact communities, especially in sprawling cities; regional planning to mainstream biodiversity, nature and ecological restoration; promoting sustainable production and consumption; promoting Nature-Based Solutions (hereafter referred as NBS); promoting, developing, safeguarding or retrofitting with soft infrastructure for water management while improving hard infrastructure to address biodiversity outcomes; promoting ecosystem-based adaptation within communities; maintaining and designing for ecological connectivity within urban spaces; increasing urban green spaces and improving access to them; increasing access to urban services for low-income communities; and promoting urban agriculture to increase local food supply.
This study, as part of the author's ongoing research activities on these topics, is focused on the ecological transition in the EU panorama. It is structured in three main parts. The first part frames the topic in the international scientific framework. The second one, with reference to the EU panorama, highlights the fundamental role of NBS with reference to the methodological approach, and latest and most innovative ongoing policies, strategies, and practices, analyzing the paradigmatic case study of the *GreenQuays project* of the Municipality of Breda (in The Netherlands) under the EU Urban Innovative Actions initiative (hereafter referred as UIA). The third and final part develops the discussion and the consequent conclusive remarks, with possible future research directions. It aims, on the one hand, to highlight the active and decisive role of cities in the implementation of NBS, on the other, the need for these to become an integral part of urban planning

[5] NDCs stands for Nationally Determined Contributions, at the heart of the Paris Agreement and the achievement of its long-term goals. They embody each country's efforts to reduce domestic emissions and adapt to the impacts of climate change.

[6] In particular, the study by Büchele and Andrä crosses the four levers of digital transformation with strategic sectors of the green economy and evaluates the influence they may have with reference to the German economy: the possibility of using a vast amount of sensors for green technologies and digital data; the development of automation applied to dynamic supply chains, created by connecting machines with communication and information systems; the development of digital interfaces between companies and their customers and/or users; the use of the digital network for the exchange of information. It therefore evaluates the possible impact of the greater activation of levers in some sectors of the green economy: for the production, accumulation and dispatching of renewable energy, in the promotion of more sustainable mobility, for the efficient use of materials and the circular economy, and in the management of water networks. The analysis shows that the development of digitization in these sectors of the green economy in Germany could make it possible to reduce greenhouse gas emissions by 200 million tons from 2016 to 2025 and to increase the added value in these same sectors, again by 2025 of 20 billion euros.

processes through an integrated, forward-looking and wide-ranging design approach. This approach is essential for the effective territorialization of the UN 2030 Agenda and for the implementation of the Green Deal at a local level, given the challenges arising from the ongoing ecological, digital and energy transitions.

2. Cities as Main Players of the Ecological Transition in the EU Policies

2.1 Urban Challenges and changes ongoing toward sustainability

Within the wide and complex global framework above outlined, cities account for 70% of global CO2 emissions, and, in the face of the growing pace of urbanisation, face huge challenges related to sustainable waste management, mobility, climate adaptation and energy. Today, approximately 56% of the global population (about 4.4 billion people) live in cities. By 2050, it is estimated that nearly 7 out of 10 people will reside in urban areas (State of Green, 2023). Furthermore, lately (on 19 June 2023), the World Meteorological Organization together with the Copernicus climate change service released the latest "State of the Climate Report in Europe", which paints a gloomy picture for our continent: first in warming, fastest in warming from the 1980s to today -it travels twice the global average-, in 2022 alone extreme climatic events have caused the premature death of over 16,000 people (99.6% due to heat waves)[7]. Anyway, in the face of a multifaceted global crisis, as their political, economic, and technological power grows, cities can seize the opportunity to be leaders in the green transition and drivers of the green economy, helping to achieve the United Nations SDGs. Through intelligent solutions they can ensure that sustainable economic activities, energy consumption and positive environmental impacts are optimized (Droege, 2008; State of Green, 2020). In a nutshell, urbanisation, with its related expansion and densification phenomena, brings both opportunities and challenges related to the ongoing transition process.

Regeneration of urban areas is a significant priority, which needs to take into account environmental quality, social justice and sustainable development (Bianconi et al., 2020; Filippucci, & Salvati, 2018; Pertoldi et al., 2022; Pultrone, 2019, 2020, 2021a, 2021b, 2022). Transforming cities and regions into vibrant, sustainable, and resilient living places has become a key global priority (Newman et al., 2017). This is reflected in numerous policy initiatives at local, region al and national scale, and internationally through the 17 UN SDGs (particularly SDG 11). Together these are part of a global call to rethink and redesign urban environments through innovative solutions that address multiple issues, considering that land degradation and transformation[8] have contributed to about a quarter of greenhouse gas emissions in the last decades and that –although the issue is recognized as a global concern– approaches to addressing it have often been inadequate and fragmented (Di Gregorio et al., 2017; Pileri, 2022; UNEP, 2021; Zucaro & Morosini, 2018).

For this reason, the role and responsibility of urban planning are even more important in guiding the just, green, and sustainable transition (Pultrone, 2022; RETICULA, 2021; State of Green, 2020, 2021 and 2023;

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[7] The 2022 edition of the World Meteorological Organization's (WMO) State of the Climate in Europe report, produced jointly with the Copernicus Climate Change Service (C3S*), paint a sombre picture for Europe last year. According to the findings, Europe is the fastest warming of all the WMO regions, warming twice as much as the global average since the 1980s. What's more, high-impact weather and climate events in 2022 resulted in over 16,000 reported fatalities, of which 99.6% were attributed to heatwaves. For more information, see https://climate.copernicus.eu/wmo-c3s-release-sombre-findings-joint-state-climate-europe-2022-report?utm_source=socialmedia&utm_medium=tw&utm_campaign=wmo-c3s_june23.

[8] It is considered appropriate here to return to the distinction between soil transformation and land degradation, as illustrated by UNEP, 2021, where it specifies that transformation can be legal or illegal but is usually intentional. Ecosystems are deliberately altered with the aim of increasing the delivery of a particular benefit, or set of benefits, to a group of people, often at the expense of other benefits and almost always with a loss of biodiversity. Degradation, on the other hand, is the loss of ecosystem function, in transformed or natural soils, as a result of human actions and is usually not intentional. Degradation, like transformation, is typically accompanied by biodiversity loss. Degradation is widespread and ongoing, even accelerating, across the planet in both the developed and developing world. Rehabilitation aims to reverse degradation, but not necessarily to reverse transformation. Restoration, which aims to return both function and biodiversity to some previous state before transformation occurred, is harder to achieve and takes much longer.

Tîrlă, Manea, et al., 2014). At EU level, the transition challenges have been taken through the goals of the policies aimed at supporting cities to design sustainability interventions that benefit all residents, ensuring accessibility and equitable enjoyment of environmental public goods in line with residents' right to place and to a clean and healthy environment (EEA, 2012), and *The Green Deal* project has emerged as a far-reaching change in an ecological direction with the "Next Generation EU" Recovery Fund (EC 2015, 2019a and 2019b). As a matter of fact, this essential issue is tackled at several policy levels, but cities appear the drivers of sustainable development in EU, since it places where all the global challenges are coming together and where new solutions can be tried and tested by requiring an integrated, place-based, and participatory approach (Ali, 2016; Beatley, 2012; Pultrone, 2019 e 2020).

Above all, the ecological transition must be considered together with the digital and energy transition as a single major challenge, i.e., an important and joint effort to tackle a problem with a high impact on society and the whole planet in an integrated way, in a renewed relationship with nature (Colding and al., 2020). Indeed, many cities are experimenting with best practices in the framework of the urban green transition, which offers multiple themes and declinations of implementation[9]. These aim to make cities greener, livable, and connected to cope with the consequences of population growth, urbanization, and climate change (Walker et al., 2004; Demuzere et al., 2014; Tulisi, 2017; Wildt et al., 2021; Winslow, 2021; Johnson et al., 2022).

In this process, holistic and strategic urban planning, and development in the areas of mobility and infrastructure, climate adaptation, as well as environmentally friendly architecture and construction play a central and decisive role (Papa et al., 2015). This is why, as urban challenges align, it becomes crucial to identify and share inspiring and effective solutions to radically improve cities and, more generally, our common home (State of Green, 2023).

2.2 Green solutions as tools supporting the ecological transition paradigm

At the heart of the ecological transition paradigm are undoubtedly the NBS, which are internationally recognized as a key part of climate action and biodiversity and need to be more widely deployed, including through the supportive policy framework offered by the EU Green Deal and related initiatives.

Over the past 20 years, several concepts have emerged to address the general challenges of integrated planning for green spaces, including NBS and Green and Blue Infrastructure[10] (hereafter referred as GBI).

For instance, Green Infrastructure (GI) and its integration into spatial planning has emerged as one of the most appropriate and effective ways to improve microclimate and tackle the impacts of climate change, specifically the Urban Heat Island (UHI) effect (Isola et al., 2023; Salata and Yiannakou, 2016).

Urban greenspaces have also been studied as networks, by means of the creation of models capable of measuring the performance of the system in its entirety, posing the basis of a new multy-disciplinary research field called *green network* (Tulisi, 2017). Other research is focused on the relations between the definition and implementation of a green infrastructure (GI) and hydro-geological hazard (Lai et al., 2021).

NBS aim to promote natural processes of urban development to help overcome the challenges of renewable energy, food security, water resources and climate change (Kabisch et al., 2017).

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9 Particularly significant in this direction is the experience of Danish cities, which have a long tradition of holistic planning, in which concern for the environment, people and businesses go hand in hand. For more information see https://stateofgreen.com/en/.

10 In the EU Green Infrastructure Strategy (2013), *green infrastructure* is defined as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces and other physical features in terrestrial (including coastal) and marine areas, and on land, green infrastructure is present in urban and rural settings. Blue infrastructure is similar to the one of green infrastructure and covers natural and semi-natural areas including aquatic ecosystems, coastal and marine areas. Peri-urban areas are of high relevance for the development of green infrastructure, and the concept of such infrastructure can be enriched with Nature Based Solutions (NBS). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52013DC0249.

According to Korkou, Tarigan and Hanslinm (2023), while there is a growing literature on urban NBS, including GBI in cities, there is still a knowledge gap on how these climate mitigation actions can be integrated into planning and design urban landscape, as well as their mitigation potential.

GI development should support natural processes to achieve broader sustainable impacts and benefits and is central to the adoption of NBS to contribute to crucial functions such as clean air and water, rainwater, biodiversity, and beautiful landscapes, thus providing multiple functions for ecosystem and biodiversity benefits. Considering the concept of multifunctionality in urban GI planning, five main related themes can be identified that should be incorporated into planning, both at the urban and territorial scale: 1) planning methods for urban GI, 2) evaluation approaches of urban GI, 3) ecosystem services and their benefits, 4) sustainability and climate adaptation, 5) urban agriculture. And, to guarantee multiple functions in urban infrastructures, the following are considered necessary: spatial distribution, optimal distance, integrated network, accessibility and public participation and engagement.

According to Winslow (2021), the characteristic of GI includes the following principles: 1) complete combinations between urban-rural areas and contexts; 2) integration with other urban infrastructures; 3) multifunctionality that provides for multiple services; 5) connectivity of form and function in the landscape; 6) multiscalar for natural and cultural processes and 7) transdisciplinary combining expertise from different disciplines. Within this context, NBS can therefore be considered an umbrella concept (fig. 2) that encompasses multiple dimensions (strategic, spatial planning, soft engineering and performance) and is based on a broad knowledge base of approaches including ecosystem services, ecosystem-based adaptation, ecosystem-based disaster risk reduction, ecological engineering, blue infrastructure, GI, blue-green infrastructure, urban forestry sustainable urban drainage systems, low impact design and other concepts (European Commission, 2013, 2019b, 2020, 2021 and 2022). According to the EU Research and Innovation policy agenda on Nature-based Solutions and Re-naturing Cities, NBS are solutions 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 (European Commission, 2015). NBS also contribute to the improvement of urban liveability[11], in addition to the factors related to safety, health, economic and educational resources, infrastructure, culture and environment which influence the different classifications developed at national and international level, with more effective results, when possible, create synergies between them.

If appropriately designed, NBS can perform multiple functions beyond specific ones such as, for example, rainwater management or the reduction of heat islands, and therefore play a key role in creating the "livable city" (Alderton et al., 2019; Gough, 2015; Higgs et al., 2019; Young & Hermanson, 2013). To sum up, NBS are an essential tool for climate change adaptation and increasing urban biodiversity, supporting a triple bottom line of planet, profit and people, where the goal is to increase urban resilience.

[11] The concept of livability – referring to concerns related to the long-term well-being of individuals and communities – includes factors such as neighborhood amenities, including parks, open spaces, walkways, neighborhood commerce, as well as environmental quality, safety and security. health, the availability and quality of public transport, educational institutions and healthcare facilities, the overall cultural and social atmosphere of a place, such as the presence of diverse recreational activities and opportunities for community involvement. The liveability of cities is assessed annually by the Economist Intelligence Unit (EIU) and monitored through its global liveability ranking. In 2023, Vienna in Austria ranked first for the second consecutive year as the most livable city (see: https://www.eiu.com/n/campaigns/global-liveability-index-2023/).

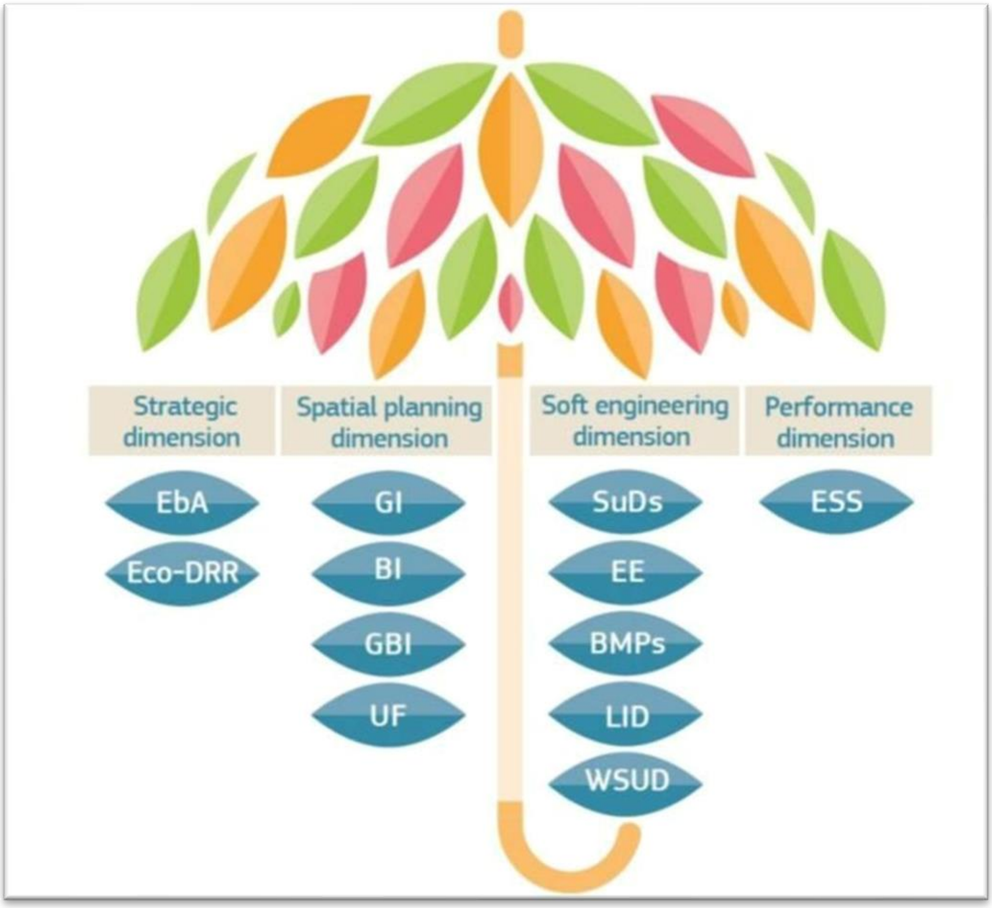

Fig. 2. Conceptualization of NBS an umbrella and their relation to key existing concepts: EbA (ecosystem based adaptation); Eco-DRR (ecosystem-based disaster risk reduction); GI (green infrastructure); BI (blue infrastructure); GBI (green-blue infrastructure); UF (urban forestry); SuDS (sustainable urban drainage systems); EE (ecological engineering); BMPs (best management practices); LID (low-impact design); WSUD (water-sensitive urban design); ESS (ecosystem services)

2.3 From a "People-centric" to "Life-centric"[12] transition: strategies and practices

Jointly addressing the challenges of biodiversity, pollution, resources and climate provides the starting point for how *green cities* support ecosystems and build resilience. In this context, the increased focus on solutions in the GBI sector offers an effective and efficient approach to address these challenges in cities. While GI is important, it alone is not enough to achieve a green and healthy urban environment. Therefore, its integration in other sectors, beyond the protection of biodiversity and addressing the climate challenge, is of great relevance, so developing links with other policy areas such as zero pollution of air, water and soil, sustainable mobility, building renovation, energy, water resources management, circular economy and public health.

In this context, *Greening Cities*[13] is one of the topics of the second EUI-Innovative Actions (EUI-IA) Call for proposals opened in May 2023 dedicated to topics aligned with the New Leipzig Charter (2020) and the European Union's priorities, such as the green and digital transitions, as well as the Urban Agenda for the EU.

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[12] The two words refer to the *White Paper for A Green Transition-Urban green transition-transforming our cities for a new reality* (2023), showing how Danish urban planning is witnessing a shift from a "people-centric" to "life-centric" approach, recognising planetary boundaries and life in all its diversity, rather than simply human wellbeing.

[13] The topic *Greening Cities* contributes to and has interconnections with a number of EU policies and initiatives such as EU Green Deal, EU Biodiversity Strategy, EU Forest Strategy, EU Soil Strategy and Nature Restauration Law proposal, EU Strategy on Adaptation to Climate Change, EU Green Infrastructure Strategy, EU Zero Pollution Action Plan, New European Bauhaus Initiative, EU Renovation Wave Strategy, Affordable Housing Initiative, New European Mobility Framework, EU Missions on Climate-Neutral and Smart Cities and Adaptation to Climate Change, European Partnership Driving Urban Transitions of Horizon Europe, Covenant of Mayors for Climate and Energy, Green City Accord, European Green Capital and Leaf Awards, and Intelligent Cities Challenge and Urban Agenda for the EU. See also: https://www.urban-initiative.eu/innovative-actions-greening-cities.

Furthermore, it is also consistent with the *Green City* theme of the New Leipzig Charter, which puts forward a vision for the sustainable urban future in Europe, with the emphasis on the social and economic aspects expressed by the concepts of *Just City* and *Productive City*.
More specifically, urban authorities are called upon to answer to the following prompts:

- *Developing and enhancing urban green spaces* by focusing on projects that contribute to halting biodiversity loss, to verifiably and significantly reducing air pollution and to combatting heat waves, and at the same time, to achieving climate objectives and improving health and well-being of citizens.
- *Constructing green mobility corridors* with the help of GI within urban areas and between urban centres and peri-urban areas, that contribute to reducing air and soil pollution and noise, using artificial intelligence for traffic management systems, promoting sustainable multimodal urban mobility including active mobility modes such as cycling, and at the same time, to achieving climate objectives and improving health and well-being of citizens.
- *Preventing droughts and flooding* via projects focused on sustainable water management, including rainwater, in urban areas, with the help of green infrastructure that contribute to preventing droughts and flooding as well as to improving water quality, and at the same time, to reducing disaster risks and land take.
- *Designing and renovating buildings and their surrounding areas*, particularly in socially deprived quarters with NBS by integrating GI and NBS in the design and/or renovation of buildings and in their surrounding areas, including efficient resource management, also by using recycled construction material.

Hence, urban authorities are at the forefront and well-positioned to experiment with innovative solutions to bring forward the multiple benefits of GI through NBS. In a sustainable transition process, the support of capable institutions and governance is indispensable to coordinate actions across agencies and stakeholder coalitions. Alongside it, governance arrangements are often required to formulate and implement the multisectoral policies that stimulate the adoption and scaling up of innovative solutions to climate change and other sustainable development challenges (IPCC, 2018 and 2022). Concerning the main key actions to be undertaken to jointly address the Earth's environmental emergencies and human well-being, and with reference to the item Cities and Settlements, UNEP (2021) identifies the actors involved in the process and the different scalar and/or complementary levels of possible interventions, as outlined in table 1, where the recurring presence of keywords such as *NBS*, *sustainable Urban Planning*, *urban services*, *GBI* and *spaces* is noticed. The same subjects are the main actors also according to The Global Assessment Report on Biodiversity and Ecosystem Services (IPBES, 2019)[14]. In a broader sense, the increasing awareness of public bodies, managers and planners on the importance of NBS, the active participation or collaboration of all interested parties in urban green plans and projects is considered fundamental, also in order to prevent any conflicts between the different interests involved (Kivimaa, et al., 2019; Ferreira et al., 2020).

The GreenQuays Project as an Emblematic Case Study for a Sustainable Transition

It has been reiterated several times that cities are particularly vulnerable to the impacts of climate change and at the same time driving factors of the climate emergency, key players in achieving a carbon neutral society that guarantees *Just Transitions*. They operate as a venue for innovation, co-creation and citizen-led participatory actions, using technology, and have the potential to implement radical local experiments that can be scaled up and scaled across Europe.

[14] IPBES is an independent intergovernmental body comprising over 130 member Governments. Established by Governments in 2012, IPBES provides policymakers with objective scientific assessments about the state of knowledge regarding the planet's biodiversity, ecosystems, and the contributions they make to people, as well as options and actions to protect and sustainably use these vital natural assets.

Indeed, some projects under the former EU initiative UIA can inspire and promote locally based green transitions in other EU cities, each called to tackle global challenges locally and concretely, as well as territorialize the 2030 Agenda SDGs.

Developed over the period 2020-2022[15], it aims to develop and test green technology, specifically designed to support the development of a vertical ecosystem and to create conditions for the growth of herbaceous plants, ferns, and mosses. Various techniques are used to achieve this, such as tree sections in the quay walls, material choices and drainage system, and the combination of these different techniques applied in an inner-city context makes this project unique.

Anyway, beyond the specific project and its technical aspects, it is important to underline here, for the purposes of this study, that it involves a nature-inclusive development of the quays and surrounding (green) public space, by improving the quality of GBI and, at the same time, the quality of life of the inhabitants, also with a view to social cohesion and inclusion. In the coming years, Breda is committed to sustainability in the broadest sense of the word.

Actors of ecological transition	**Examples of key actions to be taken to address Earth's environmental emergencies and human well-being together with reference to Cities and Settlements**
Governments - legislature, judicial and executive branches at national, subnational and local level	Design and develop socially and environmentally sustainable cities and settlements by embracing NBS, promoting enhanced access to services such as clean water and energy and public transport, and making infrastructure and buildings sustainable.
Intergovernmental organizations	Promote sustainable urban planning, NBS for climate and biodiversity in urban areas, retrofitting of GBI, and access to urban services including clean energy and water.
Financial organizations	Develop and promote innovative financing for sustainable infrastructure. Support sustainable urban planning and investments in low-carbon infrastructure, including mass transportation, congestion charges, NBS and green and blue spaces.
Private sector	Engage with and support government in sustainable urban planning, public transport, energy-efficient buildings and partnerships to enhance access to urban services.
Non-governmental organizations	Campaign for and support sustainable urban planning and improved access to urban services and community initiatives, especially for the urban poor.
Individuals, households, civil society and youth groups, and indigenous peoples and local communities	Engage in participatory processes to advance sustainable urban planning and initiatives to increase access to urban services and promote NBS and GBI.
Scientific and educational organizations	Support sustainable urban planning and development, including the use of NBS. Promote education, information and awareness on sustainable cities and settlements and their importance for human health.
Media and social networks	Document the impact on people and nature of unsustainable systems in urban areas and support campaigns for transformations in how cities and settlements are planned and designed, including the supply of essential services.

Tab. 1 Actors and actions to better transform humankind's relationship with nature, elaboration of the author from UNEP (2021:37-45)

[15] These are the main Milestones: Small scale is built in the Nieuwe Mark (April 2020); launch event (May 2020); Start building real life pilot (April 2021); Detailed holistic design of the network of green infrastructure in the pilot site (December 2020); Real-life pilot is realized (August 2022); Municipal Guide on Renaturing the New Mark (August 2022).

GreenQuays project matches perfectly with its public trustees' ambition to be the first European city in a green park by 2030, since the ongoing *TransformA(c)tion*[16] process of the green river *Nieuwe Mark* provides a vital space for rich flora and fauna, and an even more vital contribution to a livable city centre. The multiple challenge addressed, common to many other cities in Europe, arises from the unsustainable urbanization choices of the past, from the deterioration of urban ecosystems and from the lack of resilience to climate change. The drivers of urban decay vary across ecosystems and locations, but the main pressures include the expansion of grey infrastructure, soil pollution, hydrological changes to water bodies, and climate change in general. These affect the ability of ecosystems to function, provide ecosystem services and cope with other challenges, such as controlling flood damage and providing livable places and recreational opportunities.

Therefore, innovative solutions are required that can ensure that they can continue to live in a livable city in the future, as part of a broader vision because it is "life-centric" and not only "people-centric" (Figg. 3, 4).

The partnership is made up of the following actors, each with specific skills, roles and responsibilities, with a view to complementarity and above all synergy, which also includes the participatory approach and the involvement of the inhabitants in the implementation phase: Municipality of Breda; The Baronie Area Federation of Nature Associations; Stadshart-Valkenburg Residents' Association; Delft University of Technology; Wageningen University and Research; Waterboard Brabantse Delta - regional water authority; Van den Berk Nurseries-private company; RAVON-NGO.

As already mentioned, *GreenQuays* project's main objective is the realization of sustainable urban renaturation in Breda using climate-proof design and nature inclusive regenerative solutions - green quays linked to public green spaces - as part of a bigger scheme targeting the urban restoration of the river Mark.

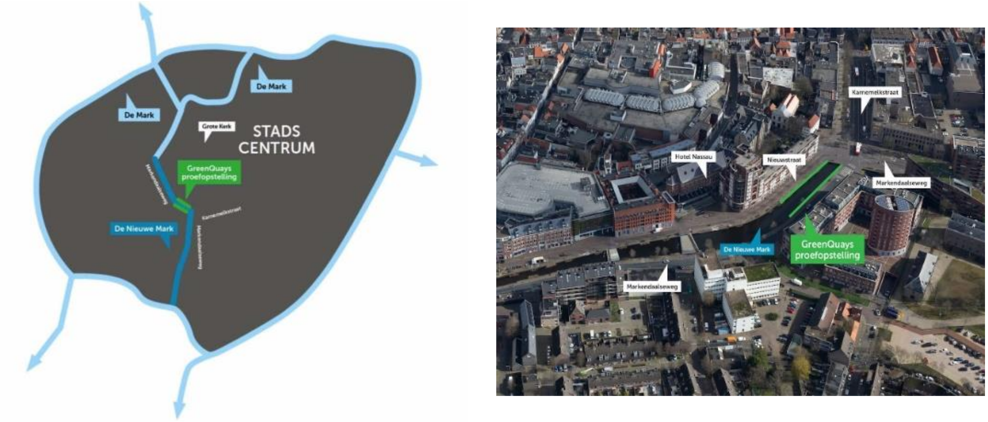
The results of the project – as part of an integrated and far-sighted planning process in the city, whose effects can continue and intensify over time through an integrated planning and territorial governance approach – can be summarized as follows, considering the available documentation:

- new technical solutions[17] and approaches for implementation of regenerative urban renewal in the river Mark.
- A participatory planning process for inclusive co-creation of public space to adequately address the needs and desires of citizens, and to contribute to the strengthening of local communities.
- An optimal green environment for flourishing flora and fauna through renaturing the grey infrastructure currently surrounding the river based on technical solutions and participatory inputs.
- A network of green public areas alongside the river establishing a living cohabitation between nature and people.
- Optimization of said solutions 1) to be scaled-up throughout the New Mark urban renewal strategy adopted by Breda; and 2) to be replicated elsewhere in Europe.
- Showcase a sustainable urban river renaturation process in densely built urban areas aiming at the restoration of ecosystems, the greening of urban environment.

The necessary management, monitoring and assessment activities prove fundamental to bring out the lessons learned useful for the continuous improvement of the "landing" processes and implementation of the principles of the ecological transition, allowing their implementation in other different territorial contexts, with appropriate declinations and adaptations.

[16] The use of the word *TransformA(c)tion* instead of transformation, and of the adjective *TransformActive* in the title of the article, as a pun, derives from the intention to underline the active role (action) of cities in the process of sustainable transformation required for the transitions in progress.

[17] Among the interesting innovative aspects, it should be noted that data for the wall plants are collected with an app (Vera-app) and find thus their way into the "Verspreidingsatlas", an Atlas of the Netherlands that documents the distribution of every wild plant.



a b

Fig. 3. (a) Planimetric schematization and (b) bird's eye view of the area affected by the project with information concerning the main parts and elements

3. Discussion and Conclusions

The article highlighted, at first, that the current expansive mode of development degrades and exceeds the Earth's finite capacity to sustain human well-being. As outlined so far, a growing number of reports and reviews describe the impact of and vulnerability to climate change of biodiversity and ecosystem services, both within and outside nature conservation areas. The impacts of climate change on biodiversity and ecosystem services are complex. Climate change, land-use change, land degradation, and air and water pollution act synergistically to cause pervasive, extensive, and systemic damage to biodiversity and ecosystem services on land and in the ocean. Globally, land-use change is the direct driver with the largest relative impact on terrestrial and freshwater ecosystems (IPBES, 2019), which calls into question the role and responsibility of Urban Planning, at the centre of the UN-Habitat "wheel of prosperity" (2013) together with Government Institutions an Laws. Above all climate change – accentuated and accelerated by anthropic action that disrespects the "common home" and the value of natural ecosystems for the life of the whole Planet Earth – is disrupting species interactions and ecological relationships (UNEP, 2021).

Fig. 4 The GreenQuays project proposes the development of green and blue infrastructures as an opportunity for inclusion, too

Indeed, the world is failing to meet most of its commitments to limit environmental damage and this increasingly threatens the achievement of the UN 17 SDGs. Many changes in the climate system become larger in direct relation to increasing global warming, including increases in the frequency and intensity of hot extremes, marine heatwaves, heavy precipitation, and, in some regions, agricultural and ecological droughts. Nature can be conserved, restored and used sustainably while simultaneously meeting other global societal goals through urgent and concerted efforts fostering transformative change.

The Sustainable Development Goals and the 2050 Vision for Biodiversity cannot be achieved without transformative change. The transformational changes in order to achieve a sustainable world require the responsible and undelayable commitment of different actors and presents options for action in the interconnected sectors of environment, economics, finance, energy, food, water, health and cities (EC, 2018 and 2021). Within this complex context, globally and locally, the conservation and sustainable use of biodiversity, GBI and ecosystem services have the potential to contribute significantly to mitigating climate change and to helping human societies adapt to its impacts. In addition, there are powerful economic and social arguments for taking action to protect biodiversity and ecosystem services.

This approach recognizes and values natural resources including land, soils, air, water and living resources, since nature can be conserved, restored and used sustainably while simultaneously meeting other global societal goals through urgent and concerted efforts, both forward-looking and far-reaching, fostering transformative change (IPBES, 2019). Therefore, innovative integrated, interdisciplinary and cross-sectoral approach is needed to strengthen collaboration across governance levels and advance urban support structures that:

- creates evidence for urban transitions, through inter- and transdisciplinary research and innovation, involving all stakeholder groups and considering technological, social, economic, cultural, planning and governance aspects;
- addresses urban dilemma interrelationships between various goals, strategies and interests as they define key policy areas critical for achieving SDGs and urban strategies;
- provides a favorable environment for urban experimentation, capitalizing knowledge and science-policy cooperation beyond joint calls to achieve city authorities' strategies and strengthen exploitation and scaling-up of research and innovation actors' results aligned towards urban transformations (Raworth, 2017) more effectively.

Greener, more sustainable, and more efficient urban development can be achieved by applying new technologies. Consequently, the global demand for smart city solutions is growing rapidly, primarily driven by the three global megatrends of urbanisation, green transition, and digitization (United Nations, 2022b).

Cities have a central and decisive dual role as a sphere of concentration and amplification of the crisis and, at the same time, as a privileged sphere of experimentation[18] (Sengers et al., 2019) acceleration of the multiple transition process underway, such as in ongoing UE policies, strategies, and projects (IPCC, 2022; McQuaid et al., 2021; Pultrone, 2018). Ongoing multiple transition involve multiple sectoral and cross-sectoral policies and the digital and ecological transitions must be seen as one major challenge. Ongoing policies, initiative, strategies, and projects –among which we also recommend the Driving Urban Transitions to a Sustainable Future (DUT), the new JPI Urban Europe program launched in 2022, which cannot be dealt with here but is worthy of further study and research[19] – provide innovative opportunities for integrated planning and synergistic implementation on climate action and the SDGs, since greater awareness of the benefits of nature-

[18] Given the extensive and varied scientific literature on the concept of experimentation with reference to the sustainability transition, it is understood here as an inclusive, practice-based and challenge-led initiative, designed to promote system innovation through social learning under conditions of uncertainty and ambiguity (Sengers, Wieczorek & Raven, 2019: 153).

[19] The challenges are grouped into three themes called Transition Pathways: Positive Energy Districts (PED), the 15-Minute City (15mC) and Circular Urban Economies (CUE). For more information, see https://jpi-urbaneurope.eu/driving-urban-transitions-to-a-sustainable-future-dut/

based solutions can greatly help to advance the protection of biodiversity and promote the just transition and sustainable development models.

Transitioning to a circulating and ecological sphere (CES) can greatly advance protection of the environment, biodiversity, and climate (Dzebo and Shawoo, 2023). Given the interconnected nature of climate change, loss of biodiversity, land degradation, and air and water pollution, it is essential that these problems are tackled together, in an integrated way (UNEP, 2021).

The ecological transition is and must be the pillar of a resilient recovery, of a real *Green Deal*, in which greater attention and caution are paid to the relationship with nature, to the climate and ecological crisis. The mitigation and adaptation measures are not attributable only to energy policies, they affect other decisive sectors such as industry, agriculture, land use, construction and transport.

The protection of natural capital and the resilience of ecosystems are therefore essential conditions because they ensure the flows of ecosystem services without which there is no possibility of well-being and development. Just as it is necessary to go beyond the immediate responses to the multiple crisis underway with vision and plans for the future in which urban and territorial planning has a fundamental role (Ronchi, 2021). In this regard, over the last decade, the scientific and academic interest in developing concepts and theories that reflect a more holistic approach of socio-ecological systems to urban planning and design based on transdisciplinary integration has grown considerably, with reference to following themes: ecosystem services, socio-ecological systems, resilience, biodiversity, landscape, green infrastructure, as well as integrated and holistic approaches. This last approach includes the other six as a new potential paradigm of ecological urban planning and design capable of applying theoretical concepts related to sustainability (ecosystem services, socio-ecological systems and resilience, components of a sustainability flow) in a spatial context (biodiversity, landscape, green infrastructure: components of a spatial flow). This new paradigm, defined as "urban consonance" with reference to an interesting study by Heymans, Breadsell, Morrison, Byrne, & Eon (2019), reflects a harmony or agreement between nature and people and describes the harmony of evolution of key ecological urban planning and design through interdisciplinarity, where cities are considered as complex and dynamic socio-ecological system.

In this framework, NBS address social, economic, and environmental sustainability issues simultaneously, thereby presenting a multifunctional, solution-oriented approach to increasing urban sustainability, resilience, liveability (Dorst et al., 2019). Many European cities are actively playing their role as key agents of transformation, involved in numerous initiatives and networks that jointly shape policies with an urban dimension, as the case study of *GreenQuays Project* stands out.

The challenges of the ecological transition – which sees cities as a qualifying factor – are strongly connected to each other and above all sign of a profound historical change in society and the economy, a real change of civilization, to live better "according to" nature and not "against" nature. Indeed, in order to transform the challenges of the ecological transition into opportunities, there is a need for broad support which can be won by taking care, punctually and attentively, also of the social dimension. Therefore, future research should evaluate the contribution of participatory processes to the quality of decisions, building public trust in the decision-making process and to the success of implemented social learning strategies (Ferreira et al., 2020).

Another interesting aspect worthy of further in-depth research and development is the mainstreaming of NBS, where planning tools and practices that support how urban NBS are implemented in a coherent and holistic way, are instrumental in pursuing sustainability transitions urban. This process of adoption and "becoming a norm" in policy and planning is commonly understood as mainstreaming. In order to be effectively implemented for cities, it cannot become just another slogan or buzzword for the aspiration of sustainability, but must be pursued, reformed and reformulated through urban planning and the implementation of multi-level governance to enable the overcoming unsustainable practices, assumptions, cultures and norms, which for too long have dominated the planning and development of cities.

In a nutshell, it then becomes essential to better focus attention on how and where the integration of NBS takes place in the transition process towards urban sustainability, how this can become an integral part of the definitive transformation of urban planning systems and practices to create sustainable, resilient, inclusive cities projects in line with Objective 11 of the 2030 Agenda (Adams et al. 2023). Anyway, the ecological transition for a circular society and economy in the use of resources and climate-neutral requires not only a great deal of scientific knowledge and a great deal of good and appropriate technology, but also needs to make use of the different cultural riches of peoples, the art, poetry, inner life and spirituality (Papa Francesco, 2015).

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Fig. 4: https://www.greenquays.nl/project

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Promoting a local and just green deal

School open spaces as a strategic opportunity for the city in the ecological transition

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Abstract

Recent policies like the European Green Deal emphasize the urgency of implementing the ecological transition. However, there are associated risks, including the exacerbation of socioeconomic inequalities and an overemphasis on large infrastructure projects. The ongoing debate recognizes the need for a place-based approach, with cities at the core of the European transition and active citizen engagement. School open spaces can play a key role in implementing a local, sustainable, and equitable green deal, starting from their role of public equipment widespread in the city. This paper aims to assess how these types of spaces can be strategic, which are the fields of action of the transition process in which they can have the greatest impact and which areas to be improved. The paper starts from the definition of four strategic issues and four governance principles for localising the EGD. Then we selected and described twenty-five European best practices in the regeneration of school open spaces from 2019 to the present and we assessed if and how they deal with transition strategic issues and governance principles. Finally, research results are discussed together with potential pathways for the implementation of actions related to the local Green Deal.

Keywords

European Green Deal; Public Spaces; Urban Regeneration; School Courtyards; School open spaces

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1. Introduction

In recent years, the framework outlined by international policies such as the United Nations 2030 Agenda for Sustainable Development, the Paris Agreements and the European Green Deal (EGD) has highlighted the urgency of implementing integrated and large-scale interventions for sustainability, ecological transition and climate neutrality, severely hampered by the global upheaval caused by the COVID-19 pandemic and war in Ukraine. EGD priorities (European Commission, 2019) are not only environmental goals, but also a set of deeply cross-cutting transformations (Wendler, 2022) and a radical paradigm shift towards a new way of living, producing and moving (European Commission, 2020a; European Environmental Agency, 2021), as well as a decisive opportunity for Europe to position itself "as a green specialisation area through innovation" (Mccann & Soete, 2020, p. 8). The EGD is also seen as a strategic framework for implementing the 17 Sustainable Development Goals of the UN 2030 Agenda, through the adoption of a "whole of government approach" that creates synergy between the vast overlapping areas of these two policies (Papa & Sachs, 2021, p. 7).

In the face of such a framework of intentions, EGD transition policies present several weaknesses, including: lack of rethinking of a development model based on environmental inequality (Ciplet et al., 2015) and unequal relations (Velicu & Barca, 2020); adoption of an overly strong sectoral approach in different policy areas (ETTG, 2022); concentration of resources on major infrastructural interventions regarding cities and territories to the detriment of ordinary maintenance of everyday life contexts.

The transition is also associated with some risks or 'negative externalities', including: triggering processes of environmental gentrification (Checker, 2011) and ecological gentrification (Pearsall & Anguelovski, 2016); aggravating existing socio-economic and territorial inequalities (Coppola et al., 2021); being reduced to greenwashing within public debate (Delmas & Burbano, 2011). On the basis of these assumptions, discussion has been taking place in both scientific debate and European institutions regarding the need to adopt a place-based approach (Barca, 2009) as a fundamental pillar for a more effective and just transition in response to space-blind and place-neutral models, which have been criticised for their standardisation and inability to take into account territorial specificities (Bentley & Pugalis, 2014). In this perspective, the 'local' scale has become increasingly important (Gisotti & Tarsi, 2023) and is considered indispensable for achieving quick results and obtaining adequate financial resources. Therefore, cities and metropolitan areas are now undisputedly the main drivers of the green transition (Alberti et al., 2019), as they are where structural socio-economic issues, poverty and segregation are most present (Abdullah, 2021a) and are the most vulnerable to impacts of climate change. Moreover, they have become home to urban models based on proximity, such as the French *ville du quart d'heure* (Moreno, 2020), particularly due to repercussions from the pandemic (Pisano, 2020).

By updating some classical conceptions of urbanism (Marchigiani & Bonfantini, 2022), these models re-articulate the city into neighbourhoods that offer better quality of living. In summary, the local scale (i.e cities and neighbourhoods) is seen as playing a crucial role, in the belief that a systematic and lasting transition must be rooted in policies, projects and transformations at the closest scale to citizens (Abdullah, 2021b), who can and must be involved in participatory processes.

With reference to this framework, recent studies have highlighted how school open spaces can contribute to implementing an ecological transition process at the urban scale that is local, more effective, and just. This paper aims to assess how these types of spaces can be strategic, which are the fields of action of the transition process in which they can have the greatest impact, generating positive effects, and those that should be improved. The aim of the paper is therefore to indicate possible developments and improvements in the field of urban regeneration policies linked to the transition involving school open spaces.

To argue this hypothesis the paper is structured as follows. The second paragraph is a literature review about the role of school open spaces in the ecological transition processes. The third paragraph illustrates the methodology we have developed to conduct our analysis. The fourth paragraph presents the results of the applied methodology, that verified the treatment of strategic issues and governance principles to localise the EGD in twenty-five best practices regarding regeneration of school open spaces, carried out in Europe mostly from 2019 (year of publication of EGD). The fifth paragraph discusses the results of the study and conclusions (paragraph 6) outlines some axes of work to improve the implementation of the EGD at the local scale.

2. School open spaces for ecological and just transition: a literature review

The role of school open spaces (courtyards, gardens, areas pertaining to school activities, areas surrounding schools) as a field of action for a green and just transition fits into the scientific debate and constitutes a rich landscape of ideas and innovative approaches. A literature review highlights first the crucial role that school open spaces can play in educating for ecological transition, promoting more sustainable and conscious practices (Stevenson et al., 2020; Toomey et al., 2023). Schools could be strategic for educating in the city of transition, seeing that they can sensitise the behaviours of new generations through their direct participation (Dessì & Piazza, 2020). Engaging teenagers in actions aimed at improving the quality of their daily spaces, such as school environments, leads to educational and relational benefits (European Commission, 2022). It triggers a cultural shift tied to increased awareness of environmental issues (Gill, 2014; Van Dijk-Wesselius et al., 2018). The analysis of the literature reveals a shared imperative for a paradigmatic change - an integrated, strategic, and interdisciplinary transformation - that requires a re-evaluation of various aspects of daily life, of which the school is particularly relevant. This includes new actions to encourage slow and sustainable mobility, the integration of natural elements, the promotion of circular practices (Tulisi, 2017; Renzoni & Savoldi, 2022).

Schools can take on the role of pivotal centres for educational and social experimentation within the community, promoting new approaches to learning and civic engagement, and advocating for social innovation practices (Renzoni & Savoldi, 2019; Mattioli et al., 2021). This concept is explicitly articulated by the Organization for Economic Cooperation and Development (OECD), which, in 2020, published "Back to the future of education: Four OECD Scenarios for Schooling" to encourage the development of a forward-looking educational vision (OECD, 2020b). The emphasis is placed on breaking down physical barriers within school structures and establishing stronger connections with local communities starting from the school.

The school's open spaces are also decisive to contribute to the development of healthier cities and foster the well-being of children as we can see in the case of urban areas that are implementing creative interventions on streets in areas surrounding schools (Cannella et al., 2022). These initiatives, such as the global movement promoting streets for kids and school streets originating in Europe (Clarke, 2022), distinguishes itself for its advocacy of sustainable mobility (Shbeeb., & Awad, 2013) and the cultivation of children's autonomy in urban environments (Tonucci, 2020; Thomas et al., 2022). In this framework, the literature highlights how further public spaces can be created by implementing innovative urban design strategies, starting with the creation of pedestrian areas near schools (Alberti et al., 2019). This not only improves the overall quality of public spaces, but also involves the configuration of new school squares that meet neighbourhood needs (Gaglione & Ayiine-Etigo, 2022; Pileri et al., 2022).

In parallel, schoolyards can become increasingly open and permeable elements within urban landscapes (Fianchini, 2017; Palestino et al., 2020), designed to be used beyond school hours and thus implementing the network of public spaces in a healthy way (Adelmann & Davis, 2015; Masiani, 2020). Numerous authors concur that the adoption of environmentally friendly strategies, incorporating nature-based solutions in the design of schoolyards (Dessì & Fianchini, 2021; Van den Bogerd et al., 2023), is crucial for the preservation of biodiversity and the ongoing battle against climate change (Doswald & Osti, 2011). This aids in constructing a more sustainable and resilient environment capable of adapting to the challenges presented by climate change while facilitating the gradual restoration of degraded ecosystems over time (Bohnert et al., 2022; Fratini, 2023). A noteworthy advantage of employing nature-based solutions in schoolyards lies in mitigating urban heat island effects (Rivera Gomez et al., 2019).

As known, green and wooded spaces, as opposed to paved surfaces, absorb less heat, providing relief from summer heatwaves and contributing to a reduction in outdoor temperature (Barò et al., 2022; Ceci M. et al. 2023).

This underscores the significance of championing an integrated approach to projects, with a focus on closing natural cycles and enhancing sustainability through the incorporation of specific technologies (Kabisch et al., 2017). The literature review accentuates how schools could contribute significantly to the creation of a distinct, cohesive, and deeply rooted welfare system, both in terms of physical infrastructure and cultural and social aspects (Patti, 2021; Vassallo et al., 2022). The dynamic catalytic potential of school open spaces in propelling a local, just, and green transition emerges, producing positive impacts on the environment and also on education, health, and social cohesion.

The literature underscores that effectuating a green transition in school open spaces necessitates not only addressing strategic concerns but also instigating a shift in governance principles (Pasqui, 2019). This entails the adoption of a participatory methodology and the embracement of a transversal, transdisciplinary, and place-based approach (Vanos & Pfautsch, 2023). The transformation of school open spaces into green environments is based on a growing body of literature that shows the importance of student involvement in the design (Derr & Rigolon, 2017) and management of the same to instil a sense of responsibility towards the spaces shared, promoting inclusiveness and community (Lanza et al., 2021; Vicente et al., 2023). Moreover, for the implementation of effective strategies and the attainment of far-reaching results in these projects, it is essential to adopt a transversal or multilevel approach in public policies that demands significant stakeholder engagement and substantial financial resources. Another critical aspect involves embracing trans-sectoral, allowing for the incorporation of a wide range of perspectives and addressing diverse needs (Lamacchia et al., 2021; Bricocoli et al., 2022).

3. Methodology

As mentioned above, the aim of this paper is to assess how school open spaces (e.g., courtyards, gardens, school-proximity spaces, areas pertaining to school activities) can contribute to a more effective, place-based and just transition, highlighting in which areas they can be more strategic and generate positive effects and which are, on the contrary, areas for improvement. To verify this hypothesis, we have developed a methodology composed of the following steps:

1) selection of the main principal European policies developed from 2019 onwards to implement a place-based approach to the EGD at the urban scale;
2) identification and definition, within the framework of the abovementioned European policies, of four strategic issues and four governance principle that are, in our interpretation, fundamental to localise the EGD;
3) collection of twenty-five best practices related to regeneration projects for schoolyard and school-proximity spaces in Europe, selected through desk research[1]. Our selection favoured relevant projects that implemented a systematic approach (intervening in several schools in the same city) or complex projects with strong partnerships. Most of the examined experiences began after 2019, having taken as a starting point the publication of the EGD. A few experiments that started prior to publication of the EGD have also been included, having gained more impetus from the publication of the EGD onwards;
4) description of the twenty-five best practices according to an analysis grid that includes starting date, intervention scale (schoolyard or school-proximity spaces), how the initiative was generated, main objectives pursued and physical outcomes achieved through the project implementation (tab. 1);
5) analysis of each best practice for its correspondence to the abovementioned strategic issues and governance principles, illustrated in tab. 2 (that includes the field 'scale of intervention' due to its relevance). According to various studies that analysed projects and plans in the field of climate adaptation and ecological transition (De

[1] The research on European best practices was conducted within "FIABA. Firenze impara ad abitare con gli adolescenti", a project carried out by the Department of Architecture of the University of Florence within the actions developed as official partner of the New European Bauhaus programme (line "Educating next generation, growing a new living"). The scientific coordination of both FIABA and the NEB line "Educating next generation" is by Maria Rita Gisotti. The research group of FIABA is composed of Maria Rita Gisotti, Benedetta Masiani (author of the research on best practices), Rosa Romano (DIDA-Unifi) and Antonia Sore (DIDA-Unifi).

Luca et al. 2021; Geneletti & Zardo 2016), we applied a qualitative content analysis to read and assess best practices. We opted for this analytical approach and not for applying a methodology with rigidly defined criteria (e.g. multicriteria analysis or keyword frequency-based method) also given the great heterogeneity of both projects and the documentary materials traceable for their study, partly represented by scientific literature and partly by grey literature.

6) Illustration of the results of this analysis by means of two radar graphs (Fig. 1), useful for evaluating quantitatively the fields of the transition processes most affected by the projects.
7) Qualitative description of the results obtained from the analysis.

4. Results

4.1 Localising the EGD in European policies

In recent years, European policies have developed a vast field of work to implement a place-based approach to the EGD. In 2020, the European Committee of the Regions (CoR) launched the Green Deal Going Local (GDGL) programme to place cities and regions at the heart of the EU's transition and give greater recognition to Local and Regional Authorities (LRAs), given their legal competences and proximity to people in the process of transition towards climate-neutrality (European Committee of the Regions, 2021) and the fact that "they implement 70% of climate mitigation measures, 90% of climate adaptation policies and 65% of UN Sustainable Development Goals (SDGs)" (European Committee of the Region et al., 2022, p. 18).

The GDGL policy document identifies eleven policy areas, largely similar to those of the EGD. Among these, the most strategic areas for planning and design at the urban scale are 'Sustainable transport', 'Preserving Europe's natural capital', 'Transition to a circular economy', 'A zero-pollution Europe', 'From farm to fork' and 'Clean, reliable and affordable energy'.

Another important initiative is the "New Leipzig Charter. The transformative power of cities for the common good" (NLC), adopted at the Informal Ministerial Meetings on Urban Matters in November 2020 (European Commission, 2020b). It aims to update the 2007 Leipzig Charter, which promoted integrated and sustainable urban development with respect to urgent global challenges.

The NLC states the importance of implementing policies in European cities on three spatial levels: neighbourhoods, local authorities and the so-called 'functional area' (as stated in the Territorial Agenda 2030), i.e., the regional or metropolitan scale. Moreover, it stresses the importance of developing three specific dimensions: the just city, green city, and productive city. The latter is based on a diversified, digital, and low-carbon economy. Finally, the NLC proposes five key principles of good urban governance, namely (1) placing common good at the core of urban policy, (2) practising an integrated approach, (3) incentivising participation and co-creation, (4) implementing multi-level governance and (5) pursuing the place-based approach and endogenous development model.

In 2021, the European Commission's 100 Intelligent Cities Challenge (ICC) launched the Local Green Deal programme (LGD), "a local tailor-made action plan to accelerate and scale-up a city's green transition. It builds on and joins up existing strategies (e.g., sustainable energy and climate action plans, circular economy plans, resilience, or economic development plans) legislation, market and financial incentives into a coherent approach to advance the EU Green Deal locally" (European Commission, 2021a, p. 4).

The key principles of the LGD that are most relevant to urban planning and design with spatial impact are: (1) "build on what is already there", using municipal governance to network and enhance existing sustainability strategies and policies; (2) develop integrated and cooperative processes both 'vertically' (between EU, national and regional policy development processes) and 'horizontally' (between municipal administrative sectors); (3) encourage a collaborative approach between stakeholders; (4) develop sustainable technological solutions to support the transition.

Another flagship initiative is the New European Bauhaus (NEB), launched in 2021 by the Presidency of the EU Commission to accompany the EGD with a large, collective, and interactive training project regarding the ecological and digital transition (European Commission, 2021b).

The NEB aims to encourage "a new lifestyle where sustainability matches style, thus accelerating the green transition in various sectors of our economy" (European Commission, 2021b, p. 2). The NEB, which has a community-based perspective, is essentially a networking and communication programme involving citizens in co-design processes based on three 'core values' - beautiful, sustainable, and together - which respectively refer to aesthetic experiences, ecological ethics, and inclusion. The NEB offers a project methodology to all institutional and non-institutional stakeholders taking part in the transition process based on the adoption of three 'key principles', i.e., being multilevel (from global to local), participatory and transdisciplinary (New European Bauhaus, 2022).

4.2 Strategic issues and governance principles for localising the EGD

From the study of the above-mentioned policies and of the related debate (Abdullah, 2021b; C40 Cities, 2020; Fernàndez De Losada & Abdullah, 2020; OECD, 2020a; Rosado García et al. 2021) we assumed as the key strategic issues for a local and just transition the following:

1. sustainable mobility (ranging from public transport systems to cycling and walking paths);
2. new public spaces (returning spaces to people and nature, rethinking and reclaiming streets and creating liveable local communities);
3. greening (actions for urban forestry, restoration of degraded ecosystems and use of nature-based solutions to both preserve biodiversity and fight climate change);
4. circularity (closure of natural cycles, creation of urban gardens for proximity food chains and production-consumption-reuse of materials);

Similarly, we assumed as the key governance principles for a local and just transition the following:

1. participatory approach (engaging the widest possible range of actors, particularly the most vulnerable population groups, in co-design and co-creation processes aimed at raising awareness of the transition);
2. transcalar approach (supporting multi-level and multi-stakeholder cooperation and involving all governmental levels, from local and regional/metropolitan to national and European, particularly regarding funding opportunities);
3. trans-sectoral approach (pursuing integration between areas of intervention of public bodies at the same scale and related disciplines);
4. local-based approach (basing projects on specificities of natural and built environments and on social, economic, cultural, and historical aspects of local contexts).

4.3 Best practices in the regeneration of school open spaces

The study meticulously investigates twenty-five best practices associated with interventions in school courtyards or adjacent spaces. The cases are presented in chronological order and are thoughtfully described (tab. 1), emphasizing crucial elements for their comprehension. They specify the scale of intervention, type of initiative, primary goals, and implementations. This tabular compilation presents the case studies and forms the bedrock of the study's examination, providing a structured overview of the interventions under consideration.

Best practices 2015	
1.	***Courtyards in action, Turin, Italy***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	Local initiative promoted by Architects Without Frontiers Piemonte, Sheldon Studio with the support of Compagnia di San Paolo Foundation. It brings together several schools in and around Turin in the common need to retrain the school grounds.
Main goals	– Enhancing the schoolyard as a fundamental space in which the pupil becomes a citizen. – Returning a beautiful and liveable place to the school community. – Connecting the courtyard, a community and meeting space, with the neighbourhood.
Project implementation	Yes. The first implementation was in 2015 and in the Sabin schoolyard. Other implementations are ongoing to date.

Best practices 2016	
1.	***(AIS), Amsterdam, Netherlands***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	A municipality-led initiative developed between 2016 and 2024 aimed at (re)designing and greening approximately 85 schools and city playgrounds.
Main goals	Giving an impulse to primary education schools across the city to (re)design and green their playground. Providing monetary support and making the playground as publicly open as possible and including it in the school's educational vision.
Project implementation	Yes. In the period 2016– 2018, the municipality provided a budget of €3 mln and subsidies were granted to 70 different schools. For the 2019–2024 period, the municipality has made available a budget of €5.4 mln, and subsidies will be provided to 15 schools per year.
2.	***Green oasis from school to neighborhood, Rome, Italy***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Multidisciplinary project of the University of Rome Sapienza titled "Municipio II Green Network", involving a very wide network of actors.
Main goals	Promoting urban, social and cultural change for the San Lorenzo neighbourhood in line with Cop21 in Paris and UN-Habitat III. Implementing micro projects of immediate use (the Oasis) to make climate change tangible. Actively involve the local community in an eco-artistic urban regeneration project with the aim of developing participation, conviviality, belonging to places and a sense of identity.
Project implementation	Yes. Oases were planned and implemented between 2016 and 2020 in the San Lorenzo neighbourhood.
Best practices 2017	
1.	***Cuidados en entornos escolares, Madrid, Spain***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	The project stems from the collaboration of several municipal departments and crosses specific plans and strategies, namely: the Madrid Urban Regeneration Strategy of the Department of Urban Planning, the Air Quality Climate Change Plan of the Department of Environment, and the Public Health Program of the City of Madrid. The project targets and involves 3 educational institutions.
Main goals	– Creating a new school ground model by transforming the schoolyards of nursery and primary public schools through a participatory process. – Developing a preliminary intervention strategy on the city's schoolyards aimed at the identification of environmental resources and play areas available in and around all Madrid schools. – Carrying out the transformation of three schoolyards as pilot projects in order to promote healthy habits, integration with the neighbourhood and to improve adaptation to the impacts of climate change. – Developing a methodological guide for intervention in and around schools.
Project implementation	Yes. The project was implemented between 2017 and 2019 leading to the redevelopment of 3 schoolyards in 3 institutions in Madrid.
2.	***Metamorphosis project, Bolzano, Italy***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	This project received funding from the European Union's Horizon2020 research and innovation programme under grant agreement. The Metamorphosis project grew out of a partnership among 12 members including 7 cities: Alba Iulia (Ro), Graz (AT), Meran (IT), Munich (DE), Southampton (Uk), Tilburg (NL), and Zurich (CH).
Main goals	– Transforming neighbourhoods in a child-friendly way to increase the quality of life for all citizens. – Reducing the use of private cars for taking children to school. – Enabling children to go to school by foot or by bike.
Project implementation	Yes. The project was implemented between June 2017 and May 2020.
3.	***School Streets Hackney, London, UK***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Project sponsored by the municipal administration.
Main goals	– Promoting and encouraging students to walk and bicycle to school safely. – Reducing traffic outside schools. – Improving air quality through urban greening interventions.
Project implementation	Yes. The pilot project started in 2017 with five schools and was completed in 2021. In addition, 40 more School Streets were created throughout the district..
Best practices 2019	
1.	***Climate shelters project "Refugis Climatics", Barcelona, Spain***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	The City of Barcelona has received funding from Urban Innovation Action (UIA), a program of the European Commission, for the project "Adapting schools to climate change through green, blue and grey".
Main goals	– Converting 11 schoolyards into climate shelters. – Opening school spaces to citizenship during extracurricular hours. – Raising awareness of climate change issues. – Evaluating the impact achieved on environmental, health, well-being parameters, etc.
Project implementation	Yes. Between 2019 and 2022 a total of 2.213sqm of new shaded areas were created in the 11 schools involved. 74 trees were planted and 26 new water points were installed.
2.	***Green Blue Schoolyards is a subsidy and technical support programme by the city of Rotterdam for 2019 – 2022 that involves at present 6 schools***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	Green Blue Schoolyards is a subsidy and technical support programme by the city of Rotterdam for 2019 – 2022 that involves at present 6 schools.
Main goals	– Supporting schools to transform their outdoor spaces into natural play areas for outdoor educational projects and community use. – Increasing the number of green spaces (such as parks) and blue spaces (such as lakes, canals, or riverbanks) starting with the redevelopment of schoolyards.
Project implementation	Yes. The programme focused on 6 schools in areas with fewer public green spaces and higher socioeconomic vulnerabilities, selected to cover different areas of the city. Further scale will be assessed after this phase of the programme is completed.

3.	***The garden we would like, Florence, Italy***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	The project is part of CSS-Sustainable School Communities, a participatory path involving secondary schools in the Metropolitan City of Florence. "Il giardino che vorremmo" was coordinated by the Pratolino LDA in collaboration with DIDA - Department of Architecture of the University of Florence, the Carabinieri Forestali (Vallombrosa Biodiversity Unit) and with educators from the META Cooperative.
Main goals	– Developing skills of responsible participation in environmental caring. – Identifying strategies and actions aimed at implementing "good practices for sustainability" by involving the school community.
Project implementation	No. The project was mainly an open-air educational and research project. Students could be eventually involved in the implementation phase through self-construction workshops.
4.	***Oasis project, Paris, France***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	The Oasis project stems from the Paris Resilience Strategy adopted by the Paris Council and is supported by the Caue (Conseil d'Architecture, d'Urbanisme et de l'Environnement). The initiative is the winner of a European call for "Urban Innovative Actions" aimed specifically at the redevelopment of 10 schoolyards by the summer of 2020.
Main goals	– Converting schoolyards into climate shelters by reducing the heat island effect and providing a range of possible technological solutions. – Outlining a methodology and guidelines for upgrading schoolyards based on the principles of bioclimatic.
Project implementation	Yes. Several implementations from the 2019-2020 school year with the monitoring of impacts on microclimate.
5.	***School Streets, Hoogstraten, Belgium***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Initiative promoted by the Municipal Administration. With this project the municipality won the Flemish Road Safety Award 2019.
Main goals	– -Redesigning the area around 8 schools. – Closing to motorised traffic a street in front of the entrance of the school twice a day. – Looking at the routes to school with the eyes of a child, actively involving children, but also parents, in devising and implementing measures.
Project implementation	Yes. The 8 schools involved have implemented the proposal, and the administration's intention is to extend it to other schools.
6.	***School Streets, The Hague, Netherlands***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Project sponsored by the municipal administration
Main goals	Reducing traffic-related air pollution and improving road safety
Project implementation	Yes. In 2019, the city organised its first School Road experiment and in one year managed to implement 15 more. Some of the participating schools have requested that the measures become permanent.
Best practices 2020	
1.	***Canopy Plan, Strasbourg, France***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	This project is financed via the budget of the city of Strasbourg with the mobilisation of external funding such as that of the Rhine-Meuse water agency within the framework of the territorial water-climate contract.
Main goals	– Demineralising and greening courtyards to adapt to climate change. – Rethinking the educational value of school courtyards. – Substantially contributing to the fight against global warming and enabling the schoolyards educational function to be rethought.
Project implementation	In progress. Experimental demineralisation interventions were initiated in the first 3 schools from autumn 2020. In 2021, 2 childcare facilities and 7 schoolyards were reconfigured. The program for the 2022 is to carry out implementations in 8 schoolyards. From 2023 onwards, the aim will be to intensify the interventions.
2.	***CLEVER Cities Project, Hamburg, Germany***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	The project was developed in the framework of the European-funded H2020 and includes the District Office of Hamburg-Harburg (DHH), the urban development agency, and three scientific partners. Three different focus topics have been defined for the project area: (1) a green corridor, (2) green roofs and façade and rainwater management, (3) and green schoolyards.
Main goals	– Fostering the redesign of schoolyards located in the project area using Nature-Based Solutions. – Planning interventions including the so-called researchers’ garden that combines the curriculum with gardening and outdoor activities and the realisation of aquaponics.
Project implementation	Yes. Originally, the schools planned to turn an existing area of the schoolyard into a school garden and outdoor classroom. However, the neighbourhood is currently undergoing demographic changes that are increasing demand for primary schools. As a result, the local school authority has instead proposed enlarging both schools and restructuring their schoolyards. Some interventions have been implemented between 2021 and 2022.
3.	***Contract d’écoles, Bruxelles, Belgium***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Initiative part of the Regional Plan for Sustainable Development (PRDD) and Strategy 2025 of the Brussels-Capital Region
Main goals	– Increasing school-city interaction by activating collaborations with sociocultural entities in the neighbourhood. – Enriching the cultural offer and neighbourhood sports facilities through the sharing of school spaces. – Enhancing youth groups' autonomy, and spirit of initiative, and improving social integration. – Improving the usability of public space and underutilised green areas and reducing the spatial density of the urban fabric.
Project implementation	In progress. In 2019 the Brussels-Capital Region government selected 4 school contracts for the period 2020-2024. A program of action and an investment plan for the implementations were developed.

4.	***Innovative Poles Zerosei, Bari, Italy***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	Regional initiative to foster the implementation of specific interventions on 0-6 Poles. The Regional Education and University Section, with the support of ARTI (Agenzia Regionale per la Tecnologia e l'Innovazione della Puglia), has initiated a collaboration with the municipalities of Altamura, Bari and Capurso to carry out three design competitions for the implementation of innovative 0-6 Poles.
Main goals	– Proposing the role of childhood education services as urban equipment of high social, aggregative and functional value. – -Promoting 0-6 Poles as polarities for education aiming to work-life balance. – Clarifying the characteristics of childcare poles in relation to new pedagogical directions and the nature of contexts. – Creating a toolbox for regional regulatory activity in the context of 0-6 Poles.
Project implementation	No. These are design competitions. Action is planned to valorize the outcomes through a conference, an exhibition and the publication in a special volume of all the entries of the participating projects.
5.	***Streets for kids Gjon Buzuku Play Street, Tirana, Albania***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Program of NACTO (National Association of City Transportation Officials) and GDCI (Global Designing Cities Initiative). It involves several cities all over the world, Tirana is the only European city.
Main goals	– Ensuring safe mobility with an emphasis on accessibility for children and their caregivers. – Creating structural changes in the city's streets. – Developing a methodology to systematise and transform these individual initiatives into a comprehensive School Streets program.
Project implementation	Yes. The pilot initiative was implemented in 2020, then expanded to 10 other trials.
6.	***Turin Mobility Lab, Turin, Italy***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Initiative part of the national experimental home-to-work and home-to-school sustainable mobility program. Many of the experiments involve the proximity space of educational institutions.
Main goals	– Reducing emissions, vehicular transit, and architectural barriers. – Experimenting with integrated mobility and public space planning, near schools and at the neighbourhood scale. – Promoting a sustainable mobility intervention model capable of combining needs analysis and "collaborative design" pathways.
Project implementation	Yes. Numerous interventions in schools in the San Salvario district of Turin starting in June 2020.
7.	***Protegim les escoles, Barcelona, Spain***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Project sponsored by Barcelona City Council, Gobierno de los Comunes and the Socialist Party of Catalonia.
Main goals	– Creating a plaza in front of 200 schools in the city. – Shortening pollution and noise related to vehicular traffic by reducing the number and speed of lanes. – Increasing safety in proximity to schools. – Expanding recreational and green areas by incorporating new street furniture and creating areas for spontaneous play.
Project implementation	Yes. The implementation process started in 2020 and its completion is scheduled in 2023.
Best practices 2021	
1.	***Design your schoolyard, Antalya, Turkey***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	The project is part of a participatory process with the fund/support of ITU Housing UYGAR Research Center and Antalya Bilim University and aims to develop a methodology to redesign schoolyards of Antalya Muratpaşa study area, starting from Antalya Muratpaşa Dumlupınar Middle School.
Main goals	– Strengthening the students on sustainable practices and supporting them in imagining and designing their school environment. – Enhancing the role of the courtyard as a learning space particularly with respect to environmental sustainability issues through the practice of informal education. – Raising awareness of multi-disciplinary design of courtyards including sustainable design, alternative learning styles, education theories.
Project implementation	No. The project consists of online and face-to-face workshops that began in January 2021 and concluded with a participatory project in July 2021.
2.	***The green schools in Lucca, Lucca, Italy***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	Project developed under the "Experimental Program of Interventions for Urban Climate Change Adaptation," funded by the Ministry of Ecological Transition (General Directorate for Climate, Energy and Air), involves 18 schools and 1 public park.
Main goals	The aim is to reduce climate change effects by protecting outdoor spaces, depaving some surfaces and creating green curtains that increase shading on horizontal and vertical surfaces. The project aims to facilitate outdoor teaching and enhance students' comprehension of natural cycles.
Project implementation	In progress. Interventions in the 18 schools and public parks are in progress.
3.	***The construction site space, Bologna, Italy***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	The initiative is promoted by the Urban Innovation Foundation (FIU) and is part of the City of Bologna's Plan for Emergency Pedestrianism.
Main goals	– Pedestrianizing spaces near school entrances. – Enhancing the school surroundings as a place for socialising. – Increasing pedestrian safety in the proximity of schools. – Implementing temporary "tactical" interventions that can function as a test before final implementation.
Project implementation	Yes. The first realisation is 2022 in Via Procaccini which is followed by several other realisations, some of which are currently in progress.

	Best practices 2022
1.	***Cortile Mondo, nature becomes a school, Turin, Italy***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	Project developed as part of the BottomUp! initiative for urban regeneration and social inclusion conceived by the Foundation for Architecture of Torino.
Main goals	– Opening the school to collaborate with citizens in the school and area community. – Seizing the opportunity of a school green area and making it a public space. – Applying outdoor education and transforming the garden into a place
Project implementation	Yes. The project in the courtyard of the Chagall School in the Aurora neighbourhood was realised in 2022.
2.	***FIABA Florence learns to live with adolescents: schools as living labs for the city in transition, Florence, Italy***
Intervention Scale	Courtyards of educational institutions (CEI)
Initiative	The project was conceived and coordinated by DIDA - Department of Architecture of the University of Florence, with the involvement of the Direzione Edilizia of the Metropolitan City of Florence, the ITT Marco Polo and Liceo scientifico Castelnuovo (high schools in Florence). FIABA was funded by the Education and Training Sector of Fondazione Cassa di Risparmio di Firenze.
Main goals	– Co-designing the transition city with kids, focusing on combating climate change, sustainable mobility and accessibility, and caring for collective places. – Experimenting with the transition city through small concrete interventions in schools that show improvements in schools and neighbourhood liveability. – Creating a new relationship between school and city by experimenting with the opening of redeveloped gardens and courtyards to citizenship, according to appropriately arranged times and modalities.
Project implementation	In progress. The project was completed in February 2023 and is scheduled to implement some of the proposed interventions from November 2023.
	Best practices 2023
1.	***Open Squares for the schools, Milan, Italy***
Intervention Scale	Proximity of educational institutions (PEI)
Initiative	Program launched as a new phase of the Piazze Aperte (a project of the City of Milan, developed by the Agenzia Mobilità Ambiente Territorio-AMAT), in collaboration with Bloomberg Associates, National Association of City Transportation Officials (NACTO) and Global Designing Cities Initiatives.
Main goals	– Increasing public space and pedestrian areas available to young children in front of schools. – Returning a square to each neighbourhood, conceived as a public space to meet and socialise. – Involving residents in neighbourhood-scale urban regeneration processes through "tactical" spatial interventions and short-term, low-cost and scalable policies.
Project implementation	In progress. In February 2023, 87 proposals for action were collected and will be evaluated in the coming months.

Tab. 1 European best practices from 2015 to 2023

4.4 The role of school open spaces in localising the EGD

At this point of our study every good practice was examined in relation to the treatment of the four strategic issues and of the four governance principles that emerged from our interpretation of the European policies for localising the EGD. We have retained the indication of the scale of intervention for its relevance. Table 2 presents the results of this analysis. The results of the analysis are also presented quantitatively in the two radar charts below. With regards to the strategic issues, we can see that the most present in the twenty-five best practices were new public spaces (22) and greening (18), followed by sustainable mobility (12) and then circularity (10). Regarding the governance principles, the local-based approach was the most adopted (20), followed closely by the participatory approach (19) and then the transcalar and trans-scalar approaches (12 each).

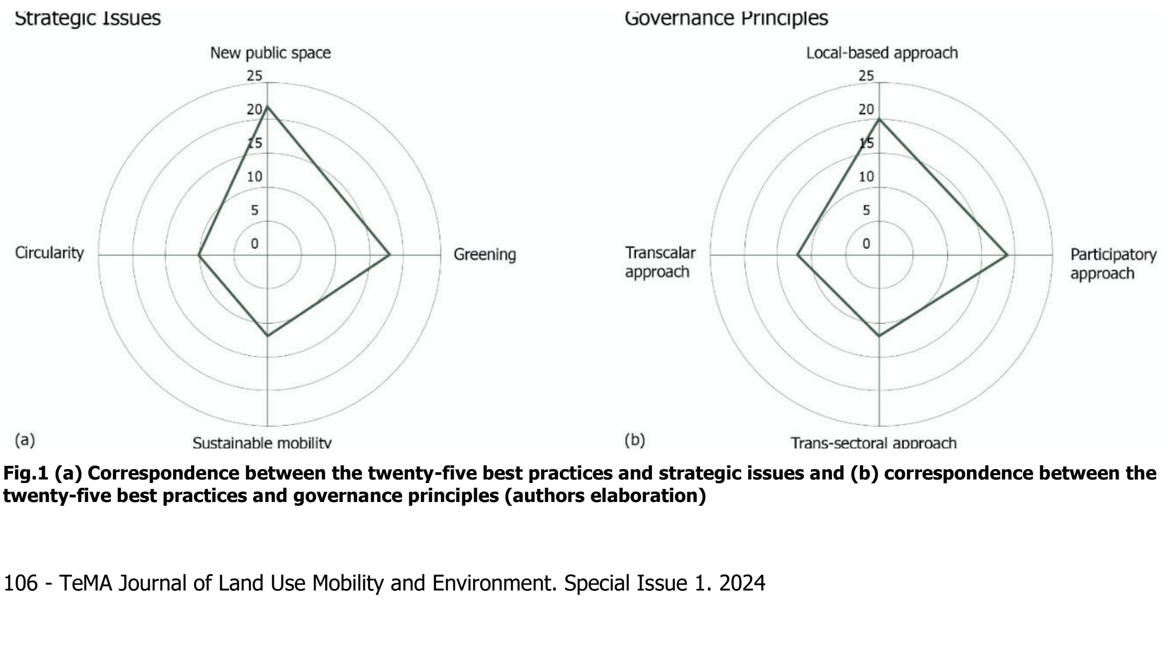

Fig.1 (a) Correspondence between the twenty-five best practices and strategic issues and (b) correspondence between the twenty-five best practices and governance principles (authors elaboration)

	Strategic issues				Governance principles				
Best pract.	*Sustainable mobility*	*New public spaces*	*Greening*	*Circularity*	*Participatory approach*	*Transcalar approach*	*Trans-sectoral approach*	*Local-based approach*	**Int. scale**
1.		●	●		●			●	(CEI)
2.		●	●				●	●	(CEI)
3.		●	●	●	●			●	(PEI)
4.	●	●	●	●	●	●	●	●	(CEI)
5.	●	●			●	●			(PEI)
6.	●	●			●			●	(PEI)
7.		●	●	●	●	●	●	●	(CEI)
8.		●	●	●	●			●	(CEI)
9.			●	●	●			●	(CEI)
10.		●	●	●	●	●	●	●	(CEI)
11.	●	●			●			●	(PEI)
12.	●	●			●			●	(PEI)
13.			●	●		●			(CEI)
14.		●	●	●		●	●		(CEI)
15.	●	●	●		●	●	●	●	(PEI)
16.		●	●	●		●	●	●	(CEI)
17.	●	●			●	●		●	(PEI)
18.	●	●			●	●	●	●	(PEI)
19.	●	●	●				●		(PEI)
20.		●	●	●	●		●	●	(CEI)
21.			●			●			(CEI)
22.	●	●	●		●		●	●	(PEI)
23.		●	●		●			●	(CEI)
24.	●	●	●		●		●	●	(CEI)
25.	●	●			●	●		●	(PEI)

Tab.2 Table crossing best practices with strategic issues and governance principles for a local and just transition

We will now give a qualitative interpretation of these results.

Sustainable mobility (12 projects) was mainly dealt with in relation to school-proximity interventions and was only marginally considered in schoolyard projects. A recurring solution for addressing mobility and safety challenges in areas near schools was the implementation of 'school streets' observed in locations such as Hackney, Hoogstraten, Gjon Buzuku, and The Hague (Giezen & Pellerey, 2021). Some initiatives experimented with integrated planning of mobility and public space, promoting a sustainable model that combines needs analysis and 'collaborative design' as seen in the *Turin Mobility Lab* (Renzoni et al., 2021).

Interesting cross-cutting experiments, such as those in Madrid (*Cuidados en entornos escolares*), showcased a more systemic vision and heightened awareness of sustainable mobility.
Concerning projects creating new public spaces (22), several experiments proposed squares in front of schools, as in Milan (*Piazze Aperte)* (Salvador, 2023; Alberti & Radicchi, 2022) and Bologna (*Cantiere Spazio*) (Longo et al., 2022) or similar spaces, as in Barcelona (*Protegim les escoles*). Many started as temporary proposals, based on tactical urban planning solutions, eventually becoming permanent changes (Lydon & Garcia, 2015). The creation of new public spaces was also addressed in most schoolyard experiments, such as in Turin (*Cortili in azione*). Cross-cutting experiences, as in Brussels (*Contrat école*), improved school surroundings, enhancing public space usability and creating inclusive spaces for the entire community (Cartes Leal, 2015). Greening was a significant aspect in the analysis (18 projects), developed differently at the two intervention scales. For school-proximity spaces, some projects adopted greening strategies for urban forestation or the transformation of disused areas into multifunctional green spaces, such as in Rome (*Oasi verdi dalla scuola al quartiere)* (Fratini, 2020). In schoolyards, projects like *Cortile Mondo, la natura si fa Scuola*, and *Amsterdam Impuls Schoolpleinen* enhanced environmental quality with natural elements like trees, plants, and green areas, contributing to biodiversity.
The use of Nature-based solutions proved beneficial for both the environment and the local community. Strasbourg (*Canopy Plan*), Paris (*Oasis Project*), Barcelona (*Climate Shelter Project*), Madrid (*Cuidados en entornos escolares*), and Rotterdam *(Green Blue Schoolyards*) adopted solutions to combat climate change, preserve biodiversity, and restore natural resources. Schoolyard spaces were re-envisioned as climate shelters, promoting a healthier environment and resource circularity. Circularity, when it was present (10 projects), was related to greening. This was particularly true regarding schoolyard spaces (9 projects) and much less so regarding school-proximity spaces, as the latter are complex interventions that require a lot of maintenance. Notably, circular practices played a crucial role in sustainable initiatives, such as urban gardens and responsible water resource use.
Participation methodology was applied in most case studies at both scales (19 projects), even though the participatory processes were different. The Bologna experience (*Spazio Cantiere*) was distinguished by the rigorous methodology it applied to involve citizens in school-proximity spaces. Two of the most successful schoolyard experiments in terms of participation are the Antalya case (*Design your schoolyard*) (Sabir Onat & Yirmibesoglu, 2023) and the Florence project (*Fiaba*) (Gisotti & Masiani, 2023). The former is distinguished by its integrated and participatory co-design methodology. The latter stands out for its robust intergenerational approach, involving high school and university students along with teachers in a participatory process focused on the application of nature-based solutions (NBS) in project development. Approximately half of the projects (12) used a transcalar or multilevel approach to public policy. These are characterized by systematic interventions and a large output (developed over several years), due to the substantial number of stakeholders involved and considerable amount of funding allocated. These projects were either on a national scale, as in Lucca (*Le scuole verdi*), or an international scale, as in Hamburg (*CLEVER Cities Project*) and Bolzano (*Metamorphosis Project*). The latter two were Horizon programmes involving a broad partnership, variety of stakeholders and experts, which are relevant for implementation of NBS in urban contexts (Arlati et al., 2021). Trans-sectoral approach was identified in projects (12) affecting a variety of public action sectors and numerous disciplinary competences including technical, design, and pedagogical skills. Often these projects worked on at least three of the strategic issues as in Paris (*Oasis Project*) and Barcelona (*Climate Shelter Project*) and were also unsurprisingly Urban Innovative Actions (UIA). Finally, many the experiences we selected (20 projects) had adopted a local-based approach to their design. Even if the final verification of this aspect can only be ascertained once the projects are completed, most of the proposed actions were based on place specificities, giving priority to "building on what is already there" principle (LGD) and creating positive transformations from existing resources, which are understood as opportunities offered by the physical space or social and economic characteristics of the context. Among the most notable experiments, we wish to point out the *Poli Innovativi Zerosei* project for the municipalities of Bari, which took place under the auspices of a public tender (Annese et al., 2022) and the Florence project (*Il giardino che vorremmo*) (Arnetoli et al., 2022).

5. Discussion

In this study, we analysed the potential of school open space regeneration projects to trigger and/or support the implementation of EGD at the local scale, to pursue a place-based ecological transition, therefore more effective and just. To this end, we have taken on four strategic issues and four governance principles stemming from the study of European policies for localising the EGD and have verified their treatment in twenty-five good practices at European level. Starting from the results described above, we now present some possible explanations for these outcomes with the aim of identifying three points on which to act in the field of urban regeneration policies related to transition.
We have seen that the creation of new public space and greening are treated very frequently in regeneration projects that act on school open spaces: actually schools have been created as public facilities in the city, their presence throughout urban fabrics and neighbourhoods is continuous and systematic and for this reason they can be intervention sites for the widespread regeneration of cities and can generate climate shelters, green infrastructures and new public spaces that greatly improve the whole urban environment.
Starting from the rich heritage represented by these collective equipment (Bricocoli et al., 2022; Renzoni, 2019; Marchigiani & Bonfantini, 2022) it is possible to structure widespread ecological and morphological 'infiltration' processes (Marot & Catsaros, 2020) rather than working in the direction of large projects concentrated in specific urban sectors that produce gentrification and inequalities. In this sense, operating on schools can create better and greater access to urban public space - redeveloped also in an ecological key - favouring a place-based transition, for this reason more just (Klinenberg, 2018).
However, we must not forget that the activation of these projects is far from easy. Sometimes they are macro-projects involving many schools that were supported by complex multi-level governance operations and substantial funding (e.g., the UIA in Paris and Barcelona). Often, they arise from isolated initiatives of local administrators, enlightened school leaders, researchers engaged on the subject, parents' associations. Although these virtuous experiences are more and more numerous, they maintain an episodic character, they are distributed in a scattered way concentrating, as a rule, in districts or urban contexts vital, well equipped from the point of view of social capital, of available resources and technical expertise (such as the twenty-five good practices we have examined).
Passively supporting these regeneration processes entails the risk of producing an increase in disparities and inequalities and phenomena of gentrification (Barò et al., 2022). Moreover, while most of the twenty-five good practices have been completed, it is also true that there are several minor projects on school open spaces that are not implemented, not infrequently because of the difficulty of moving from the preliminary to the technical and economic feasibility. This fuels frustration in school communities and citizens who have taken part in co-design processes of these spaces, representing a boomerang for the participatory approach so much applied in this type of experience. To begin to face these critical issues, a first fundamental point is to operate a firm and systematic political and financial investment in local authorities (Ahn et al., 2023) to activate the creation of school regeneration networks in the city and in every urban context, increasing the staff of the public administrations responsible for the development of these projects and tracing the resources for the implementation of interventions.
Only by starting this restructuring is it possible to imagine a change of direction that would allow to move from the episodicity of the good practices that we have illustrated to the systematic nature of a real public policy. Concretely this new attention to the integrated regeneration between school and city could be inserted as a working theme in the tools of urban and metropolitan strategic planning, to gain relevance as a piece of a shared vision for the city of the future on which to start building a confrontation between stakeholders.
A second fundamental aspect to act on is the development of intersectoriality. We have seen that, among the principles of governance, the transcalar approach and the trans-sectoral approach are applied in just under half of the projects and appear as the biggest challenges to be faced in this field. It is about encouraging and supporting integrated projects both vertically (between different levels of public administration) and horizontally (between areas of intervention of the same public administration) (Papa & Sachs, 2021).

At this end, it would be desirable to create a sort of cross-sectoral steering committee that integrates the sectors and competences of urban planning, education, and school facility management.
This is currently a crucial point, as massive transformations of cities are taking place through Next Generation EU funding. This steering committee could coordinate interventions that would otherwise be conceived and implemented haphazardly and would fail to use existing synergies that need to be formalised and supported. A strengthening of the intersectoriality could also lead to a greater integration of strategic issues less treated in the projects on school open spaces: this is the case of sustainable mobility and circularity that not only concern a larger scale but also require wider and more structured cross-sectoral coordination, which is more difficult to achieve.
The third point that we propose is the enhancement of the rich heritage of good practices to date carried out (of which the projects analysed represent a significant sample) through the creation of guidelines, which would lay the foundation for promoting integrated school-city regeneration projects in all contexts.
Guidelines may contain three levels of indication:

- *Procedural aspects:* i.e. how to start, develop, implement, and maintain an integrated school-city regeneration project, also with reference to the procurement of resources; which actors, institutional and otherwise, involve; the modalities of participation for an effective involvement of school communities and citizens; the need to provide for the maintenance of interventions, an essential theme especially when projects are based on greening materials.
- *Methodology*: i.e. implement pre-intervention analysis, especially for those greening interventions that are very popular today in school open spaces but sometimes designed independently of ex-ante surveys on the positive impacts they produce; read and represent the characteristics of the school context, so that the project is consistent with it and as much as possible place-based; plan interventions in order of priority (in some contexts such as Italy, the projects on school open spaces concern a building stock largely degraded that would require first of all a safety against the risk of earthquake and fire as well as the maintenance of some basic equipment).
- *Design solutions:* i.e. the collection of design solutions (with special reference to Nature Based Solutions) that can be adopted to meet various needs, which can be traced back to the four strategic issues previously illustrated (sustainable mobility, greening, new public space, circularity). Such solutions could then be declined for specific contexts of intervention.

6. Conclusions

The study presented in this article aims to contribute to the wider field of research on the improvement of EGD transition policies, with special reference to some of its weaknesses such as the creation of environmental and territorial inequalities, the adoption of sectoral approach in different policy areas, the concentration of resources on major infrastructural interventions to the detriment of the maintenance of everyday life contexts, the creation of ecological gentrification. Starting from the idea that the local scale can play a crucial role to cope with the abovementioned critical issues, this study considers the school open spaces as test beds for a place-based transition, more effective and just. Such spaces can contribute to localising the EGD, dealing with the strategic issues and governance principles for its implementation. However, although attention to these spaces has increased considerably in recent years, the interventions have been episodic and fragmented, lacking a systematic vision.
This entails the risk of creating further disparities in access to urban services and public spaces.Hence, it is decisive that public action and in particular local authorities act on a primarily political front, strengthening its role as a major player in the management of urban transformations, and also acquiring adequate economic resources for this task.
It is also essential that, in the process of transition, the major issues to be central to urban policies (such as that of the integrated regeneration between school and city and more generally between public facilities and the city) are defined in a strategic vision. Furthermore, an integrated and cross-sectoral approach is needed to achieve more meaningful and lasting results in the long term, enhancing possible synergies between areas of intervention of public administration but also with the wider world of research and civil society.

Authors' contribution

This paper is the result of a joint reflection by the authors. Section 1, 3, 4.1 and 4.2, 5 and 6 were written by Maria Rita Gisotti and Section 2, 4.3 and 4.4 by Benedetta Masiani.

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Strategies for adapting the dense Italian cities to the climate change

The case study of the San Salvario historical neighborhood

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Abstract

The urban fabric of European cities is subject to significant pressures from human activity and climate change. The devastating effects of climate change on urban environments threaten the quality of life of citizens and ecosystems. In particular, historic and dense-tissue cities face challenges in adapting their established urban fabric devoid of green areas. The lack of green spaces for social gatherings becomes a critical issue in addressing the climate and environmental crisis. Dense cities such as Barcelona and Copenhagen are promptly responding to the climate emergency through adaptation plans.

This essay identifies the 19th-century neighbourhood of San Salvario in Turin, as a case study to develop a morphological analysis aimed at proposing nature-based strategies to improve the adaptation potential and resilience. The design elements identified in the two best practices cities inspire hypothesizing replicable architectural solutions in dense urban contexts such as the study area under consideration. Finally, the paper addresses the limitations arising from the lack of holistic strategic planning, which in the case of Turin is based on fragmented interventions disconnected from the existing ecological network rather than on a long-term plan. The paper also reflects on the need to include additional assessments of ecosystem services, taking into account their economic valuation.

Keywords

Adaptation; Climate Change; Healthy City; Nature-Based Solutions; Green Infrastructure.

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1. Introduction

The effects of excessive anthropogenic impacts, combined with the intense phenomenon of urbanization (Mazzeo & Polverino, 2023), are pushing cities to face the need to resiliently redefine their spaces and architectures (Guida, 2022 a; Negrello et al., 2022). According to a study conducted by Martinez-Solan et al. (2021), European cities, particularly those in the Mediterranean region, will be the primary hotspots of climate change, experiencing significant disruptions in terms of both increased seasonal averages and extreme weather events (Guida, 2022 b). Cities are undergoing rapid and profound changes and are subject, along with their populations and ecosystems, to various climate stresses. As reported in the Report on Climate Change Risk Analysis (2020), among the countries in the Mediterranean region, Italy is one of the most affected by extreme phenomena, with a 55% increase compared to 2022 (CMCC, 2023). Especially in the last years, prolonged periods of drought were experienced in Northern Italy between 2022 and 2023, while severe floods occurred in Bologna in May 2023.

Among the factors amplifying the impacts of these phenomena in urban contexts, the primary cause is the lack of widespread green infrastructure due to extensive soil impermeabilization. Indeed, soil impermeabilization through construction and artificial materials is one of the main forms of degradation associated with urban development and expansion, influencing microclimatic dynamics within and around urban areas (Fini et al., 2017). The high anthropogenic pressure on the soil, resulting from its impermeabilization, can also cause flood risks by altering the urban hydrological cycle. This leads to a reduction in the capacity to intercept, store, and infiltrate rainwater, especially considering the changing precipitation patterns associated with climate change. Furthermore, there is an increasing frequency of intense short-term rainfall events that jeopardize the safety of citizens and infrastructure (Costa et al., 2021).

Another aspect contributing to the need to redesign the urban environment in European cities is the nature of the surfaces (asphalt, concrete, stone, etc.), with limited green areas or high albedo, exacerbating the urban heat island (UHI) phenomenon (Perini et al., 2021), which is further amplified by the expected increase in the frequency and intensity of heatwaves in the coming years (Rousi et al., 2022). Consequently, this not only has a negative impact on the urban system in terms of the poor resilience of the built fabric but also leads to a decline in the psychophysical well-being of citizens (Negrello et Ingaramo, 2021; Tong et al., 2021) and significant disparities in access to green spaces for disadvantaged groups (Hasee, 2017).

After highlighting the negative environmental and social outcomes of the climate crisis in dense European urban areas, a third economic factor also emerges: the costs resulting from the effects of climate change. These include energy consumption for cooling, health costs associated with increased mortality and morbidity during heat waves, and expenses related to restoration after extreme flood events (Ceci et al, 2023).

This calls for reconsidering the urban design of current public and private spaces, aiming to intensify and densify green infrastructure and implement targeted solutions, such as nature-based solutions, to address the current deficiency, especially in densely populated urban areas (De Noia et ali, 2022). The strategic role of the environmental system in sustainable urban development is widely recognized, particularly within urban areas. In fact, greenery significantly contributes to environmental conservation (Coticelli, 2015) and citizen health (Angrilli, 2021). However, significant obstacles hinder the establishment of a robust green infrastructure system in consolidated urban areas. These obstacles include real estate speculation and climate change, which threaten the survival of existing green areas (e.g., through prolonged periods of drought). Furthermore, a critical point concerns urban planning systems: despite the existence of climate resilience plans, there is difficulty in implementing strategic projects for green densification (e.g., through targeted nature-based solutions), as urban policies tend to favour models of dense cities by utilizing abandoned (or even virgin) land to meet the growing demand of the real estate market (Coticelli, 2015), despite the demographic decline in cities like Turin.

It is important to emphasise that while the development of a dense city represents a sustainable model for reducing land use, it does not necessarily guarantee the resilience of urban environments (Neuman, 2005) to the direct effects of climate change, which they are partly the cause.

The objective of this research is to illustrate the challenges that dense urban fabrics in Italian cities, composed of narrow streets, devoid of vegetation, and characterized by high soil impermeability, face by introducing an analytical method that identifies and analyzes the criticalities and potential of the morphologies of spaces and architectures in the target neighbourhood under study. The aim is to propose replicable nature-based solutions for climate change mitigation and adaptation, solutions that have already been tested in other contexts, to enhance the well-being of citizens (healthy cities) and the environment. The proposed solutions are the result of an analysis of best practices at the European level which have been critically examined and re-proposed in the identified case study. To this end, the choice of the analysis location and design proposal has fallen on the San Salvario neighbourhood, situated in the city of Turin. Specifically, the focus will be on the "quadrilatero" (Bocco, 2007), the neighbourhood's original settlement developed in the second half of the 19th century, which still exhibits many typical characteristics of that era's villages. Elements such as courtyards, distribution of balconies, narrow streets, high population density, and construction are just a few examples of features found in 19th-century neighbourhoods in other Italian cities like Milan, as well as in European cities like Barcelona and Paris. Additionally, as highlighted in the appendices of the "Strategic Plan for Green Infrastructure" published by the Municipality of Turin (2020), the area presents an underdeveloped green space system. The near absence of green infrastructure renders the neighbourhood vulnerable to environmental risks and poses health concerns for its residents, such as the heat island effect and poor air quality, while also limiting the presence of meeting spaces and socialization within the neighbourhood.

2. Best adaptation practices: Barcelona and Copenhagen

In this section, two European cities that have developed adaptation plans, characterized by different climates, have been selected. The geographical selection was made to obtain a diversified sample of climates and, consequently, NBS solutions. The objective is to demonstrate how it is possible to address the climate emergency in various European contexts by implementing Nature-Based Solutions.

The choice fell on two cities that exhibit recurrent urban forms in European urban fabrics, such as grid patterns (mostly composed of modules) or less regular patterns (not derived from the precise juxtaposition of a module). The selected cities are Barcelona, characterized by a typically Mediterranean climate, and Copenhagen, with a Baltic-continental climate.

1.2 Barcelona

Barcelona has ambitious plans, such as the Climate Plan 2018-2030, to make the city increasingly sustainable and socially inclusive. The main objectives are to reduce high summer temperatures and promote sustainable mobility by discouraging the use of private vehicles. Building upon these considerations, Salvador Rueda has developed the concept of "Superblocks," aiming to surpass and reinterpret the traditional "blocks" conceived by Cedrà in the early 20th century in a sustainable manner. The project (fig. 1) involves grouping nine urban blocks into a "superblock," where pedestrian areas are created and private vehicles are only occasionally permitted. This enables the implementation of nature-based solutions and permeable surfaces, creating more community-dedicated spaces (Ajuntament de Barcelona, 2022). Initially, the project faced opposition from motorists and merchants. However, initial doubts were dispelled as residents began to enjoy the benefits of a traffic-free neighbourhood, thereby allowing for project expansion (Comelli, 2019). Among the adaptation-focused projects implemented by the municipality of Barcelona, which incorporate the application of NBS, the following streets are noteworthy: Carrers de Consell de Cent, Rocafort, Comte Borrell i Girona, and Carrer Pi i Margall, Pasajes san Juan) and Superilla Sant Antoni (Ingaramo et al., 2023.

Among the recurrent Nature-Based Solutions for mentioned urban spaces, we can identify: biodiversity corridors, depaving, new permeable/green pavements, increased tree coverage, rain gardens, and pocket gardens.

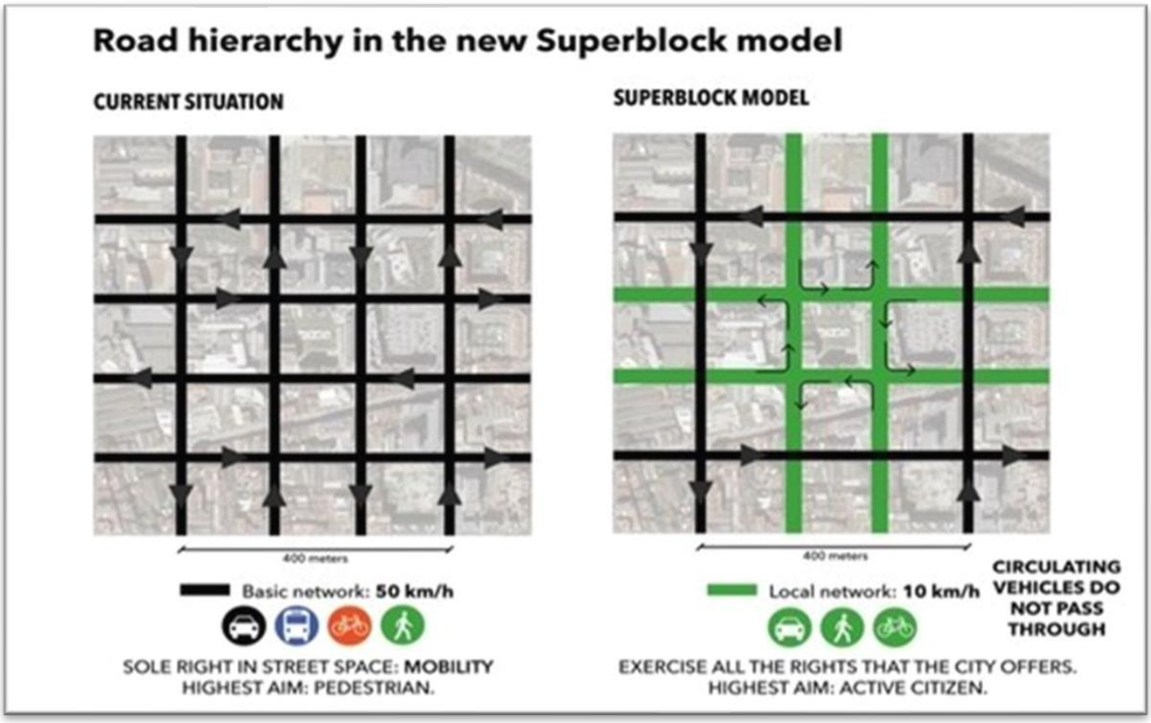


Fig.1 Barcelona "superilla" or superblock model in comparison with the current traffic flow

2.2 Copenhagen

Copenhagen stands out among European cities for its morphological modification of urban space aimed at increasing the resilience of the built environment (Negrello, 2023). The Danish capital is a virtuous example of how climate change can facilitate urban development (Xu et al., 2021). Since 2011, the municipality has adopted a proactive plan to address the climate crisis and mitigate the impact of future calamities. The severe cloudbursts in 2008 and 2011 resulted in extensive damage, highlighting the potential influence of future climate events on the city, prompting the administration to develop the Copenhagen Climate Plan, approved in 2015.

Within this plan, local architects were called upon to develop a comprehensive masterplan. Among them, SLA Architects also took charge of implementing one of the solutions designed to address the challenges related to rainwater drainage (fig.2) in the Inner Nørrebro district, directly involving the community. The solution is based on the creation of a robust urban green infrastructure that specifically addresses the issue of managing torrential rains to prevent flooding, while simultaneously creating a new series of cohesive urban spaces that provide a stronger social community, greener and more natural experiences and new creative opportunities for all residents of Copenhagen. A central aspect was the engagement of citizens in the project's development, making them personally responsible for the care of the neighbourhood (Ingaramo & Negrello, 2023; Negrello, 2023). Hans Tavsens Park is a rainwater collection basin during storms for the Inner Nørrebro district. The excess rainwater is then directed through Korsgade to Lake Peblinge. Along the streets, two solutions are adopted: a portion of the water is absorbed and biologically purified by vegetation, while another portion is channelled along the sides of the roadways, where visible or underground artificial streams are established. Among the identified projects, Sankt Kjelds Square and Bryggervangen,Klimaquartier Østerbro, green roofs along Kalvebod Brygge (Ikea, Cactus Tower), and Enghaveparken are mentioned. Among the recurring Nature-Based Solutions for the mentioned urban spaces, we can identify: biodiversity corridors, rain gardens, bioswales, public green roofs and green walls.

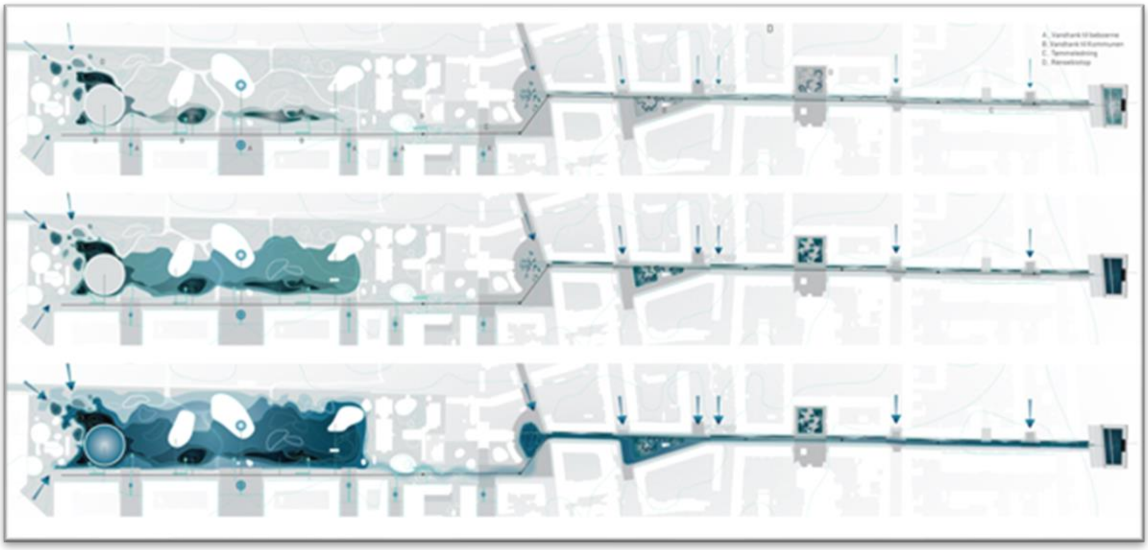


Fig.2 The project *The Soul of Nørrebro in Inner Copenhagen.* Diagram of water management

3. Best practices: NBS abacus

Building upon the analysis of approaches outlined in the best practices of Barcelona and Copenhagen, this study identifies and categorizes project interventions that integrate green elements (Nature-Based Solutions) and are better suited for dense and compact urban contexts. Specifically, by considering sustainable development goals and urban resilience as foundational concepts, the study identifies design strategies (Tab.1) addressing environmental, social, inclusive, and economic aspects, as outlined in the matrix. The solutions presented indicate the scale of intervention, the primary benefits (environmental, social, economic), and the corresponding SDGs.

4. Methodology

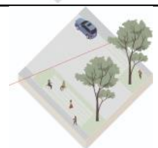
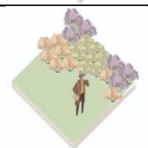
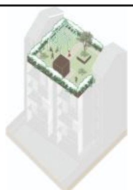
The research is dedicated to identifying strategies, interventions, and solutions aimed at enhancing the ecological potential of urban spaces and adapting morphologies and architectures to the impacts of climate change in cities characterized by a dense built fabric within the Italian context.

The term "dense urban fabric" refers to an urban area characterized by the concentrated presence of buildings, infrastructure, and activities within a relatively limited space. This urban configuration often results in higher building density and reduced availability of public open spaces and green areas. Dense urban fabric poses specific challenges and opportunities in terms of architectural and urban design, mobility, environmental sustainability, and quality of life.

Defining Italy as the geographical area of study, the city of Turin was selected for its characteristics, as outlined in the next paragraph. The chosen area is the historic district of San Salvario, representing the typical historical Italian dense city fabric.

The research is structured with an initial analysis of the dense fabric under examination, upon which subsequent NBS will be experimented. The analysis, replicable in other contexts, aims to identify the main elements constituting the built environment, focusing on the following categories:

1. Green analysis: this aims to highlight the state of the art (and, in this case, the absence) of various types of green spaces present in the area.
2. Built morphology analysis: this involves examining buildings, streets, and public and private spaces to identify their main features and the types that would require subsequent interventions. To facilitate this, a classification system was developed to categorize the identified urban elements.

NBS - Action	Graphical Disposition	Area	Benefits	SDGs
Biodiversity Corridor/ Greening		Square Street	thermal comfort / cooling / permeability / biodiversity / better air quality/ new social place	3 11 13 15
Parking Desealing		Square Street Courtyard	water management / permeability	3 6 11 13
Draining Green Pavements And Parkings, New Tree-Lined Avenues		Street	permeability / better air quality / biodiversity / thermal comfort / new social place	3 10 11 13 15
Pedestrianization / Greening		Square Street	permeability / better air quality / biodiversity / thermal comfort / new social place	3 10 11 13 15
Raingarden (Vegetated space for rainwater management)		Square Courtyard	water management / permeability / biodiversity / new social place	6 11 13 15
Bioretention area/ Bioswale (area or channel designed to slow and capture stormwater runoff, filter pollutants and increase rainwater infiltration)		Square Street Courtyard	water management / permeability / biodiversity	3 6 11 13 15
Biodiversity Hot Spot Between Parkings (Small areas with diversified tree species to promote pollinators.)		Square Street Courtyard	water management/permeability / biodiversity / thermal comfort / new social place	3 6 11 13 15
Pocket Garden (Interstitial gardens positioned in urban gaps such as intersections or between buildings)		Square Street Courtyard	permeability / biodiversity / new social place	3 10 11 13 15
Green Wall		Buildings	thermal comfort / biodiversity / new social place	3 10 11 13 15
Extensive Green Roof		Buildings	permeability / thermal comfort / biodiversity	3 10 11 13 15
Intensive Green Roof		Buildings	permeability / thermal comfort / biodiversity / new social place	3 10 11 13 15

Tab.1 Abacus of selected strategies

The second phase encompasses the implementation of NBS identified in the state-of-the-art best practices related to climate adaptation. This involves incorporating the identified best practices into the urban layout of San Salvario. The proposed interventions are designed to enhance the proportion of permeable surfaces, green spaces, and high-quality public areas. According to the strong sustainable model, such interventions that enhance the biosphere also foster social values and stimulate the local economy (Ingaramo & Negrello, 2023).
The final phase involves the quantitative analysis in terms of percentage change post-intervention. The following aspects have been considered:

- permeable surface area;
- presence of trees;
- spaces for social interaction.

4.1 Case Study: San Salvario, Turin

The study was conducted in the historic district of San Salvario, located in the city of Turin, one of the selected cities for the "100 climate-neutral cities by 2030 - by and for the citizens" project by the Mission Board for Climate Neutral and Smart Cities. From an environmental perspective, the city as a whole presents significant challenges and a limited capacity to adapt to climate change (Ellena, 2022).
Despite being considered the "green capital" of Italy due to its abundance of trees, Torino is reported by Legambiente to have one of the worst air quality levels among European cities. Furthermore, Torino's Climate Resilience Plan indicates that 46% of the municipal territory is at medium/high risk for heat island phenomena, particularly in densely built and impermeable flat areas such as the San Salvario district.
The analysis focused on the historical core of the district (fig.3), known as the "quadrilatero", delimited by physical barriers such as Corso Vittorio Emanuele to the north, Via Nizza to the west, Corso Massimo D'Azeglio to the east, Corso Marconi to the south. The district features a strictly grid-like urban structure, reminiscent of the Roman patterns found throughout the historic city. This characteristic can be considered a potential asset as it allows for the replication of solutions and actions within the "quadrilatero" area.
Despite the vibrant nightlife and the lively setting of restaurants and bars, the absence of high-quality urban spaces hinders the daytime usability of public space within the inner fabric of the neighborhood. Nevertheless, the neighborhood demonstrates particular dynamism along the thoroughfare of Madama Cristina, where the local market is also active during the morning.
The dichotomy between day and night leads to different experiences of the urban space: during the day, the neighbourhood life is primarily concentrated along the commercial axes of Via Madama Cristina, where the local market is located, Corso Guglielmo Marconi, and Corso Vittorio Emanuele, which connects the Centro district with San Salvario. Conversely, during the nighttime hours, the most frequented areas of the district are located near Largo Saluzzo.
After the closure of daytime activities, the neighbourhood transforms into an outdoor social lounge, with social spaces concentrated in the terrace areas of various dining establishments. However, the district lacks high-quality public spaces where people can sit amidst greenery or multifunctional and inclusive areas to install urban furniture and children's play areas.
San Salvario has also been the subject of experimental initiatives by the municipal administration, which has approved the creation of specific pedestrian areas. However, there is no comprehensive and structured vision aimed at pedestrianization and traffic reduction within the district.
This very lack has prompted some groups of citizens to initiate bottom-up participatory processes to identify strategic areas for the development of pedestrian and green spaces for the community, as exemplified by the "Largo al Giardino" project, proposing the transformation of Largo Saluzzo into an open square for all. Lastly, the characteristics of this neighbourhood, including its spatial layout, presence of local activities, market,

shared mobility infrastructure, subway, bicycle lanes, proximity to the central train station, university, etc., make it suitable for embracing the concept of the "15-minute city" (Rhoads & et al., 2023).

Fig.3 Framework of the project area (black buildings)

4.2 Analysis of green spaces

The territory of the San Salvario quadrilateral, despite its proximity to Torino's main park, Valentino Park, lacks green areas (Fig.4). Nonetheless, it features some tree-lined avenues and sporadic tree plantings, which, in certain instances, exhibit subpar quality.

The only public green spaces are entirely represented by the tree-lined avenues of Corso Massimo D'Azeglio, Corso Vittorio Emanuele II, and Corso Guglielmo Marconi, as well as select segments adorned with smaller and sparser trees, such as Via Nizza or Via Claudio Luigi Berthollet.
Conversely, private greenery predominantly resides within courtyards or private gardens, primarily extending westwards towards Valentino Park. In the absence of other nearby natural havens where citizens can unwind or take respite, these spaces serve as the exclusive green enclave of the neighbourhood.
This discernment arises from the annexes of the "Strategic Plan for Green Infrastructure" (Comune di Torino, 2020), which substantiate that denizens of the San Salvario quadrilateral lack access to green expanses within 300 metres of their dwellings (excluding lots proximate to Corso Massimo).

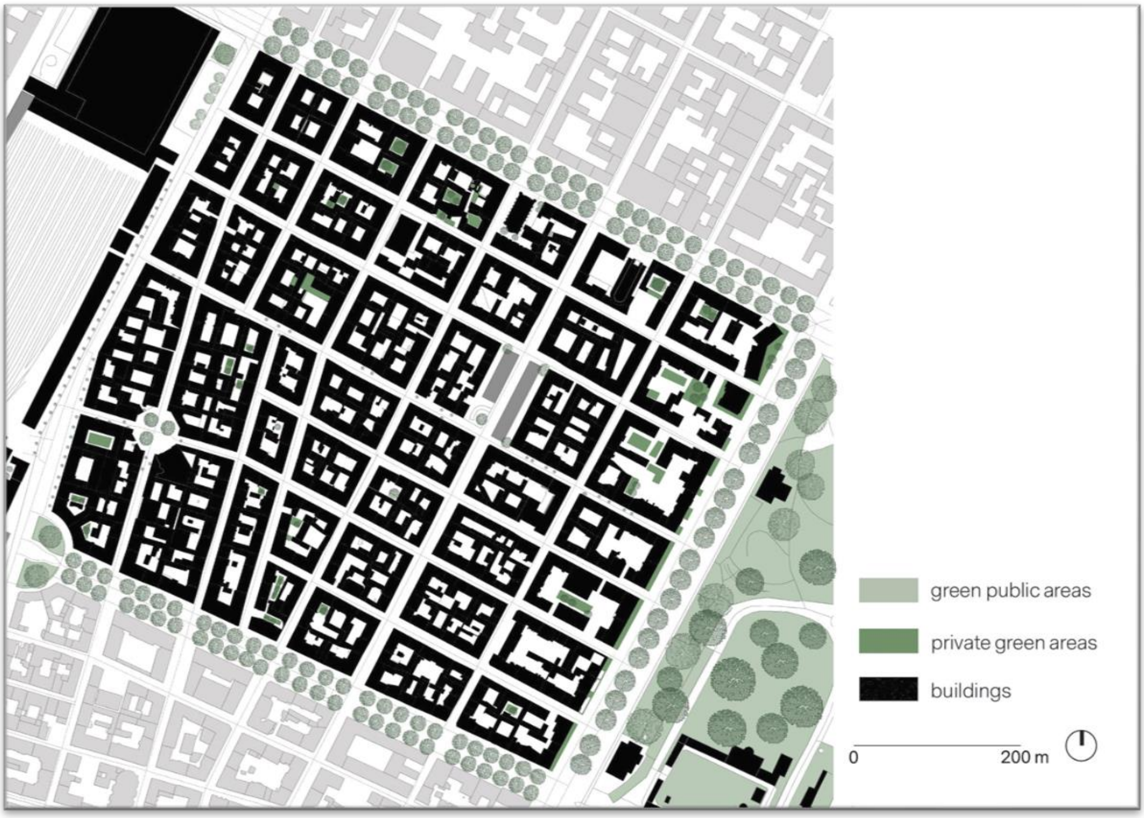


Fig.4 Map of the state of green areas

4.3 Morphological analysis

The analysis of morphology plays a fundamental role in identifying the forms of the built environment and the potential for the introduction of green infrastructure to address critical issues in the neighbourhood, both from an environmental and social perspective. Specifically, key and recurring elements have been identified within this studied urban fabric, including squares (fig.5), streets (figg.6-7), courtyards (figg.8-15) and buildings.
It is important to note that, in addition to courtyard architectural typologies, there is a significant lack of quality spaces due to the predominant allocation of land for roads and on-street parking, despite the presence of a dense public transport network (including the underground) and cycle paths in the neighbourhood.
The presence of private vehicles is also observed within courtyards, often converted into parking areas, as well as in squares, or rather, potential squares, which are often divided by high-traffic roads, thereby creating a lack of social spaces in the neighbourhood.
As depicted in fig. 4, the urban fabric is characterized by a limited presence of green infrastructure, which hampers surface permeability.

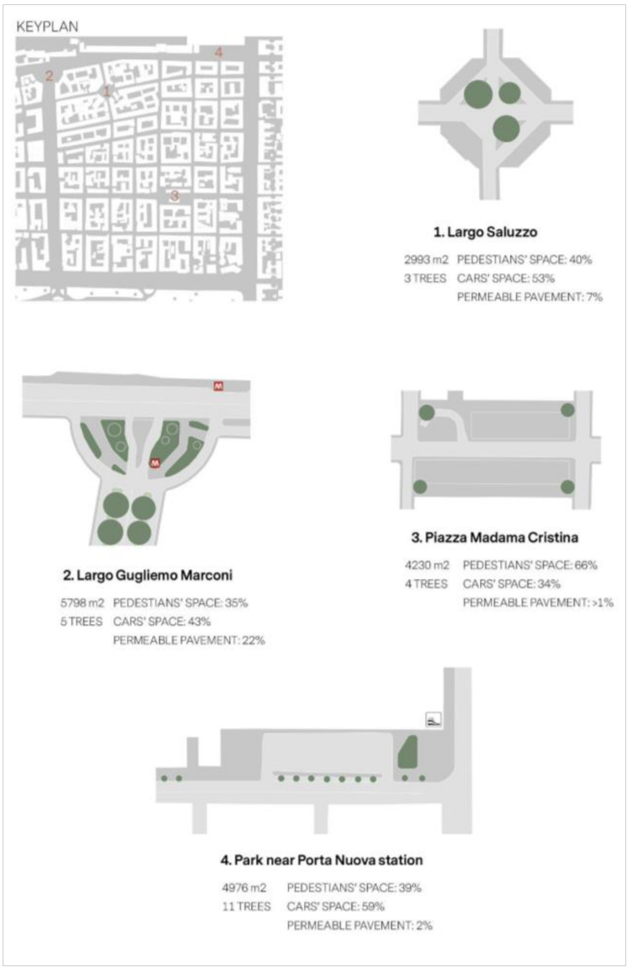


Fig.5 Analysis of square

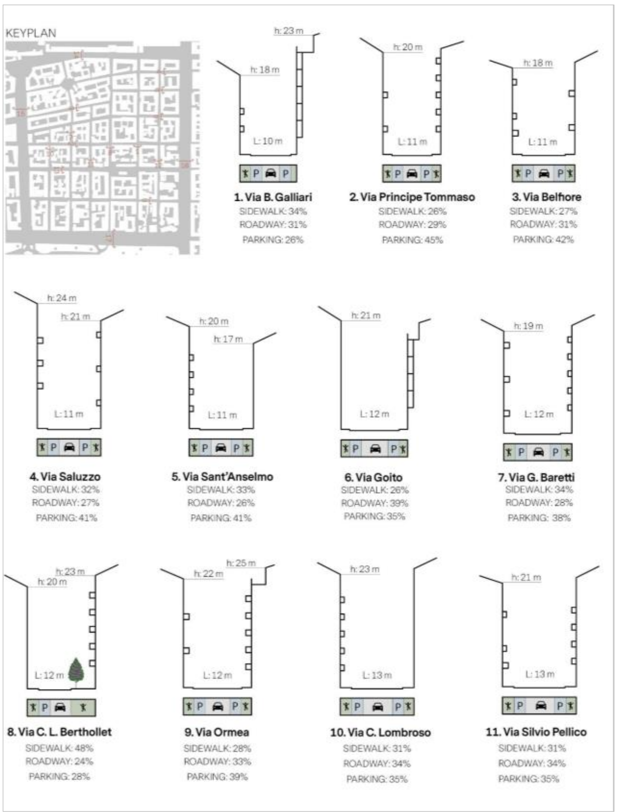


Fig.6 Analysis of streets - (part 1)

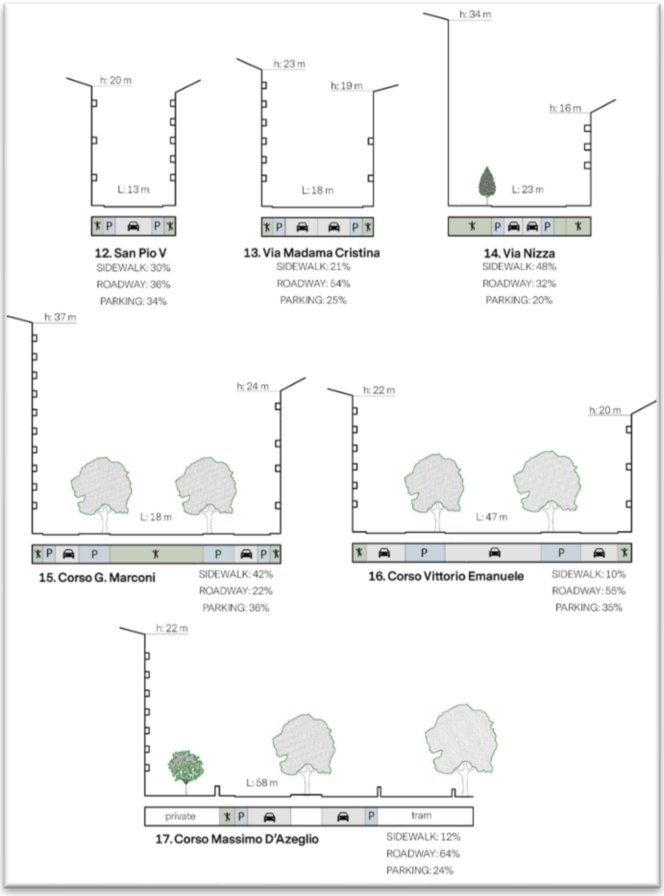


Fig.7 Analysis of streets - (part 2)

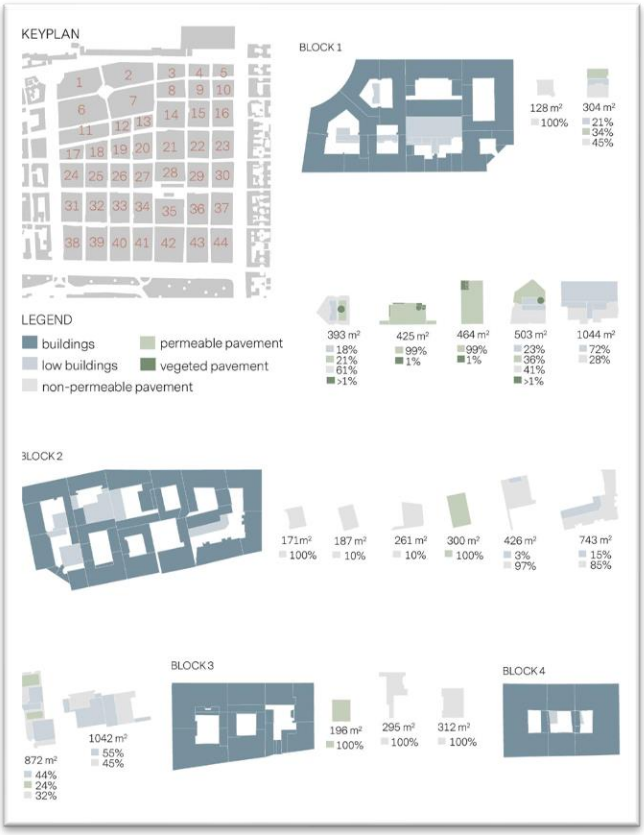


Fig.8 Analysis of the courtyards (part 1)

Fig.9 Analysis of the courts (part 2)

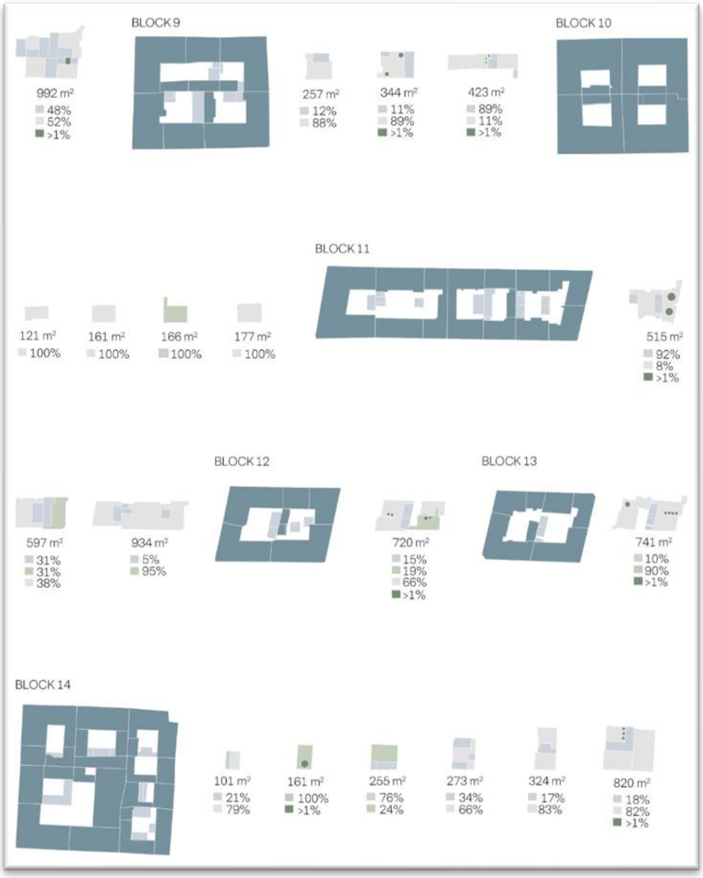


Fig.10 Analysis of the courts (part 3)

Fig.11 Analysis of the courts (part 4)

Fig.12 Analysis of the courts (part 5)

Fig.13 Analysis of the courts (part 6)

Fig.14 Analysis of the courts (part 7)

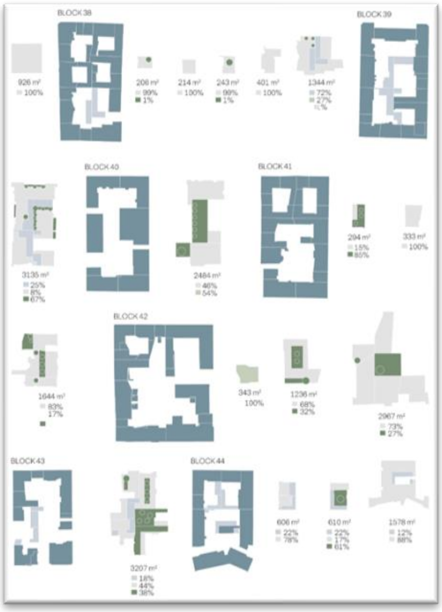


Fig.15 Analysis of the courts (part 8)

Table 2 categorizes the most relevant morphological characteristics constituting the neighborhood fabric. It identifies spatial typologies (extensive, linear, vertical) and assesses the potential of these spaces in green transition projects, considering both environmental and social aspects, while also highlighting their limitations to be considered in the projects.

Element	Development area	Limits	Potential
Square	Extensive area	Existing infrastructure* Historical/landscape features Spaces with pre-existing identities	high
Street	Linear area	Existing infrastructure* Acceptance of extraordinary interventions**	medium
Courtyard	Extensive area	Private/semi-private places Historical/landscape	high
Building	Vertical area	Private/semi-private places Historical/landscape	medium
*(sewerage, district heating, energy, telecommunications, etc.) **road pedestrianization, reduction of parking space, new bike lanes, etc.			

Tab.2 Table of the main elements of the morphology of San Salvario

5. Application and result

The comprehensive analysis conducted on the neighborhood distinctly reveals that the shortage of public spaces for socialization and the absence of green areas are currently compromising the area's quality of life, significantly influencing the overall adaptability of the city.

This predicament exposes both residents and the architectural heritage to noteworthy risks in the face of extreme events. The foremost objective is, therefore, to fortify and optimize the existing spaces, aiming to ensure a substantial improvement in the quality of life and bolster urban resilience.

Considering the recurrent presence of internal road sections measuring between 10 and 12 meters, courtyard buildings characterized by recurring dimensions and modularities, along with distinctive public spaces like the captivating Largo Saluzzo, three representative elements were singled out for each category. These elements are earmarked for redesign through the implementation of Nature-Based Solutions (NBS).

The pilot cases pinpointed for redesign interventions utilizing NBS are Largo Saluzzo, Via Baretti, and the internal courtyard of block 13 (Fig.16).

Fig.16 Map of the selected locations

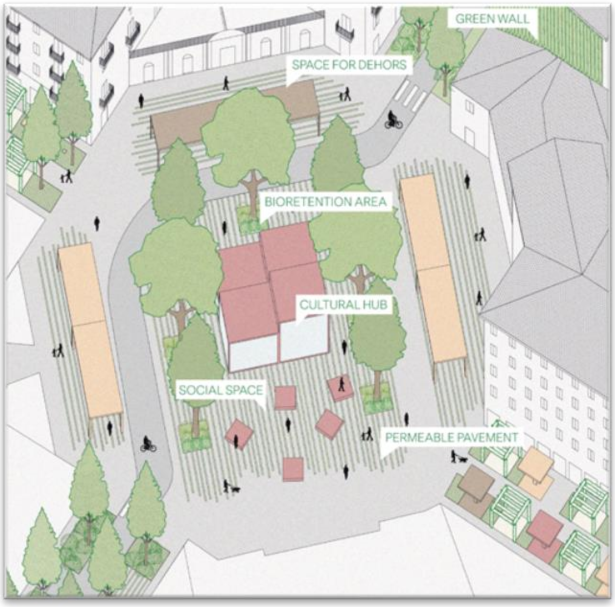


Fig.17 3D view of project in Largo Saluzzo

The NBS, delineated in the matrix (Table 1), were selected by considering the specific context of San Salvario (streets, internal courtyards, squares), aligning with the desired benefits and functionalities, as well as the Sustainable Development Goals (SDGs) to pursue.

Concerning the streets, projects were diversified with a focus on reducing car space to promote pedestrianization, considering the outstanding connectivity to the city and its adjacent center. The area boasts exceptional public transportation access, featuring three metro stops, proximity to the train station, dedicated cycling lanes, and an expansive underground parking facility – albeit currently underutilized – situated in the adjoining Parco del Valentino. For the high-traffic streets where cars have unrestricted access, the applied strategies entailed increasing the width of sidewalks and reducing parking spaces, thus allowing for the integration of vegetation and permeable surfaces. In pedestrian streets, on the other hand, a denser vegetation approach was chosen to enhance citizen utilization, especially during the summer, and efforts were made to separate spaces between cyclists and pedestrians.

Lastly, given the lack of significant gathering spaces in San Salvario, the revaluation of social spaces became crucial. For these areas, inclusive spaces were created for the neighbourhood, introducing biodiverse "pocket gardens," and due to limited space availability, multi-level solutions were adopted. We present below the results of three proposed projects for the area under investigation (fig 16). The first project (fig.17) is dedicated to Largo Saluzzo, currently an octagonal square crossed by two perpendicular vehicular streets and characterized by a limited presence of vegetative elements. The project's objective is primarily to limit private car traffic on one of the two streets, increase the presence of vegetation and permeable surfaces on-site, and transform it into a safe social space. In the heart of the square, a cultural center has been established to serve as a focal point for engaging social activities. The decision is motivated by the fact that currently, transit traffic is primarily generated by residents in the area and by service vehicles for catering establishments. Additionally, individuals passing through in futile search of parking contribute to the traffic, given that the area is predominantly occupied by bar terraces. Furthermore, for over four years, there has been an active citizens' association called "Largo al Giardino," which supports the area's conversion process through a bottom-up approach in collaboration with the municipality.

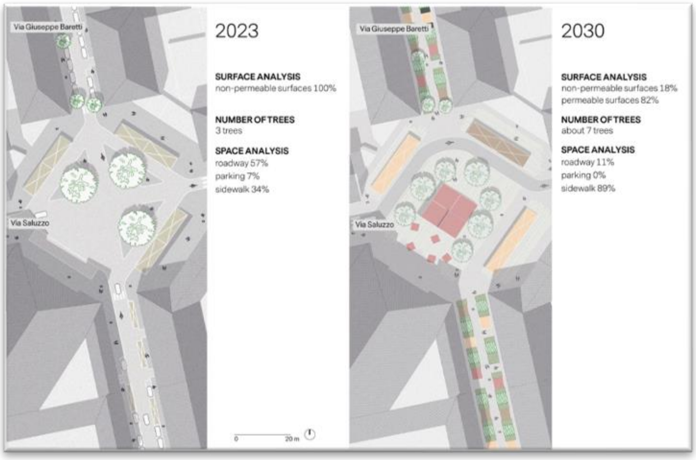


Fig.18 Before and after, project in Largo Saluzzo

Fig.19 3D view of project in Via Baretti

As shown by the data in fig.18, the project has increased permeable surfaces (82% of the surface is draining, compared to the pre-intervention 100%) and bioretention areas, introducing new biodiversity and reducing the risk of flooding. The decision to incorporate new high-albedo trees and pavements, on the other hand, mitigates the urban heat island effect, enhancing the livability of the area during warmer periods. Blank walls are treated with vertical greenery, contributing to the creation of a cooler and more biodiverse environment.

Regarding the street, we provide the example of a pedestrianized street, Via Giuseppe Baretti (fig.19). Currently, the street is traversed by cars, there are few parking spaces on both sides and terraces, while the sidewalk area is minimized. The project aims to transform the street into a pedestrian zone, restoring spaces for vegetation, permeable surfaces and public space. The project is composed of three areas: one dedicated to pedestrians and two dedicated to rows of trees of different species, biodiversity hotspots and vegetated pergolas. Architectural choices based on NBS contribute significantly to reducing the temperature in a high pedestrian traffic area, given the presence of bars and restaurants.

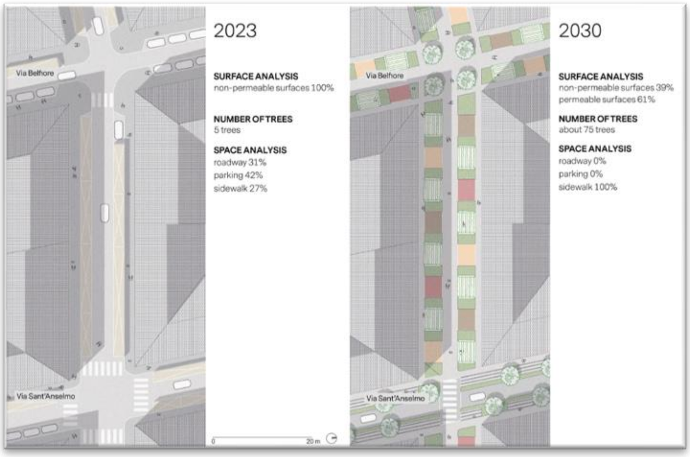


Fig.20 Before and after, project in Via Baretti

Fig.21 3D view of project inner courtyard

Additionally, they create retention areas for first rainwater in the event of sudden precipitation, helping minimize flooding, in contrast to the current situation that poses risks in this regard. Moreover, by reducing vehicular traffic, additional benefits are achieved, including a decrease in air pollutants and an overall

improvement in residents' quality of life. A roadway space has been considered for the passage of emergency vehicles, property owners, and waste collection. Figure 20 quantitatively illustrates how the implementation of NBS allows for the creation of greener environments, capable of increasing opportunities for social interaction and stimulating greater vibrant economic activities((Scalisi and Ness, 2022), particularly within the catering sector. This is because the public space project contributes to enhancing both aesthetic and microclimatic qualities.The third pilot case concerns plot number n, consisting of residential buildings. Despite being a private fabric, the courtyard space can be conceived as a collectively used area among different condominium units, similar to the courtyards found in Cerda's Eixample model in Barcelona.
Simultaneously, possible architectural solutions have been explored for one of the buildings, such as communal green roofs (of a more private nature compared to the courtyard) and facades adorned with vertical greenery. Currently, the courtyard is entirely paved and used for parking cars. The decision was made to initiate projects primarily oriented toward environmental and social development.

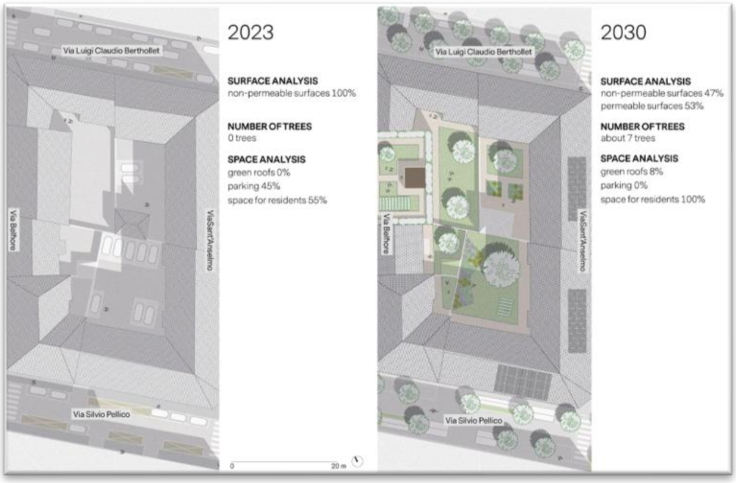


Fig.22 Before and after, project inner courtyard

The initial phase entailed the elimination of numerous existing parking spaces. The subsequent step involved introducing vegetation in the courtyards to create more evocative and healthful landscapes. Special attention was given to incorporating "rain gardens" to efficiently manage rainwater and enhance biodiversity, thereby creating a communal space for residents to foster social interactions (Fig.21). Once again, the prospect of "greening" the city stands to have a positive impact on inhabitants who, within an urban context, have limited opportunities for interpersonal engagement. This proposal poses a greater challenge, as while the public space project is managed by the municipality, the private sector faces more significant barriers, including economic and regulatory constraints (for example, if the building is subject to preservation restrictions). Nevertheless, the aim was to demonstrate how the application of NBS in architecture can contribute to the development of resilient and adaptive urban fabrics (fig. 22).

6. Conclusion

The analysis and experimentation conducted in the San Salvario neighborhood provide an opportunity to explore replicable nature-based approaches, demonstrating their suitability in dense Italian urban contexts and their contribution to increasing adaptability, improving urban quality, and promoting the values of the Agenda 2030 (SDG) and the New European Bauhaus. From quantitative data (expressed as a percentage before and after the intervention), it is evident that nature-based solutions, initially identified in the literature and subsequently implemented specifically in the three pilot cases, contribute to enhancing quality, resilience, and biodiversity. This demonstrates the feasibility of NBS even in high-density contexts through targeted interventions in public spaces and adjustments to internal mobility. From a biodiversity perspective, these initiatives transform sterile urban surfaces into ecological corridors, supporting pollinator life and promoting overall biodiversity. This aligns with the Biodiversity Strategy 2030 and the European Commission's "New Deal for Pollinators" initiative. Additionally, the increased vegetation and improved urban quality of communal spaces have a positive impact on the psychophysical well-being of the community, transforming the neighborhood into a dynamic space aligned with the concept of the "15-minute city." This not only contributes to creating a more cohesive society but also fosters a more vibrant urban economic dynamic. The experimentation has partially implemented the application of NBS within the context of the architectural project, prioritizing a greater focus on public spaces. This decision was guided by the concept that the city should ensure climate adaptation for the entire population through its communal areas. However, it is worth noting that some proposals initially directed at private residential buildings could offer replicable solutions in public structures or unrestricted settings (where volume and usage conversion are feasible, such as transforming pitched roofs into extensive/intensive green flat roofs) to provide green and communal spaces in highly densified and green-deprived environments. One of the inherent limitations of this study lies in the absence of a strategic adaptation plan, conceived as a comprehensive masterplan where various proposed projects can be synergistically integrated. Unlike other cities such as Copenhagen, which has developed a climate adaptation plan and a Strategic Flood Masterplan, or Barcelona with its "Green Axes" plan, Turin's climate resilience plan lacks an overarching masterplan to systematically guide the implementation of NBS, as seen, for example, in projects like Hans Tavsens Park or the Osterbro masterplan, integrating Sustainable Urban Drainage initiatives at the neighbourhood and urban levels. Therefore, from the perspective of urban planning and design, it becomes crucial not only to adhere to guidelines but also to develop an integrated strategic vision that connects green spaces, common assets, and private areas, coupled with a reduction in private mobility in the heart of the neighborhood, promoting an empathetic and participatory approach to urban design. Although the research has partly developed a quantitative analysis of surfaces transformed into public spaces, focusing on percentage values such as depaved and draining surfaces and the number of plants to be planted, future experiments could delve into the microclimatic impact through the use of software like Envi-met. Further studies could more comprehensively explore the ecosystemic and monetary values resulting from the application of nature-based solutions, employing dedicated software such as I-tree. As evidenced in Copenhagen's projects if Klimaquartier Østerbro, active citizen engagement proves to be pivotal, constituting a critical factor to be taken into account in subsequent initiatives. This participatory involvement is aimed at overseeing and fostering a sense of community as an integral part of the design process for communal spaces and their associated objectives. In the context of San Salvario, an inclusive approach should encompass grassroots participatory endeavors, akin to those undertaken by the "Largo al Giardino" group, advocating for the establishment of a green square and other public spaces.

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Image Sources

Fig.1 Barcelona Municipality, Urban Mobility Plan (https://www.bcnregional.com/).

Fig.2 Copenhagen-based architectural firm SLAhttps://www.sla.dk/en/.

Figg. 3-22 are elaborations by Giorgia Somale under the supervision of the authors.

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Toward a certification protocol for Positive Energy Districts (PED). A methodological proposal

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Abstract

To achieve the ambitious CO_2 emission reduction targets, set by the Sustainable Development Goals, it is crucial to act on cities. Cities are responsible for 67% of the world's primary energy consumption and about 70% of energy-related CO_2 emissions. To support the urban energy transition, a broad implementation of zero-emission districts or positive energy districts (PEDs) is expected. PEDs can be defined as energy-efficient and energy-flexible urban areas that aim to provide a surplus of clean energy to the city by using renewable energies. In developing the PEDs concept, it is necessary to consider not only the technical issue of energy systems but also the environmental, social, and economic spheres. To be effective, it is important to provide decision-makers with tools such as protocol certification for PEDs, which can effectively assess the complexity of the impacts a PEDs might have on other urban transformations from a multi-stakeholder perspective. LEED for neighborhood development, BREEAM communities, and CASBEE for cities are the most widely used and known protocols in the world for the evaluation of districts. Protocol certifications today do not consider PEDs because they are outdated, but some common characteristics can already be found within them, which allows for the possibility of reformulating scores and inserting new evaluation criteria. The aim of this research, through a review of the literature, is to analyze the current protocol certificates at the district level, identifying criteria and scores within the evaluation methods, with the aim of contributing to the definition of a PED certification protocol with effective criteria and scores to support design and development of PEDs.

Keywords

Positive Energy District; LEED Neighborhoods; BREEAM communities; CASBEE Urban Districts.

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1. Introduction

The International Energy Agency has placed great emphasis on reducing CO2 emissions in cities and related systems. Cities account for more than 50% of the global population, 80% of the global GDP, two-thirds of global energy consumption and more than 70% of annual global carbon emissions (IEA, 2020). These factors are expected to increase significantly in the coming decades: it is anticipated that by 2050 more than 70% of the world's population will live in cities(Aboagye & Sharifi, 2024), resulting in massive growth in demand for urban energy infrastructure (European Commission, 2021). Climate action in cities is essential to achieve the ambitious net-zero emissions goals(Gaglione, 2023). From this perspective, it is known that urban development in the coming years will have to shift from simple building solutions to positive-energy neighborhoods and districts (Becchio et al., 2020). All of this, along with other innovative concepts developed in the past for cities of the future, will be crucial to achieving the goals the United Nations have set for themselves in the areas of energy and climate change (Gargiulo et al., 2012; Suppa et al., 2022).

With the new perspective indicated at the World Economic Forum in 2015(Yin et al., 2022), research and innovation plan for the cities, aiming to vigorously address several global challenges that affect our cities and society: health and safety, digitization, energy, and climate change in the first place (Guarino et al., 2022). PEDs fall under this heading.

The area of Smart Cities & Communities was already defined as a priority and strategic by both the previous European Horizon 2020 program and the 17 Sustainable Development Goals established by the UN and the 2030 Agenda (Kroll et al., 2019). Over time, however, it became apparent that financing large smart city projects at the urban level was a complex task, with a huge demand for resources and investment. For this reason, the authors decided to focus efforts on smaller urban areas, such as city blocks, pilot districts and neighborhoods, towards a concept of a diffused smart land focusing initially on energy efficiency in buildings and on-site local renewable energy production(Guida & Martinelli, 2023). In recent years, to sustain the urban energy transition the concept became even more ambitious, from highly efficient buildings to net-zero ones(Lwasa et al., 2022; Niu & Zhang, 2023). Later on, by including energy sharing, waste heat recovery, e-mobility, and energy storage, the scope was broadened to include the implementation of net-zero districts or even better PEDs (Guarino et al., 2022). PEDs represent a new approach towards a sustainable and efficient city and urbanization model(EBC, 2022).

An urban Positive Energy District combines the built environment, mobility, sustainable production, and consumption to increase energy efficiency decrease greenhouse gas emissions and create added value for citizens(Bisello et al., 2024). Positive Energy Districts also require integration between buildings, users, and various energy networks, mobility services, and IT systems(Albert-Seifried et al., 2022).

Although the transformation of a neighborhood is beneficial to many stakeholders involved, points of agreement are not always found that make all projects sustainable and feasible(Fistola et al., 2023; Mazzeo, 2017). The concept of sustainability concerns the continuity of economic, social, and environmental aspects of human society and non-human environment, without compromising these aspects for future generations (Boschetto et al., 2022; Mazzola et al., 2017). A green building is a practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort (*EPA Green*, 2017). The awareness of the importance of green buildings and the effects of their energy efficiency are diffused from hundreds of kinds of certification systems around the world (Wangel et al., 2016).

In general, the role of these green assessment tools is the develop a system of measure for all the sustainability goals in a buildings/districts and more easily compare with current and past buildings/districts practices and other green buildings/districts(Volpatti et al., 2024).

The main thematic areas are energy, water, material use, indoor quality, and comfort: each area is evaluated on its net use; in other words, if the building produces or reuses resources, the evaluation is about its efficiencies and its percentage of reused, recycled or virgin materials (Boschetto et al., 2022).
Certification protocols have been introduced to give an evaluation based on a common set of criteria (Mazzola et al., 2017; Volpatti et al., 2024). PEDs need a protocol certificate that can enhance their potential, which, however, is not considered in the same way in current protocols.

1.2 Certification Protocols in the World for urban district.

Over the years, many certification protocols have been developed and constructed to assess the sustainability of neighborhoods. In general, they are all united by the definition of specific processes, criteria, and indicators, precisely because certification schemes for sustainable neighborhoods promise to provide guidance to urban development projects on how to work with sustainability issues in planning and development activities (Wangel et al., 2016). In addition, certification systems create a voluntary market engine, with the possibility of evaluating and marketing development projects as 'sustainable'(Mazzola et al., 2017).
Unlike principles, certification systems address the sustainability of an area using a predefined set of criteria and assessable indicators. In this way, they also provide a rather precise definition of sustainable development. The criteria, or credits gained for the criteria, are then aggregated, sometimes with a weighting, to provide a certificate, label and/or communicable grade (e.g., 'gold' or 'excellent') for the project (Wangel et al., 2016). The certificate, label and/or grade function as tools for benchmarking and marketing the sustainability of a specific urban development. However, the aggregation weighting and complexity of the tools make it difficult to understand what the result (vote or label) means in terms of what has been evaluated.
Furthermore, it can obscure the extent and ways in which urban development contributes to sustainability (Boschetto et al., 2022). Previous studies (Boschetto et al., 2022; Mazzola et al., 2017; Volpatti et al., 2024; Wangel et al., 2016) have reported a number of shortcomings of certification systems for neighborhoods and proposed new methods and criteria. However, these studies have mainly focused on the content of the protocols and criteria by incorporating new methods of criteria calculation.
Along the lines of previous work, with the aim of extending the analysis to PEDs and the type of structure of the certification protocol and indicators, we analyzed three of the world's best-known certification systems: LEED for Neighborhoods Development (LEED-ND); BREEAM Communities (BREEAM-C) and CASBEE for cities (CASBEE-UD).
This study differs from previous works because it analyses and discusses the existing certification protocols for urban districts, and about how sustainable development is defined in them, it aims to select common characteristics with the PEDs to identify new indicators that can be implemented and evaluate the PED with its salient features.

1.3 Complexity and Application of PED

Research all around the world is still struggling to find a unique definition for PEDs. From an energy-focused perspective, a PED is seen as an energy-self-sufficient and carbon-neutral urban district.
Indeed, positive energy means that energy districts also play an important role in producing excess energy using renewable energy sources and feeding it back into the grid (Bossi et al., 2020; Guarino et al., 2022).
However, widening the perspective, it is expected that PEDs will increase the quality of life in the cities, help achieve the COP21 goals, and improve European capabilities and knowledge to become a global model (Derkenbaeva et al., 2022).
Moreover, considering the keen interest of the European Commission to deliver at least 100 PEDs by 2050 and the current situation of the cities (Bossi et al., 2020), it is necessary to address this concept not only for new

areas of urban development and the construction of new buildings and neighborhoods but especially for the redevelopment of the existing building stock (Derkenbaeva et al., 2022).

The discussion on how and where to define the boundaries of these entities is still open and conclusions may differ depending on whether one considers physical limits and management aspects or those related to the overall energy balance and energy carriers, ranging therefore from local to regional scale (Bossi et al., 2020; Niu & Zhang, 2023).

The discussion also often starts from the local dimension of city blocks, up to the urban dimension. In this regard, some interesting research on existing tools to support decision-making toward climate neutrality in cities and districts has been already carried out (Suppa et al., 2022).

In an attempt for extreme simplification, it can be said that PEDs must strike an optimal balance between energy efficiency, energy flexibility, and local energy production in turn also achieving integrated sustainability based on environmental, economic, and social features (Guarino et al., 2022).

For PEDs several stakeholders such as cities and public bodies, industry and business, research and academia, citizens and civic society, private and professional stakeholders, and citizens play a central role in the energy transition. Satisfying outcomes of Positive Energy Buildings/Districts requires the involvement of a wide range of different stakeholders right from the beginning.

Therefore, increasing the knowledge of PEDs, public communication, dissemination, and public engagement among the public is vital (Bisello et al., 2017).

PEDs are also a complex system because people, buildings, cities, and mobility are all complex systems (Volpatti et al., 2024). We tried to find a definition in the literature that would explain why this complexity exists, the term "complexity" used by academics is a narrower concept than is employed by practitioners; in fact, certain context-related aspects that practitioners point to as being complex are identified by academics as complicated (Baccarini, D, 1996). This is because theoretical complexity focuses on emergence, uncertainty, nonlinearity, and interdependence among the elements present in a project. Purposes of this case study, we do not distinguish between the terms "complex" and "complicated" – following the common usage employed by several authors (Angelakoglou et al., 2019; Baccarini, D, 1996; Bottero et al., 2016).

Complexity will impact project goals and objectives, project planning and organization as well as staff recruitment requirements. Indicate that complexity in the project context has become the focus of attention for several reasons: it impacts the way the project is planned, executed, and controlled; it can hinder the identification of goals and objectives; it also influences how the project is organized as well as the skills required by workers; it can impact project objectives (scope, time, cost, risks, etc.).

According to (Baccarini, D, 1996), one definition of project complexity is that it consists "of many varied interrelated parts". He advocated implementing it in terms of the differentiation and interdependency of varied elements. In their paper (Baccarini, D, 1996), identified two dimensions of project complexity: structural complexity and uncertainty. In addition, structural complexity has two sub-dimensions: the number and interdependence of project elements, such as tasks, specialists, and components. He also proposed two sub-dimensions of the uncertainty dimension: uncertainty in goals and means (Baccarini, D, 1996).

Structural complexity is the easiest for practitioners and researchers to identify and increases with size, variety, breadth of scope, level of interdependence between people or tasks, pace, or variety of work to be done. Interdependence between people or tasks, pace, or variety of work to be done, number of locations and time slots, work to be done, the number of locations and time zones.

The existence of strict deadlines, e.g., closing of a construction site, or opening of an infrastructure, is a source of complexity because it leads to an increase in the pace of work and stress of the people involved.

2 Certification protocol's analysis for PED

2.1 Methodology

The objective of this research is to adapt the current urban scale procedures to enable their use in evaluating potential Positive Energy Districts developed within the project. Comprehensive acquaintance with the internal needs of different protocols and the crucial attributes of PEDs is requisite for this analysis.

For these reasons, the methodology shown in Figure 1 is introduced. The diagram illustrates how the internal criteria of various urban rating systems are analyzed and strategies and scores concerning PEDs are incorporated. This results in a modified protocol that takes PEDs into account.

In particular, the proposed methodology for revising sustainability certification protocols on an urban scale comprises five steps:

- Conduct an internal analysis of the existing protocols to identify the PED strategies already in place.
- Definition of a new criterion to include within the protocol, based on the strategies previously outlined. This will ensure that the criterion meets diverse protocol requirements, as different systems have varying internal strategies.
- Definition of the internal scores within each protocol that are related to PEDs or not, thus obtaining the division between PED scores (p_{PED}) and non-PED scores (p_{nPED}).
- Creation of the new credit score, now referred to as P_{nc}. The narrative can be constructed in two different ways:
  - Reducing the p_{PED} score by a fixed $\%_{nc}$ percentage to maintain balance in the protocol's evaluation. The $\%_{nc}$ varies for each protocol depending on the total credits of p_{tot} and the p_{PED} score. It will use the next formula to determine the erosion of the points from p_{PED}:

    $$P_{nc} = p_{PED} \times \%_{nc}$$

  - reducing the p_{nPED} score by a fixed percentage, to increase the value of the new protocol's PED score:

    $$P_{nc} = p_{nPED} \times \%_{nc}$$

- Redefine the new scores of the other internal criterion according to the formulas below in the order previously used, while ensuring that the new criterion will not alter the total score of the entire protocol:

$$P_{ic} = p_{iPED} \times (1 - \%_{nc})$$
$$P_{ic} = p_{inPED} \times (1 - \%_{nc})$$

2.2 Methodology application

In this paper, the methodology outlined above is applied to three distinct protocols at the urban level: LEED for Neighborhood Development, BREEAM Communities and CASBEE Communities.

Starting with one of the most widely used certification systems in the world for its simplicity of understanding, USGBC launched LEED in 2000. Since its inception, LEED has grown to encompass more than 16,000 projects in the USA and more than 30 countries (*LEED. "Checklist: LEED Neighborhood Development.,"* 2023).

This tool promotes sustainable building and development practices through a suite of reporting and recognizes projects which are committed to better environmental and health performance (Bisello et al., 2020). LEED intends to encourage all cities to measure and improve performance, focusing on outcomes from ongoing sustainability efforts (Karner et al., 2017).

To leverage a globally consistent method of performance measurement for a streamlined and data-based pathway to LEED certification for cities (Arabi et al., 2018). The U.S. Green Building Council (USGBC), the Congress for the New Urbanism (CNU), and the Natural Resources Defense Council (NRDC)—organizations that represent leading design professionals, progressive builders and developers, and the environmental community—have collaborated to design a rating system for neighborhood planning and development based on the combined principles of smart growth, New Urbanism, and green infrastructure and building. The goal of this partnership is to establish a national leadership standard for assessing and rewarding environmentally superior green neighborhood development practices within the framework of the LEED® Green Building Rating System™. The result of their effort was named LEED-ND (Arabi et al., 2018).

The LEED-ND criteria for sustainable neighborhoods in cities are cited in (*LEED. "Checklist: LEED Neighborhood Development.,"* 2023).

The second important certification protocol is BREEAM. Was initially introduced in 1990; BREEAM was the world's first environmental assessment method for new building designs (Arabi et al., 2018). It uses a balanced scorecard approach with tradable credits to enable the market to decide how to achieve optimum environmental performance for the project. BREEAM has now come a long and it is now employed on a global scale. The subjects in this manual fall into five assessment categories which are contemplated through suitable criteria (BREEAM, 2014). Classifying sustainability issues is hard to come by, as they often influence all three aspects of sustainability (social, environmental, and economic). The goal of BREEAM is to shed light on the intention of each issue by evaluating categories. A sixth category promotes innovation which shows the importance of it. The categories are as follows with a brief description of their overall goals: Governance (GO): Promotes the involvement of the community in decision-making regarding the development comes under the influence of the design, construction, and operation. Social and economic well-being (SE): Contemplates societal and economic factors that influence health and well-being such as sufficient housing and availability of employment. Resources and energy (RE): Address the sustainable use of natural resources and the reduction of carbon emissions. Land use and ecology (LE): Encourages sustainable land use and ecological enhancement. Transport and movement (TM): Address the design and provision of transportation and movement infrastructure to promote the use of sustainable means of transportation.

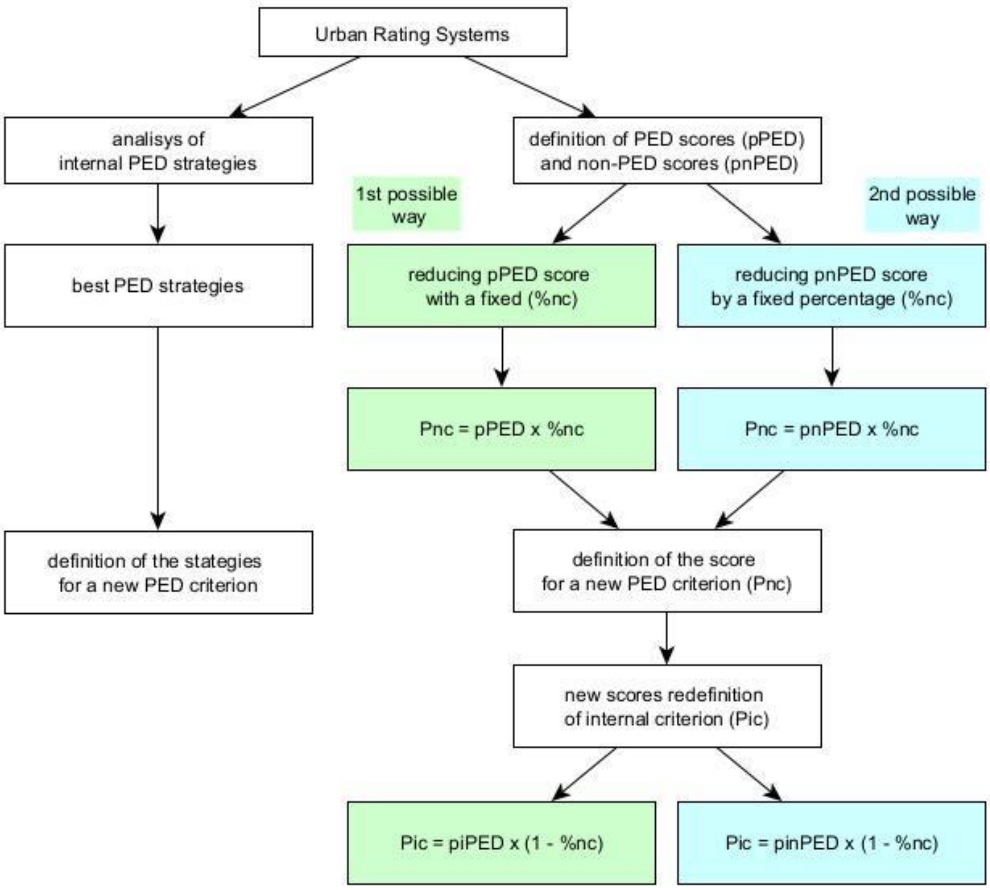

Fig.1 Proposed methodology scheme. In green and sky blue the two possible ways

Innovation (Inn): Promotes employing innovative solutions in the rating where they help obtain environmental, social, and/or economic benefit in a way that is not looked at elsewhere in the scheme. BREEAM aims to ensure that its standards provide social and economic benefits whilst ameliorating the environmental impacts of the built environment (BREEAM, 2014). As a result, BREEAM is especially likely to put a value on developments according to their sustainability benefits (Wangel et al., 2016).
BREEAM highlights the issues and opportunities that bring about a revolution in development at the earliest stage of the design process.
The rating system addresses major environmental, social, and economic sustainability objectives that have an impact on large-scale development projects (Mazzola et al., 2017).
The latest certification system studied is the most widely used throughout Asia and is the CASBEE, this acronymous means Comprehensive Assessment System for Built Environment Efficiency. Is a method for assessing and scoring the environmental performance of buildings and the built environment. CASBEE was introduced by a research committee established in 2001 through the collaboration of academia, industry, and national and local governments, which established the Japan Sustainable Building Consortium (JSBC) under the auspice of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (Arabi et al., 2018). CASBEE for urban development is a tool for assessment of comprehensive area development projects including a group of buildings (*CASBEE for Cities v.2015*, n.d.). CASBEE follows the triple bottom lines concept, which is one of the important frameworks for the assessment and identification of sustainability through the three classifications of environment, society, and economy.
Following the points of the methodology seen above, the results obtained are presented.
All strategies outlined in the protocols concerning Positive Energy Districts (PEDs) were initially identified. This enabled us to ascertain their respective strengths and weaknesses. The ensuing picture presents a comparison between the internal demands of the protocols and the core characteristics of the PEDs. The right-hand column details which parts are absent from each protocol and therefore require implementation through the definition of new criteria. In this way, it is possible to define the new adapted criterion for each protocol that is analyzed. Consequently, the scores for PED (p_{PED}) and non-PED (p_{nPED}) were determined by segregating criteria that involved PEDs from those that did not. Table 4 below reveals the outcomes.

3. Results

Before revising the protocols according to the characteristics of PEDs, by modifying their internal scores and inserting the new criterion, it was necessary to assume for p_{nc} a target weight of the latter, considered in this case to be 5 points. The two methods defined in the previous paragraph were then used, to obtain those 5 points, taking the percentage $\%_{nc}$ as 6 for the first method and 30 for the second. The following tables show the new scores calculated in this way, comparing the two methods. Note that in the first case, only the scores of the criterion that already contain PED characteristics are modified, unlike in the second case, where the criterion that does not concern PEDs are modified.
Method 1: $P_{nc} = p_{PED} \times \%_{nc}$ percentage I want to reserve for the new credit equal to 7%
Method 2: $P_{nc} = p_{nPED} \times \%_{nc}$ percentage I want to reserve for the new credit equal to 30%

$$P_{ic} = p_{iPED} \times (1 - \%_{nc})$$
$$P_{ic} = p_{inPED} \times (1 - \%_{nc})$$

In Table 5, we can see the results with method 1 and 2 for the LEED ND protocol certificate for PED with the inclusion of a new criterion encompassing all criteria identified before. As we can see from the percentage values of the breakdown of the different selected criteria that correspond with the characteristics of the PEDs, it can be seen that the Neighborhood Pattern & Design section has been largely downgraded, but despite this

being its impact in percentage terms the most important, in the redistribution of percentage points for its credits, both the M1 and M2 allocation methods take on great importance as an evaluation section.
With regard to the macro-criterion Smart location and linkage and green infrastructures and buildings remained virtually unchanged in numerical terms despite the subtraction of some criteria that were found to be inappropriate in the analysis of the PED characteristics. The new credit in this case would be 5.6% under the M1 method and 6% under the M2 method.
The difference would be 0.4%, which allows us to say at first glance that it would still be a difference of half a point at the overall level of the valuation but would have a significant impact.
In Table 6, we can see the results with method 1 and 2 for the BREEAM communities protocol certificate for PED with the inclusion of a new criterion encompassing all criteria identified before. As can be seen from the percentage values of the distribution of the various selected criteria corresponding to the PEDs characteristics, it can be seen that with the M1 method, the macro-criteria were all lowered almost uniformly and despite this, the impact in percentage point redistribution assumes great importance as an evaluation section. With the M2 method, the macro-criteria were lowered unevenly, and despite this, the difference with respect to M2 deviates in favour of existing credits by 0.3%. At the macro level, the difference is negligible, but if one analyses the values of the criteria, one realizes how the percentage composition changes. In fact, looking at the values using the M2 method, the criteria resources and ecology, and transport and movement, both increase by almost 1.5%, but all the other macro-criteria fall. The new credit in this case would be 5.75% with the M1 method and 5.46% with the M2 method.
In Table 7, we can see the results with method 1 and 2 for the CASBEE for cities protocol certificate for PED with the inclusion of a new criterion encompassing all criteria identified before.
As can be seen from the percentage values of the distribution of the various selected criteria corresponding to the characteristics of the DPEs, it can be seen that with the M1 method, the macro-criteria were all equalised at 31% for all three macro-criteria. With the M2 method, the macrocriteria were lowered almost uniformly and the difference to M1 is almost 2 % points in its favour. The new credit in this case would be 5.23% with the M1 method and 7.57% with the M2 method. It can be seen that it is an emblematic case in this protocol to use the M2 method, as it differs from LEED-ND by 2.10 % and from BREEAM CM by 1.5 %.
As far as the method 1 and 2 is concerned, we can start from the limits of the calculation where a further analysis should be to obtain whole numbers for LEED credits; however, it remains necessary to pay attention to the rounding that is done.

4. Conclusion and future developments

Cities and new districts must be sustainable, especially in economic, environmental, and social aspects. In view of the latest data on climate change and emissions in the urban environment, the IEA and the EU have developed the concept of positive energy districts (PEDs), defined as urban districts with zero net annual energy imports and zero net CO2 emissions that produce an excess of renewable energy production integrated into an urban energy system. Being a new concept, the first projects and realizations are emerging but cannot be evaluated through defined parameters and/or current certification systems. In this context, urban rating systems can help due to their internal quantitative structures (criteria and parameters) despite the fact that they do not consider the added value of PEDs. Therefore, in this research, an attempt was made to identify PED-like parameters and criteria within the three main protocols (LEED-ND; BREEAM-CM; CASBEE-UD). The assimilation of these new criteria to be implemented collected into a single criterion allowed us to identify a score that could ensure that these urban districts could be evaluated taking into account the added value of being PED. The proposed methodology in fact has the peculiarity of being able to be implemented by variables and constants regardless of the numerical value.

This allowed us to choose constant values and to make a comparison between the different certification systems by normalizing the values of all the systems to 100, reshaping the partial value of each criterion as a percentage.

A conclusion we can make about the two methods is that both allow them to be modified, to be replicated and adapted to the context according to the weight the evaluator deems appropriate. On the other hand, being a methodology based on formulas that require a consequentiality, it allows us to compare both the three certification models with each other by seeing which fields of interest are most analyzed, and with respect to projects that are evaluated using only one methodology.

Furthermore, it makes it possible to identify the weights that the different certification protocols give to the different fields of application. In this sense, compared to the criteria contained in the original protocols, compared to the criteria selected and considered similar to the PEDs criteria, a change in these weights can be seen in all three methods. It is noticeable that in the BREEAM communities the social-economic part is sacrificed a great deal in the reassignment of the criteria for the PED egg credit, whereas we find a slight alignment with the original value for the other two protocol certificates.

The analysis carried out revealed that they could be implemented with criteria that would bring out the additional qualities of PEDs.

However, some limitations of the methodology encountered are noted below:

- When reducing initial scores to obtain space for new criteria, it is necessary to use percentages and define new scores with at least one decimal point. This applies even to protocols such as LEED, which typically only use whole values for internal credits.
- It may be possible to address the aforementioned issue by implementing a rounding factor. However, this would result in fluctuations of the total score of the protocol, as the approximations can be either higher or lower.
- The methodology used could also be valid for other protocol variations, not necessarily only for PED. The methodology used could also be valid for other urban-scale protocols. Only three protocols were used in the application but could be extended to others.

Another possible direction of research could be not to insert a new criterion, but to evaluate the individual PED-defined criterion at the beginning of the methodology and force their PED characteristics or add new requirements to them (e.g., for the credit of renewables, insert that these are connected in a CER, and so on). Alternatively, I could also have evaluated the inclusion of a PED prerequisite, without which it is not possible to gain access to certification, or, without which it will also not be possible to obtain the PED label when obtaining certification, as is already the case, for example, for energy certifications in Italy, which can have a classification up to A4, but only with certain characteristics do they obtain the definition of NZEB. Possibility of giving a higher score to the new PED credit (we assumed 5, but it is possible to give a higher or lower amount. As far as the PEDs certification protocol is concerned, we can consider it a valid system that would give value to the quality of PEDs. Surely further studies on this subject could help the scientific community to solve this lack of tools in this regard.

A future development would certainly be the inclusion of partial criteria values and a redistribution of values in order to truly value a PED over other types of urban districts.

LEED v4 for Neighborhood Development Plan for PED			Criterion correspondent	Specific Aspects of the PED Framework	New criterion for LEED-ND
N°	**Smart Location & Linkage**	**23**		**Energy**	**New criterion**
1	Preferred Locations	10	16, 17, 18, 24,26	Energy efficiency	
2	Access to Quality Transit	7	24, 25	Energy flexibility	
3	Bicycle Facilities	2		Energy surplus, producing more energy than consumed	Energy surplus, producing more energy than consumed
4	Housing and Jobs Proximity	3			
			16, 17, 18, 24,26	Nearly zero energy buildings and net-zero energy districts	
5	Site Design for Habitat or Wetland and Water Body Conservation	1			
	Neighborhood Pattern & Design	**31**	13, 16, 17, 24, 25,	Energy production	
6	Walkable Streets	9			
			17, 24, 25,	Local, regional, and european energy systems and networks	
7	Mixed-Use Neighborhoods	4			
8	Housing Types and Affordability	7		**Urban and local development, real estate**	
9	Connected and Open Community	2			
			3,5,10,	Technological solutions	
10	Transportation Demand Management	2			
11	Access to Civic & Public Space	1	12	Sector coupling and cross-sectorial integration	
12	Community Outreach and Involvement	2		New business models, the future role of „citizen energy communities"(CEC) and „renewable energy communities" (REC)	New business model for PED, CEC,REC
13	Local Food Production	1			
14	Tree-lined and Shaded Streetscapes	2			
			9, 12, 15,	Active involvement of problem owners and citizens	
15	Neighborhood Schools	1			
	Green Infrastructure & Buildings	**26**			
			12, 17,	urban areas or groups of connected buildings	
16	Certified Green Buildings	5			
17	Optimize Building Energy Performance	2			
			18	Existing building stock is main challenge to achieving climate neutrality	
18	Building Reuse	1			
19	Indoor Water Use Reduction	1			
			18,	Resilience and security of energy supply	Resilience and security of energy supply
20	Outdoor Water Use Reduction	2			
21	Rainwater Management	4		**Infrastructure**	
22	Heat Island Reduction	1	5, 14, 19, 20, 21, 22	Green and blue infrastructures are important building blocks for climate change adaption strategies on the district and neighborhood level	
23	Solar Orientation	1	2, 3, 6, 7, 10, 14	Developing the role of mobility in the PED Reference Framework	
24	Renewable Energy Production	3			
25	District Heating and Cooling	2		**People**	
26	Infrastructure Energy Efficiency	1	8,9,	inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	
27	Wastewater Management	2			
28	Light Pollution Reduction	1		quality of life	quality of life
	PROJECT TOTALS (Certification estimates)	**80**	9, 12	Regulatory sandboxes, living labs, and testing environments	

Tab.1 Certification protocol LEED-ND with criterion selected that described PED characteristic at the left of the grey column, and the right in red new evaluation criteria that should be implemented in the overall evaluation in order to stick to the key points that represent a PED

N°	BREEAMS Communities for PED	
N°	**Governance**	**7**
1	Consultation and engagement	3.5
2	Design review	2.3
3	Community management of facilities	1.2
	Social and economic well-being	**33.2**
4	Economic impact	8.9
5	Demographic needs and priorities	2.7
6	Flood Risk Assessment	1.8
7	Noise pollution	1.8
8	Housing provision	2.7
9	Delivery of services, facilities, and amenities	2.7
10	Public realm	2.7
11	Microclimate	1.8
12	Utilities	0.9
13	Adapting to climate change	2.7
14	Green infrastructure	1.8
15	Inclusive design	1.8
16	Light pollution	0.9
	Resources and ecology	**21.7**
17	Energy strategy	4.1
18	Existing buildings and infrastructure	2.7
19	Water strategy	2.7
20	Sustainable buildings	4.1
21	Low impact materials	2.7
22	Resource efficiency	2.7
23	Transport carbon emissions	2.7
	Land use and ecology	**6.4**
24	Ecology strategy	3.2
25	Land use	2.1
26	Rainwater harvesting	1.1
	Transport and movement	**11.7**
27	Transport assessment	3.2
28	Safe and appealing streets	3.2
29	Cycling network	2.1
30	Access to public transport	2.1
31	Cycling facilities	1.1
	PROJECT TOTALS (Certification estimates)	**80**

Criterion correspondent	Specific Aspects of the PED Framework	A new criterion for BREEAMS Communities
	Energy	**New criterion**
3, 17, 20, 21, 22, 24	Energy efficiency	
13, 17	Energy flexibility	Energy flexibility
17	Energy surplus, producing more energy than consumed	Energy surplus, producing more energy than consumed
13, 17, 20, 22	Nearly zero energy buildings and net-zero energy districts	
13, 16, 17, 24, 25,	Energy production	Energy production
17, 20, 24	Local, regional, and european energy systems and networks	
	Urban and local development, real estate	
12, 15, 17, 20	Technological solutions	
3, 12, 15, 27	Sector coupling and cross-sectorial integration	
	New business models, the future role of „citizen energy communities‟ (CEC) and „renewable energy communities‟ (REC)	New business model for PED, CEC,REC
8, 10,	Active involvement of problem owners and citizens	
10, 18, 20,	urban areas or groups of connected buildings	
18, 20, 22,	Existing building stock is main challenge to achieving climate neutrality	
22	Resilience and security of energy supply	Resilience and security of energy supply
	Infrastructure	
6, 11, 13, 14, 17, 18, 19, 20, 22, 24, 25, 26,	Green and blue infrastructures are important building blocks for climate change adaption strategies on the district and neighborhood level	
7, 17, 23, 27, 28, 29, 30, 31	Developing the role of mobility in the PED Reference Framework	
	People	
1, 2, 3, 4, 5,	inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	
5	quality of life	
1, 5	Regulatory sandboxes, living labs, and testing environments	

Tab.2 Certification protocol BREEAM for Communities with criterion selected that described PED characteristic at the left of the grey column, and at the right in red new evaluation criteria that should be implemented in the overall evaluation to stick to the key points that represent a PED

CASBEE Urban District for PED			Criterion correspondent	Specific Aspects of the PED Framework	A new Criterion for CASBEE Urban District
N°	**Q1 - Environment**	**22.92**		**Energy**	**New criterion**
1	Rainwater utilization	1.39	1, 4, 5, 6, 7, 9	Energy efficiency	
2	Reduction of rainwater discharge amount: Rainwater permeable surfaces and equipment	0.7	27	Energy flexibility	
3	In-area resource circulation	1.39		Energy surplus, producing more energy than consumed	Energy surplus, producing more energy than consumed
4	Ground greening	2.78	4, 5, 6, 7, 9	Nearly zero energy buildings and net-zero energy districts	
5	Rooftop greening	1.39			
6	Wall greening	1.39	7,	Energy production	Technological system for energy production
7	Natural resources	1.39		Local, regional, and european energy systems and networks	
8	Landform	1.39			
9	Environmentally considerate buildings	11.1		**Urban and local development, real estate**	
	Q2 - Society	**29.62**		Technological solutions	Technological solutions
10	Compliance	5.56			
11	Area management	5.56	9, 27	Sector coupling and cross-sectorial integration	
12	Disaster prevention of various infrastructures	0.92		New business models, the future role of „citizen energy communities" (CEC) and „renewable energy communities" (REC)	New business model for PED, CEC,REC
13	Disaster prevention vacant space and evacuation route	0.92			
14	Continuity of business and life in the block	0.92	11, 27,	Active involvement of problem owners and citizens	
15	Traffic safety	3.7			
16	Crime prevention	3.7	12, 17,	urban areas or groups of connected buildings	
17	Convenience	2.78			
18	History and Culture	2.78	18	Existing building stock is main challenge to achieving climate neutrality	
19	Consideration for the formation of townscape and landscape	1.39			
20	Harmonization with the periphery	1.39	18,	Resilience and security of energy supply	Resilience and security of energy supply
	Q3 - Economy	**22.24**			
21	The development of traffic facilities: level of roads etc.	1.39		**Infrastructure**	
22	Usability of public transportation	1.39	1, 2, 3, 4, 5, 6, 7	Green and blue infrastructures are important building blocks for climate change adaption strategies on the district and neighborhood level	
23	Logistics management	2.78	21, 22, 23, 28	Developing the role of mobility in the PED Reference Framework	
24	Consistency with and complementing upper-level planning	2.78			
25	Non-housing	5.56		**People**	
26	Block management	2.78	11, 20, 25, 27, 28	inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	
27	Possibility to make demand/supply system smart	2.78			
28	Updatability and expandability	2.78		quality of life	quality of life
	PROJECT TOTALS (Certification estimates)	**74.78**	18, 19, 20	Regulatory sandboxes, living labs, and testing environments	

Tab.3 Certification protocol BREEAM for Communities with criteria selected that described PED characteristics at the left of the grey column, and at the right in red new evaluation criteria that should be implemented in the overall evaluation to stick to the key points that represent a PED

	LEED for Neighborhood Development Plan	BREEAM Communities	CASBEE Urban District
p_{PED}	80	82,1	74,78
p_{nPED}	20	18,2	25,24
p_{tot}	100	100,3	100,02

Tab.4 Results were obtained by differentiating internal criteria from protocols based on their involvement or non-involvement in PED strategies

LEED v4 for Neighborhood Development Plan		M1	M2
average pPED		80	80
average pnPED		20	20
new value criteria		5,6	6
Smart Location & Linkage		26,39	26,5
Credit	Preferred Locations	9,30	10,0
Credit	Brownfield Remediation	2,00	1,4
Credit	Access to Quality Transit	6,51	7,0
Credit	Bicycle Facilities	1,86	2,0
Credit	Housing and Jobs Proximity	2,79	3,0
Credit	Steep Slope Protection	1,00	0,7
Credit	Site Design for Habitat or Wetland and Water Body Conservation	0,93	1,0
Credit	Restoration of Habitat or Wetlands and Water Bodies	1,00	0,7
Credit	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1,00	0,7
Neighborhood Pattern & Design		38,83	38,0
Credit	Walkable Streets	8,37	9,0
Credit	Compact Development	6,00	4,2
Credit	Mixed-Use Neighborhoods	3,72	4,0
Credit	Housing Types and Affordability	6,51	7,0
Credit	Reduced Parking Footprint	1,00	0,7
Credit	Connected and Open Community	1,86	2,0
Credit	Transit Facilities	1,00	0,7
Credit	Transportation Demand Management	1,86	2,0
Credit	Access to Civic & Public Space	1,00	0,7
Credit	Access to Recreation Facilities	1,00	0,7
Credit	Visitability and Universal Design	0,93	1,0
Credit	Community Outreach and Involvement	1,86	2,0
Credit	Local Food Production	0,93	1,0
Credit	Tree-Lined and Shaded Streetscapes	1,86	2,0
Credit	Neighborhood Schools	0,93	1,0
Green Infrastructure & Buildings		29,18	29,5
Credit	Certified Green Buildings	4,65	5,0
Credit	Optimize Building Energy Performance	1,86	2,0
Credit	Indoor Water Use Reduction	0,93	1,0
Credit	Outdoor Water Use Reduction	1,86	2,0
Credit	Building Reuse	0,93	1,0
Credit	Historic Resource Preservation and Adaptive Reuse	2,00	1,4
Credit	Minimized Site Disturbance	1,00	0,7
Credit	Rainwater Management	3,72	4,0
Credit	Heat Island Reduction	0,93	1,0
Credit	Solar Orientation	0,93	1,0
Credit	Renewable Energy Production	2,79	3,0
Credit	District Heating and Cooling	1,86	2,0
Credit	Infrastructure Energy Efficiency	0,93	1,0
Credit	Wastewater Management	1,86	2,0
Credit	Recycled and Reused Infrastructure	1,00	0,7
Credit	Solid Waste Management	1,00	0,7
Credit	Light Pollution Reduction	0,93	1,0
Positive Energy District		5,60	6,0
Credit	Positive Energy District	5,60	6,0
PROJECT TOTALS (Certification estimates)		100,0	100,0

Tab.5 Certification protocol LEED-ND for PED with new evaluation criteria that should be implemented in the overall evaluation to represent a PED

							M1	M2
			BREEAM communities				**M1**	**M2**
			average pPED				82,1	82,1
STEP			average pnPED				18,2	18,2
1	2	3	new value criteria				5,75	5,46
1	2	1			Governance		8,81	8,61
1			GO	0,1		Consultation plan	2,30	1,61
	1		GO	0,2		Consultation and engagement	3,26	3,5
	1		GO	0,3		Design review	2,14	2,3
		1	GO	0,4		Community management of facilities	1,12	1,2
4	9	4			Social and economic wellbeing		40,38	39,85
1			SE	0,1		Economic impact	8,28	8,9
1			SE	0,2		Demographic needs and priorities	2,51	2,7
1			SE	0,3		Flood Risk Assessment	1,67	1,8
1			SE	0,4		Noise pollution	1,67	1,8
	1		SE	0,5		Housing provision	2,51	2,7
	1		SE	0,6		Delivery of services, facilities and amenities	2,51	2,7
	1		SE	0,7		Public realm	2,51	2,7
	1		SE	0,8		Microclimate	1,67	1,8
	1		SE	0,9		Utilities	0,84	0,9
	1		SE	10		Adapting to climate change	2,51	2,7
	1		SE	11		Green infrastructure	1,67	1,8
	1		SE	12		Local parking	0,90	0,63
	1		SE	13		Flood risk management	1,80	1,26
		1	SE	14		Local vernacular	0,90	0,63
		1	SE	15		Inclusive design	1,67	1,8
		1	SE	16		Light pollution	0,84	0,9
		1	SE	17		Training and skills	5,90	4,13
3	0	4			Resources and ecology		20,18	21,7
1			RE	0,1		Energy strategy	3,81	4,1
1			RE	0,2		Existing buildings and infrastructure	2,51	2,7
1			RE	0,3		Water strategy	2,51	2,7
		1	RE	0,4		Sustainable buildings	3,81	4,1
		1	RE	0,5		Low impact materials	2,51	2,7
		1	RE	0,6		Resource efficiency	2,51	2,7
		1	RE	0,7		Transport carbon emissions	2,51	2,7
2	3	1			Land use and ecology		12,35	10,88
1			LE	0,1		Ecology strategy	2,98	3,2
1			LE	0,2		Land use	1,95	2,1
	1		LE	0,3		Water pollution	1,10	0,77
	1		LE	0,4		Enhancement of ecological value	3,20	2,24
	1		LE	0,5		Landscape	2,10	1,47
		1	LE	0,6		Rainwater harvesting	1,02	1,1
1	3	2			Transport and movement		12,83	13,8
1			TM	0,1		Transport assessment	2,98	3,2
	1		TM	0,2		Safe and appealing streets	2,98	3,2
	1		TM	0,3		Cycling network	1,95	2,1
	1		TM	0,4		Access to public transport	1,95	2,1
		1	TM	0,5		Cycling facilities	1,02	1,1
		1	TM	0,6		Public transport facilities	1,95	2,1
0	0	0			Positive Energy District		5,75	5,46
						Positive Energy District	5,75	5,46
11	17	12			PROJECT TOTALS (Certification estimates)		100,3	100,3

Tab.6 Certification protocol BREEAM communities for PED with new evaluation criteria that should be implemented in the overall evaluation in order to represent a PED

CASBEE For cities		M1	M2
average pPED		74,78	74,78
average pnPED		25,24	25,24
new value criteria		5,23	7,57
Q1 - Environment		**31,7556**	**30,228**
Credit	Rain water utilization	1,29	1,39
Credit	Treated water	1,39	0,97
Credit	Reduction of sewage discharge amount	1,39	0,97
Credit	Reduction of rain water discharge amount: Capacity of detention pond	0,7	0,49
Credit	Reduction of rain water discharge amount: Rain water permeable surfaces and equipment	0,65	0,70
Credit	Wood material	1,39	0,97
Credit	Recycled material	1,39	0,97
Credit	Garbage separation	1,39	0,97
Credit	In-area resource circulation	1,29	1,39
Credit	Ground greening	2,59	2,78
Credit	Rooftop greening	1,29	1,39
Credit	Wall greening	1,29	1,39
Credit	Natural resources	1,29	1,39
Credit	Landform	1,29	1,39
Credit	Patch (planar) quality: Habitat space of species	0,7	0,49
Credit	Patch (planar) quality: Consideration for regionality	0,7	0,49
Credit	Corridor (network) quality	1,39	0,97
Credit	Environmentally considerate buildings	10,32	11,10
Q2 - Society		**31,2266**	**32,196**
Credit	Compliance	5,17	5,56
Credit	Area management	5,17	5,56
Credit	Understanding of hazard map	0,92	0,64
Credit	Disaster prevention of various infrastructures	0,86	0,92
Credit	Disaster prevention vacant space and evacuation route	0,86	0,92
Credit	Continuity of business and life in the block	0,86	0,92
Credit	Traffic safety	3,44	3,70
Credit	Crime prevention	3,44	3,70
Credit	Convenience	2,59	2,78
Credit	Distance to medical, health/welfare facilities	0,92	0,64
Credit	Distance to educational facilities	0,92	0,64
Credit	Distance to cultural facilities	0,92	0,64
Credit	History and culture	2,59	2,78
Credit	Consideration for formation of townscape and landscape	1,29	1,39
Credit	Harmonization with the periphery	1,29	1,39
Q3 - Economy		**31,8032**	**30,024**
Credit	The development of traffic facilities: level of roads etc.	1,29	1,39
Credit	Usability of public transportation	1,29	1,39
Credit	Logistics management	2,59	2,78
Credit	Consistency with and complementing upper level planning	2,59	2,78
Credit	Utilization level of standard floor area ratio	2,78	1,95
Credit	Handling of brownfield site	0	0,00
Credit	Inhabitant population	2,78	1,95
Credit	Staying population	2,78	1,95
Credit	Housing	0	0,00
Credit	Non-housing	5,17	5,56
Credit	Information service performance	2,78	1,95
Credit	Block management	2,59	2,78
Credit	Possibility to make demand/supply system smart	2,59	2,78
Credit	Updatability and expandability	2,59	2,78
Positive Energy District		**5,23**	**7,57**
	Positive Energy District	5,23	7,57
PROJECT TOTALS (Certification estimates)		**100,02**	**100,02**

Tab.7 Certification protocol CASBEE for cities for PED with new evaluation criteria that should be implemented in the overall evaluation in order to represent a PED

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From the lagoon-city to the lagoon of adaptive cities

Methodological approach to support trans-municipal and multilevel governance for climate adaptation in the Venice lagoon

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Abstract
The impacts of climate change and the increasing occurrence of consequent extreme events in recent years have led to significant environmental, social and economic consequences in a fragile and highly vulnerable territory such as Venice. It is precisely in this perspective, which considers areas particularly vulnerable to the effects of climate, that the scientific research program Venezia2021, coordinated by CORILA - Consortium for Coordination of Research Activities concerning the Venice lagoon system, is inserted. The research in question involves a complex process of identification and integration of innovative tools, data processing and analysis and assessment of impacts, in order to contribute to the maintenance of a proper balance of the lagoon ecosystem in a perspective of increased climate resilience. The overall objective of the research was to build a strategic, accurate and shared vision with respect to the challenges that await the preservation of the city and its lagoon, (a World Heritage Site), in consideration of climate change scenarios. Specifically, this paper analyzes the research experience of thematic axis No. 5 that led to the drafting of the Climate Change Adaptation Plan for the Venice Lagoon. The operational path that led to the construction of the plan was guided by an in-depth spatial study and development of an integrated system of analysis, assessment, planning, management and monitoring of the Venetian area capable of supporting the city and the activities that operate in it, through coordinated adaptation actions aimed at increasing sustainability and resilience as a whole.

Keywords
Climate change; Spatial planning; Innovation; Climate adaptation; Fragile territories.

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1. Introduction

The impacts of climate change in recent years have widely manifested their effects on different aspects, ranging from hydrogeological risk, overheating in urban areas (UHI), coastal and lagoon defense issues, and deterioration of historic buildings (EEA, 2017). In addition, there has been an increasing occurrence of extreme weather events, especially affecting Italian coastal areas and cities (Spano et al., 2020).

These events have caused significant losses in social, economic, environmental, and tangible and intangible cultural heritage (SNPA, 2021). One of these coastal hotspots is precisely the territory of the metropolitan city of Venice, which is historically recognized as a fragile and highly vulnerable territory (Bassan et al., 1997; Gasparoli et al., 2014; Menegazzo, 2018).

In a scenario of climate change, the management of the fragility of this environment will have increasing environmental, social, and, above all, economic consequences that, if not adequately managed, may severely affect the development of economic activities and the well-being of citizens. In this context, the scientific research program Venezia2021, coordinated by CORILA - Consortium for Coordination of Research Activities concerning the Venice Lagoon system - and financed by the Provveditorato alle OO. PP. del Triveneto, as part of the works for safeguarding Venice and the lagoon, has been included.

With the conclusion of the construction of MOSE, a major experiment, never conducted elsewhere at this scale, related to the management of a large "regulated" lagoon begins.

The scientific research, which started in 2018 and ended at the end of 2022, was intended to accompany the testing phase of the tidal regulation works, assessing their impacts, environmental, social, and economic from a sustainability perspective. It aimed to develop, in a short time, an accurate and shared strategic vision concerning the challenges that await the preservation of the city and its lagoon, a world heritage site, in consideration of climate change scenarios.

CORILA coordinated the scientific community in conducting the research, organized around five themes, to establish an effective interdisciplinary dialogue and develop every possible synergy:

- Topic 1: Lagoon interfaces: exchanges with sea and drainage basin;
- Topic 2: Sediments, chemical pollution and interaction with lagoon organisms;
- Topic 3: Lagoon aquatic forms, habitats and communities;
- Topic 4: Ecological connectivity and ecosystem services;
- Topic 5: Climate change and adaptation strategies for safeguarding the cultural heritage of Venice and its lagoon.

The research program also set out to provide strategic directions for climate change adaptation useful to the Venice Lagoon and to provide a complex and integrated portfolio of observation and data processing tools to ensure protection for the natural ecological functioning of the lagoon while safeguarding the benefits of society (ecosystem services) provided by the lagoon itself.

Within *Venice2021*, Research Line 5.3 “Climate Change Adaptation Plan and Implementation of Intervention Strategies to Safeguard the Architectural Heritage” focused on the development of an integrated system of analysis, assessment, planning, management, and monitoring of the Venetian area and its historical, artistic and cultural heritage, capable of supporting the city and the activities that operate in it, through coordinated adaptation actions aimed at increasing sustainability and resilience as a whole.

Therefore, develop methodologies and approaches capable of capturing climate change-induced changes and consequently prepare actions aimed at adaptation, impact mitigation and risk prevention in a *Climate Change Adaptation Plan for the Venice Lagoon*.

The work presented here will also enable greater awareness of local governments concerning adaptation, thus helping to convert the approach of spatial planning from sectoral-individual to holistic-integral-shared.

2. Materials and methods

Setting up actions and measures aimed at adaptation required in-depth study and analysis of the reference context to ensure suitable choices concerning the specificities and priorities of the territories.
Knowledge of the geographical context is essential to adopt tools such as suitable strategies or actions. The Guide prepared by the National Plan for Adaptation to Climate Change (PNACC, 2017a), outlined the basic steps for the identification of climate adaptation actions and proposed an ordered sequence of "methods" that can be used at each stage of the process: from the initial ones related to climate studies, the identification of vulnerabilities and the involvement of the most affected actors, as well as the reconnaissance and study of existing Plans to identify any measures already planned (PNACC, 2017b; Zucaro et al., 2018) (Figure 1).

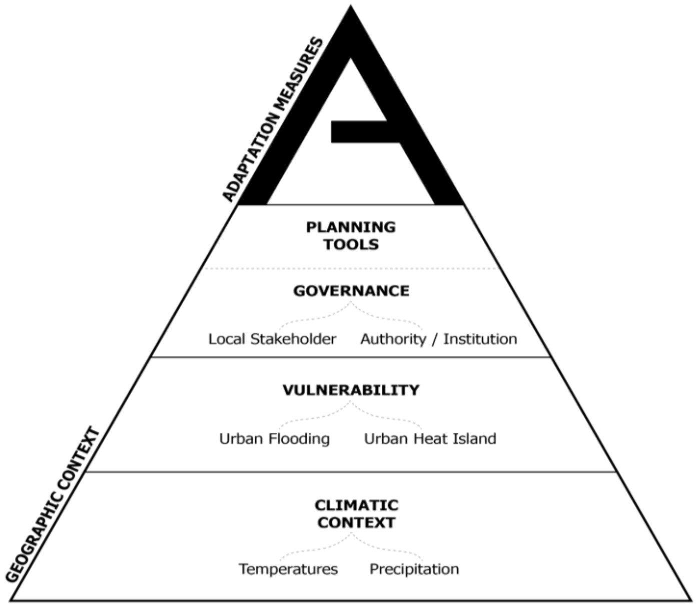

Fig.1 Methodological scheme for the identification of useful materials for research

2.1 Geographic context: identification of possible impacts attributable to climate change

The definition of the area under research considered the boundaries of the last existing lagoon boundary, decreed in 1990 by the Ministry of Public Works. This delimitation includes the inlets of San Niccolò, Malamocco, Chioggia, and the island of Sant'Erasmo. It was deemed appropriate to add a buffer area of 1 km inland (mainland) to consider the spatial system as a whole and more correctly identify possible impacts attributable to climate change. Such delimitation is important both to enable the development of an inter-municipal adaptation strategy and because of the need for a governance system that can respond effectively to the needs of each administrative entity. The (11) municipalities selected for the study are Venice, Campagna Lupia, Cavallino-Treporti, Chioggia, Dolo, Jesolo, Marcon, Mira, Musile di Piave, Quarto D'altino, and San Donà di Piave (fig. 2). The materials useful for research and later explicated focus on this identified area.
The area being researched, included in the territory of the Metropolitan City of Venice, is largely occupied by the Venice Lagoon, one of the largest and most important coastal ecosystems in Europe, and with an arrangement characterized by continuous change.

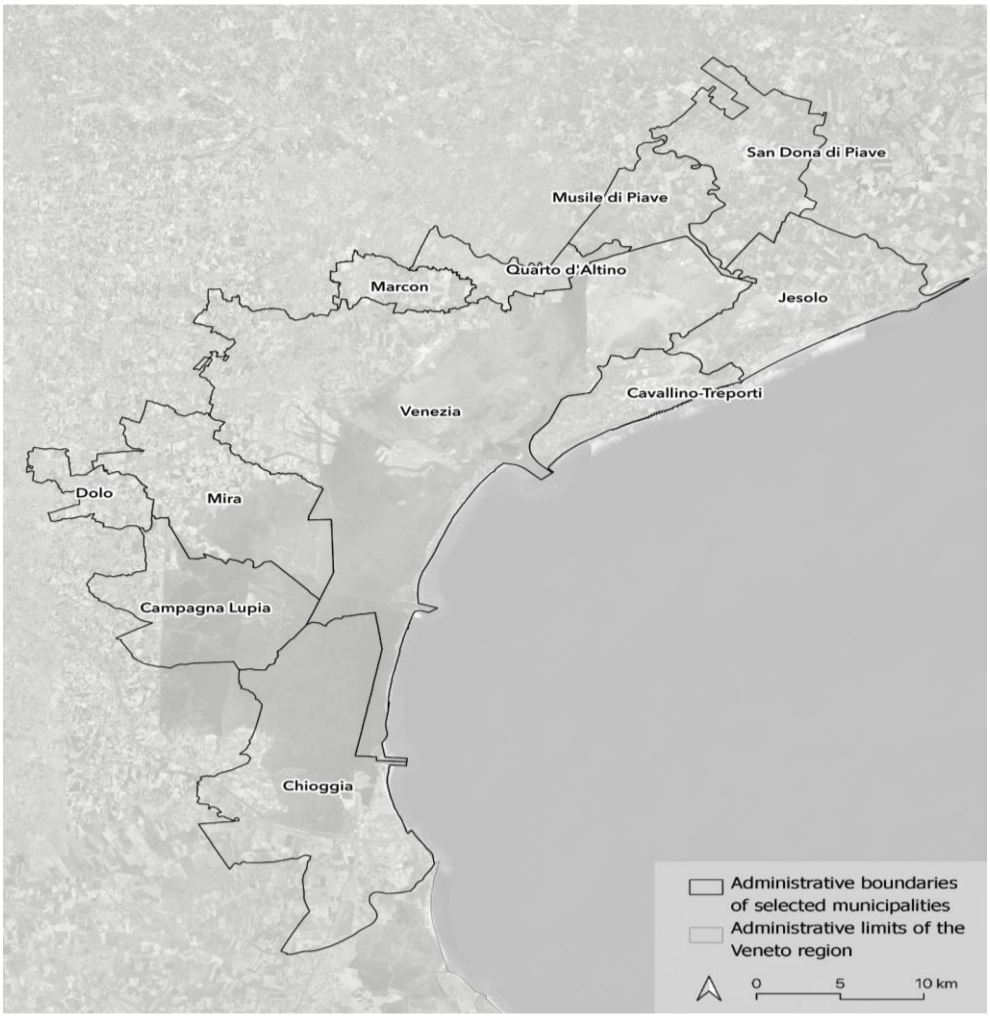

Fig.2 Study area map

2.2 Climate context: tailoring optimal choices for the specificities of territories

From the climatic point of view, as has happened in much of Europe, significant changes have occurred in Veneto and the area of the Metropolitan City of Venice over the past 70 years: the Region is positioned in a transition zone between the continental area of Central Europe and the Mediterranean area, presenting peculiar characteristics resulting from the mitigating action of the Adriatic Sea and the influence of the Alpine chain. In particular, the territory of the Metropolitan City of Venice has two major zones, one coastal and one inland, with different climatic characteristics. According to the PNACC, the territory falls into two of the six climate macroregions:

– Macro-region 1 - Prealps and Northern Apennines, characterized by intermediate values for cumulative winter and summer precipitation values and high values, compared to the other areas, for extreme precipitation events (R20 and R95p).
– Macro-region 2 - Po Valley, upper Adriatic and coastal areas of central-southern Italy, characterized by the highest number, compared to all other areas, of days, on average, above the threshold selected to classify summer days (29.2°C) and at the same time by high average temperatures (PNACC, 2017).

Regarding the analysis of temperatures in the Veneto region, the 1993-2021 mean reference values collected by ARPAV, over the whole territory show increasing temperature values between 0.5 and 1.5 °C. Average daily mean temperatures in 2022 show values everywhere over the region that are higher than the 1993-2021 average (fig. 3). These differences are generally between 0.7 °C and 1.9 °C (ARPAV, 2022). The analysis records a trend of increasing average temperatures, particularly in the autumn period (CMCC, 2021).

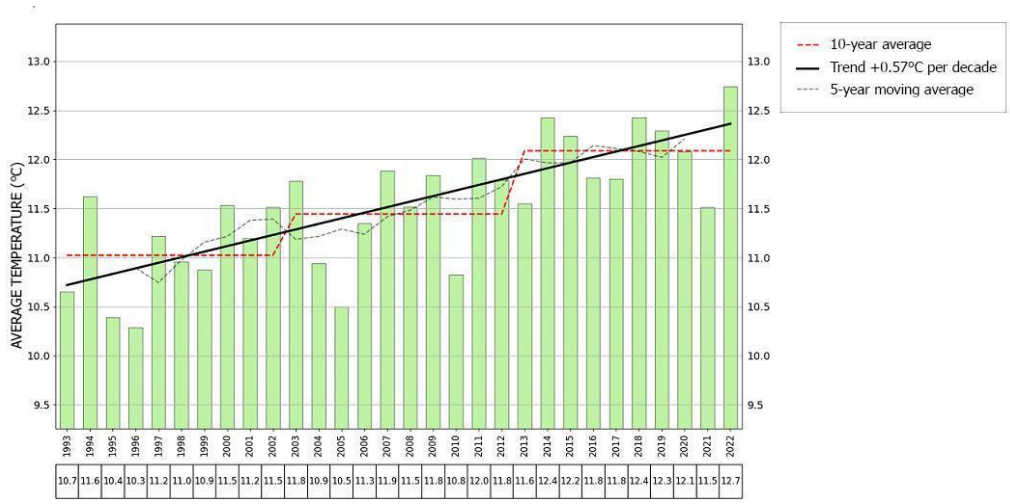

Fig.3 Average temperature in Veneto from 1993 to 2022

Concerning precipitation, if the trend in Veneto in the years from 1955 to 2004 showed a slight downward trend in annual and winter events, an increase in autumn precipitation is reported in the Region, with significant instances of increases over the annual maximum values of short-lived precipitation.

Nonetheless, compared to the temperature and precipitation data, statistics on extreme events are more limited, an intensification of their frequency also emerges in the Venice Lagoon area, in the form of heat waves, increased precipitation intensity, strong winds and tornadoes. About intense rainfall, there is a greater number of events in the 2003-2012 decade than in the 1993-2001 decade (fig. 4) especially for those of short duration, both in terms of increased frequency and intensity (ARPAV, 2022).

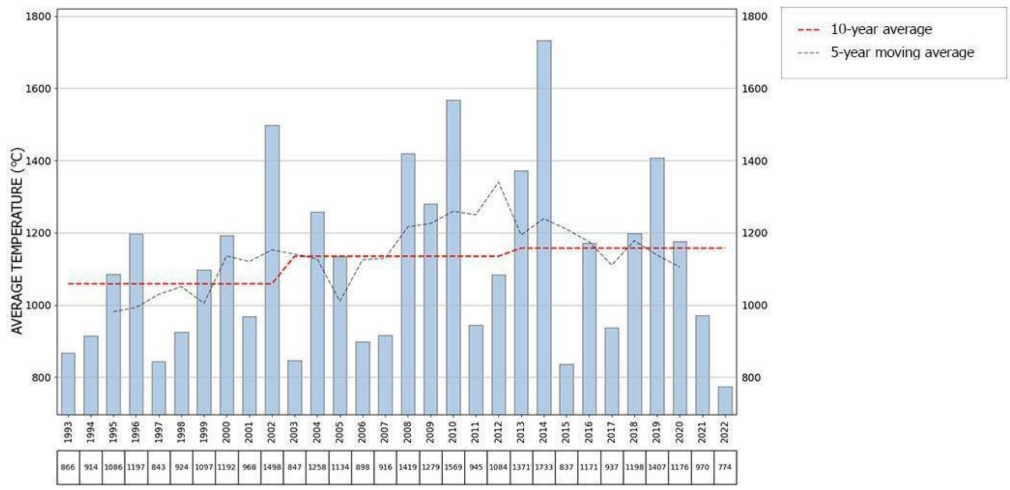

Fig.4 Average rainfall in Veneto from 1993 to 2022

2.3 Stakeholders and governance: involving different actors in the development of adaptation processes

Regarding the aforementioned climate conditions, the analysis of governance, aimed to highlight the sectors, specific tasks and competencies of each municipal structure regarding the issue of climate change and the territorial repercussions it has in environmental, social, economic, and political terms. In addition to institutional governance, an attempt was also made to schematize the system of stakeholders present within the communities, i.e., that complex and extremely diverse multiplicity of stakeholders who are involved and can be involved in the development of adaptation processes (Magni et al., 2021).

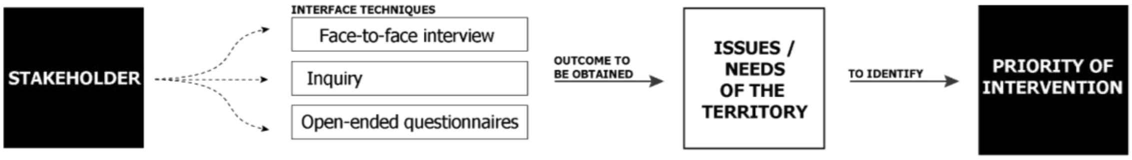

Fig.5 Reconnaissance scheme of interviews to identify problems, needs, and priorities for action

The involvement of stakeholders and other strategic parties had positive effects on the research, as broad cooperation was demonstrated through the availability and expertise of officials and managers from the technical areas of the municipalities themselves. The instrument used during the meetings (fig. 5) was that of the open, discursive interview, characterized by considerable flexibility, which allowed more information to be gleaned, simply by directing the reflections toward insights useful to the study, aimed at highlighting and clarifying the system of relationships, which only partly emerged from the prior stage of stakeholder reconnaissance.

The outcome of the meetings thus allowed for the verification and co-definition of administrative structures (fig. 6), their internal connections, but also the system of external relations, particularly through the referral of locally active stakeholders, such as trade associations and citizens' groups (which only direct knowledge of the territory can allow). In addition, the interviews provided information on:

- perceptions of the Entity for climate change risks;
- existence of norms or measures attributable to adaptation contained in municipal plans already adopted;
- socioeconomic characteristics of the local productive fabric also tying them to the presence of monitoring, carried out following extreme weather situations, to quantify the damage.

2.4 Planning tools and regulatory references: identifying measures already planned for climate change impacts

The first part of the work focused on the analysis of the vulnerabilities of the lagoon, on reconnaissance and study of the Plans in force (PNACC, 2017), to identify any measures already planned for the impacts of climate change and capable of supporting adaptation and mainstreaming measures.

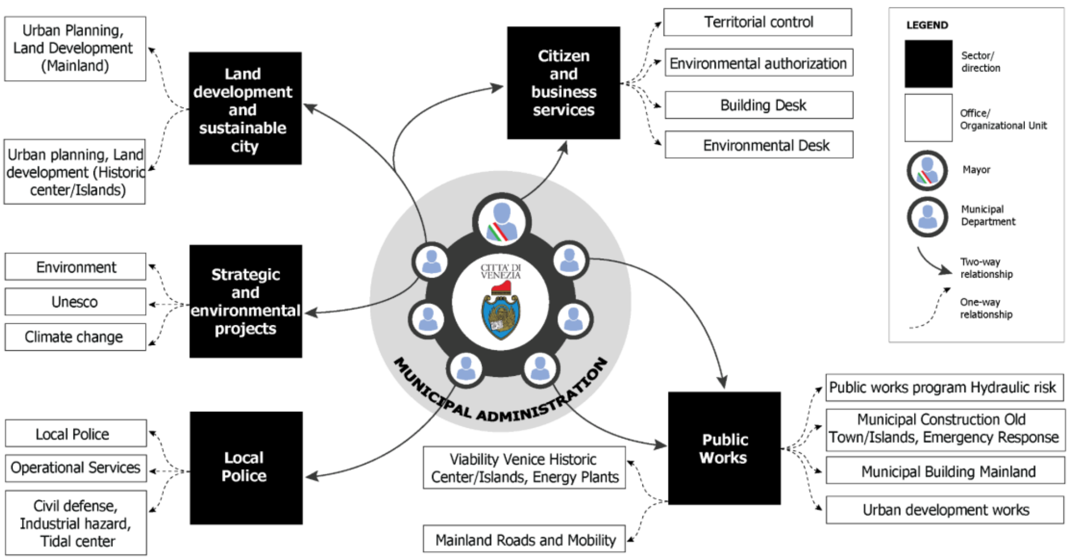

Fig.6 Stakeholder identification scheme. Example related to the Municipality of Venice

Given the inherent complexity of the Venetian context, this phase of the study also included the analysis of the present European regulations and projects, to comprehensively identify the totality of the overall forecasts of the lagoon eaves. It then moved on to a phase of data and information retrieval on environmental-climatic, socio-economic and relational aspects of governance, through various tools, made available by municipal, provincial and regional public administrations, as well as by trade associations, Chamber of Commerce of Venice and Rovigo and other sources, including territorial information systems and geo-portals. At the same time, a review of the scientific literature related to the different types of the most widely used adaptation measures (Laukkonen et al., 2009; Jabareen, 2013; Magni et al., 2019; Maragno et al., 2022) was initiated, preparatory to the drafting of the project framework (including an abacus of actions, measures and policies). The research also focused on the study of existing planning instruments and the regional regulatory environment to gain a systematic and broader understanding of the area's awareness in dealing with the concept of adaptation to Climate Change (Annex 1).

2.5 Spatial vulnerabilities: criticality and perception to understand the main socio-economic and spatial sectors exposed to impacts

The study of environmental and climatic aspects in a territorial context characterized by events of a calamitous nature has been particularly focused on certain impacts, which better than others represent elements of vulnerability and risk. This was carried out to provide information that is fundamental to understanding which major socio-economic and territorial sectors are exposed to impacts.

The cognitive framework on the impacts, vulnerabilities and risks induced by climate change on the Venice lagoon and its metropolitan city to support the initial environmental analyses useful for the definition of the climate change adaptation plan were derived from Research Line 5.2 “Impacts, vulnerabilities and risks induced by climate change”. The methodology developed in Research Line 5.2 provided an estimate of the risks induced by the multiple impacts of climate change such as urban flooding (Urban Flooding - UF) and heat waves (Urban Heat Island). By the methodologies proposed by Maragno et al., (2021), the approach proposed in Research Line 5.2 uses a geo-database that integrates a set of morphological-environmental indicators and estimates surface runoff coefficients related to flooding and urban heat island causes.

The territory of the lagoon contermination is particularly fragile and vulnerable to flooding of river bodies (too much water) and droughts (too little water), as shown with a progressive trend in recent years (CMCC, 2021). The study of climate dynamics in recent years, together with the analysis of extreme weather events that have occurred in the territory, confirm the intensification in terms of frequency and intensity, of extreme events of this type (peaks of large amounts of water and almost absolute absence) (ISPRA, 2022; Giuda et al., 2022). Awareness of territorial fragility, manifested by the increase in unaccustomed extreme phenomena, is leading to a radical change of approach in addressing the issue and the multiple impacts on the territory (Fritzsche et al., 2014). The study conducted on urban flooding (UF) phenomena for each municipality was taken into greater consideration based on a common perception of criticality (extreme weather events, flooding, overflows...). In consideration of the analyses performed, and confirmed of the meetings with the municipalities, recent tangible disasters in the studied territories play a decisive role in the perception of the phenomena. For these reasons, special attention was paid to the analysis of the vulnerability of impacts from UF. The phenomenon of urban flooding is the most perceived in the territorial context of the lagoon eaves. The issue of water, as already anticipated, has a twofold characterization: on the one hand the concentrated excess of water, and on the other hand the prolonged absence of water.

Flooding and drought are two sides of the same coin with which Venetian municipalities will increasingly have to interface. The phenomenon of water runoff from urban areas is one of the main issues related to flood risk.

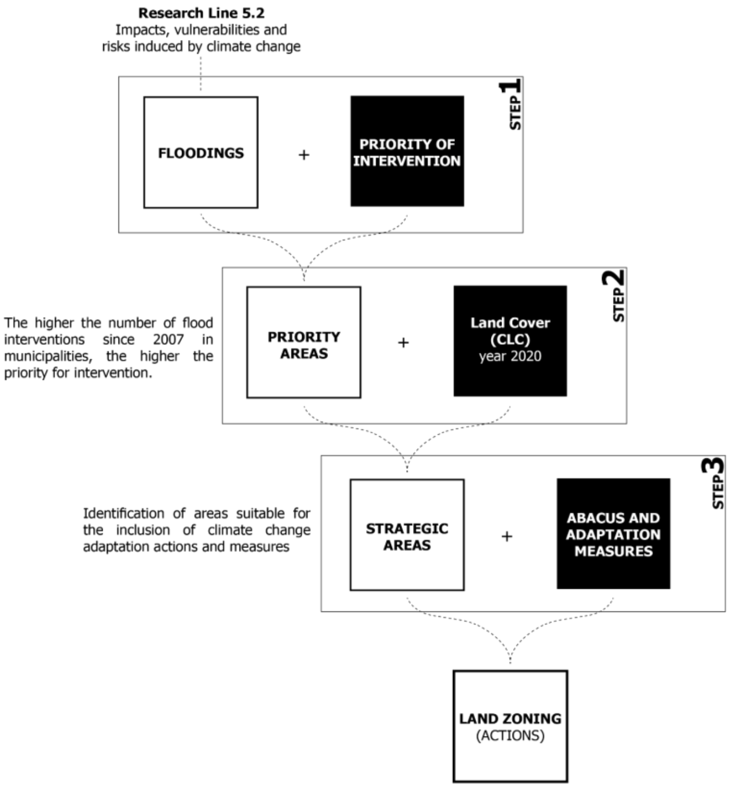

Fig.7 Methodological scheme for identifying areas suitable for the inclusion of climate change adaptation actions and measures

The issues arise from the degree of impermeability, where in natural environments stormwater is washed and filtered slowly to and through the soil, while in urban environments impermeable surfaces promote rapid runoff to receptor bodies (ISPRA, 2014; Arnbjerg-Nielsen et al., 2013). Climate change, therefore, places urban drainage systems in inefficient conditions during extreme weather events, and the problem takes priority as extreme rainfall events are expected to intensify (Lerer et al., 2015).

To reduce urban flooding and protect surface and groundwater quality, runoff must be limited and pollutant loads from urban run-off reduced. This research proposes an analysis of the main shock and stress factors related to flooding phenomena affecting the 11 municipalities of the lagoon eaves.

The study in question was conducted by Research Line 5.2 “Impacts, vulnerabilities and risks induced by climate change”, returning to the chronological study of post-event safety interventions. In this sense, the presence of an inherent fragility in the territory is emphasized regardless of the severity of the verified phenomenon. The level of information acquired refers to reports received by the Fire Department since 2007. The information, originally collected in a punctual manner, recording place and date of intervention, was synthesized using a geo-database, through the arrangement of a regular hexagonal mesh with 600 m side. The result shows a count of interventions distributed over each mesh portion.

The territory subject to the greatest vulnerability was divided into classes (5) representing the priority of intervention (fig. 7: step 1). Thus, the result was based on the intervention count distributed over each portion of the mesh about the intervention priority (the higher the number of flood interventions since 2007 in the eave municipalities, the higher the intervention priority). The methodology subsequently used to identify areas suitable for the inclusion of adaptation actions and measures made use of the use of the Land Cover map referring to the year 2020 and in particular to the III level of detail of the same map (fig. 7: step 2).

A macro-class of actions was associated with each level of detail, based on both priority level and soil prerogatives, to obtain the zoning of the territory (fig. 7: step 3).

3. Results

3.1 Identification of adaptation actions and measures about the specific socio-economic and morphological vocations of the territory

The analysis of the Lagoon and the metropolitan city of Venice that occurred in the first part of this work and the delineation of a large-scale cognitive framework made it easier to define adaptation measures for the specific socio-economic and morphological vocations of the territory. Adaptation must necessarily have as its starting point the needs of the territory in which climate change will produce its effects.
The abacus constructed within the project (fig. 8) proposed a series of measures that can be identified and selected according to the specific need required, such as the socio-economic implications or the impact to which it is called to respond. This synoptic framework will be able to facilitate municipal engineers and public administrators in adopting measures that can adapt their territories to the urgency of responding adaptively to the weather and climate changes that are increasingly affecting Venice and its lagoon. The abacus can be interrogated according to the territory's specific needs, as the zoning classification to which the specific measure can be fine-tuned is also present. Other suggestions are also present, such as limitations/benefits that the specific measure presents, whether it is a temporary or fixed measure and even the SDGs to which they respond. These will be able to best direct administrators and technicians in identifying the measures best suited to the needs presented by the territories.
The abacus intends to spatialize the measures identified in a place according to multiple factors, such as socio-economic implications (which include susceptible households, insufficient average disposable income per capita, low housing quality, etc.), impact to which it responds, expected effect, typology (i.e. green, grey, blue or policy-related measures) and characteristic, i.e. whether they are physical or organizational measures.
Socio-economic exposure translates, especially in urban environments, into a decreased capacity to respond and resilience to shock and stress situations. Adaptation, by its very nature, must necessarily refer to the localized needs in the area where climate change will produce its effects, for these reasons, to make it easy to define adaptation measures for the specific vocations and morphologies of each area, specific measures suitable for the local level are identified from the Abacus of Climate Change Adaptation Actions and Measures, to direct municipal technicians to adopt the most suitable measure for the prerogative of the area.

3.2 Spatial declination of adaptation for the Venice Lagoon area: the territorialization of plan measures

Considering the now scientific consensus that adaptation must necessarily refer to the localized needs in the territory where climate change is producing and will produce its effects, to make it easy to define adaptation measures for the specific vocations and morphologies of each area, specific measures suitable for the local level (Salata et al., 2016) were identified by the Abaco, to direct the technicians of the municipalities to adopt the one most suitable for the territorial emergency.
Following the study of adaptation actions and measures, we moved on to the identification of areas suitable for their inclusion, thus constructing specific zoning based on the morphological characteristics of the lagoon eaves and the system of the Metropolitan City of Venice. Adaptation to climate change begins with a city's ability to respond adequately to environmental shocks and stresses (Maragno et al., 2021).
The macro-classes of actions identified are:

- Typology 1: Urban Furniture (Nebulization, Drinking water fountains, Water basins, Water squares);
- Typology 2: Communication and Awareness - being organizational actions, thus interventions that do not involve spatial modifications, no mapping entries were planned - (App development, Early warning systems, Widespread speakers in the City, Promoting meetings on sustainable climate issues, Technical skills development);

- Typology 3: Risk Management (Breakwaters, Groynes, Private floodgates, Protection walls, Upgrading existing water pumps, Raising power packs for water pumps, Lightning guards, Gates to protect against storm surges, Reef reinforcement, Nourishment of emerged and submerged beach);
- Typology 4: Water Management (Permeable portions in areas used for parking, Draining asphalts, Stormwater collection in underground siphon, Stormwater collection in external siphon, Leaky or infiltration wells, Filter trenches, Infiltration and bioretention basins, Detention basins, SuDS in street environment, Construction of buffer strips, Restoration of floodplains);
- Typology 5: Urban Greening (Tree-lined boulevards, Lowland woodlands, Urban gardens, Climatic facade, Depaving, Intensive green roofs, Practicable green roofs, Productive green roofs, Extensive green roofs, Green roofs on canopies, Functional connectivity of ecological networks);
- Typology 6: Coastal Protection (Vegetating dunes, Covering dunes, Screen dunes, Establish marine protected reserves);

Typology 7: Cold Surfaces (Increase albedo of the road surface).

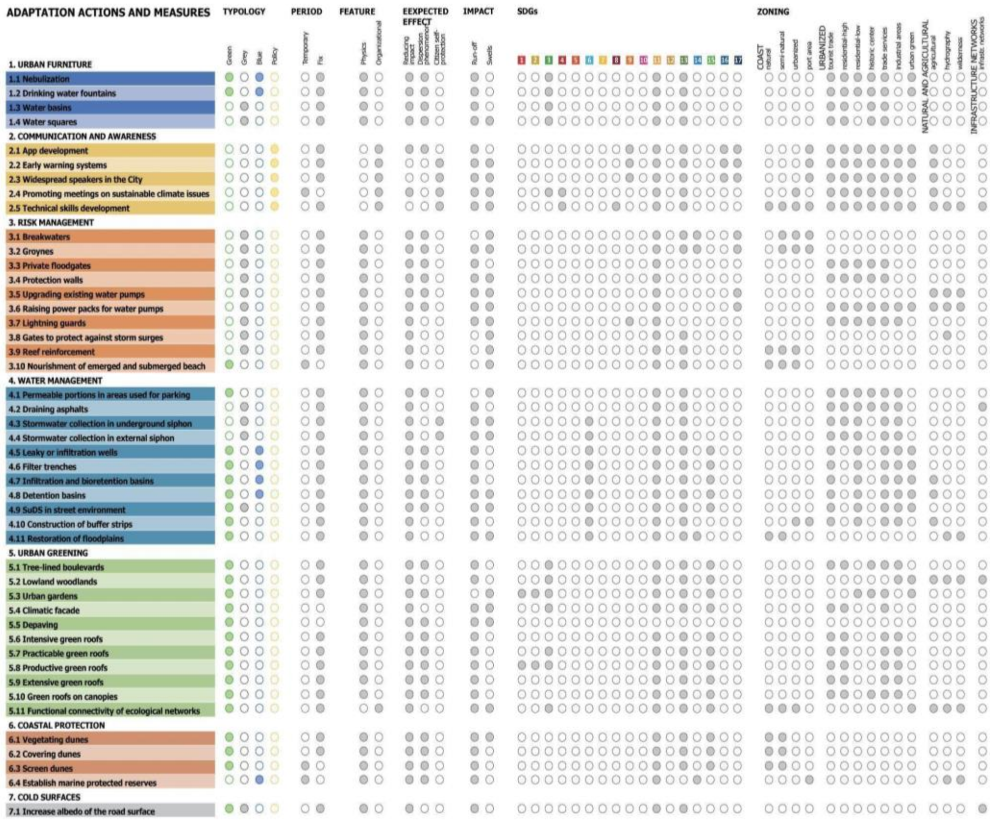

Fig. 8 Summary diagrams of adaptation actions and measures

4. Discussions

The research process that led to the drafting of the Adaptation Plan was moved by a consideration/assumption made explicit from the outset: that urban planning and the dynamics of territorial government must confront the now inevitable consequences due to climate change.

This work inevitably orients in the direction of the quality and improvement of the population's living conditions the change that local governments that insist on and relate to the Venice Lagoon are now called upon to face. The adaptation plan has clearly and directly outlined what the future involvement of urban planning processes will have to be, both of a single local scale and of an integrated system of lagoon matrix, the latter being levels

where land-government initiatives have so far neglected (or left to voluntary and punctual actions) the relationship between climate and land-use planning.
However, the initiatives implemented in recent years, despite confirming a stance by some actors to want to take new paths, have not led to adequate policy responses, both in qualitative (types of tools and policies) and quantitative terms (extension of involvement to the population or the main local and supra-local economic systems). As elucidated in the presented article, the methodology employed in the work serves as a replicable support system for diverse multi-scale and multi-level contexts. Particularly apt for expansive yet fragmented governance environments, this methodology shares the commonality of impacts and underscores the need for a unified framework in integrated management. Furthermore, the actions proposed in section 3.2 are measures strategically designed to seamlessly integrate and update existing urban planning tools.

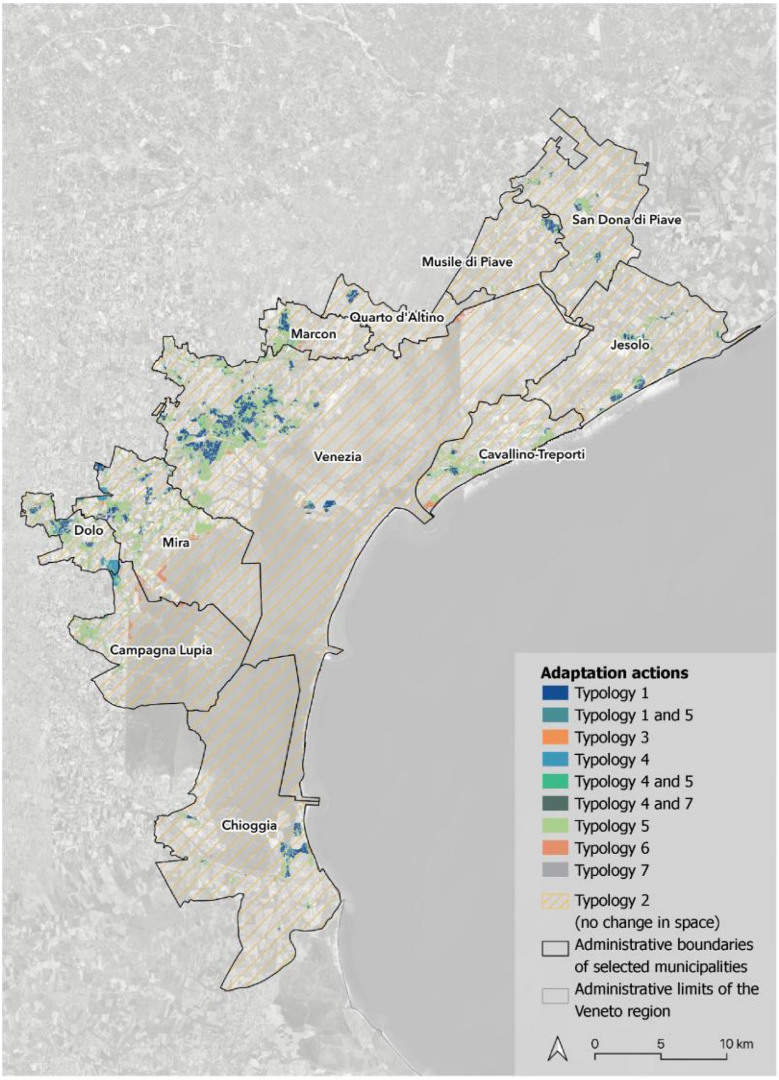

Fig.9 Zoning related to the identification of areas suitable for the inclusion of climate change adaptation actions and measures

Notably, these actions are tailored to prevent overburdening governance structures and eschew the creation of entirely new instruments, fostering a pragmatic and sustainable approach. Among the findings highlighted by this research for the initiatives of the lagoon gutter administrations is certainly the recognition of the need to overcome the specificity of partial planning, exclusively aimed at energy consumption, often without a real relationship to binding urban planning. The main reasons for this can be traced to a lack of public and shared awareness of climate variability and its spatial repercussions, a delayed response to climate disasters due to a lack of capacity and resources, and a lack of public policies and regulations in urban and environmental planning designed to manage climate change. However, if one casts one's gaze beyond these limitations, one can then recognize the potential that resides within the territory of the Metropolitan City of Venice: the latter, thanks to its broad thematic experience and its increasing role in supporting local climate planning processes, can help reduce the causes of climate change (mitigation) and to effectively protect itself from expected local impacts (adaptation).

5. Conclusions

The Adaptation Plan designed within the Research Pathway "Venice 2021 - Scientific Research Program for a Regulated Lagoon," together with the experiences carried out by the territorial entities that relate at different scales to the Venice Lagoon (Municipal Administrations, Reclamation Consortia, Basin Authorities, Metropolitan City, etc.) provides fertile ground from which to take inspiration to try to outline a roadmap for the future of the lagoon territory, imagining this tool as:

- a catalyst for adaptation mainstreaming processes: for climate change mitigation and adaptation to become structuring and structural development processes for the lagoon territory, they must be incorporated or added to any plan or strategy that the administrations belonging to the lagoon gutter are to equip themselves with or have equipped themselves with in the past, thus making the issue of climate change mainstream within the process of territorial governance. The strategic and operational proposals presented by the plan both for the entire lagoon area and for each local government thus propose new policies and actions that enter an existing framework, sometimes initiating new strands of implementation and, very often, intervening with indications for already existing plans or programs. Consequently, these strategic guidelines serve as a starting point for land-use governing bodies to address and either initiate (in the absence of comprehensive measures) or enhance (in the case of ongoing initiatives) their consideration of climate-related concerns within the dynamics of land-use planning;
- an example of thematic integration and operational interdisciplinarity: these types of plans - remaining in their nature as voluntary instruments - fit into an established context made up of multiple initiatives that touch on the issue of energy and environmental sustainability in a more or less direct way. If these (often also very heterogeneous) processes are carried out independently, they tend to weaken, generating inefficient use of resources within local governments, if not even entering into open conflict (where, for example, overlapping competencies are created). Precisely to avoid such externalities, the Adaptation Plan considers it a priority to coordinate climate initiatives with the framework of other environmental protection strategies/plans that are already in place (energy programs, sustainability programs, etc.), both at the local and macro-regional levels;
- good practice in inter-scalar planning: for the adaptation plan, the issue of scale, both in terms of time (as short- and or long-term planning of actions) but especially in spatial-administrative terms, is one of the aspects to which adequate attention should be paid in the future. If some policies or measures, especially those regarding the technological quality of facilities and buildings, are predominantly a-territorial, urban planning choices regarding land use, density, and mobility systems, key variables for energy efficiency and territorial resilience, cannot be placed indifferently under the control of a single local-level administrative entity. For this reason, the achievement of these objectives in the lagoon context has required during the drafting and will require during future implementation, an approach capable of always maintaining a strong link between scales of intervention, allowing individual local governments to govern their specific emergencies and criticalities, but without losing the strategic coherence and balances guaranteed by the large-scale strategic framework;
- an exercise in methodological and operational coherence: as is the case with any research avenue that sets out to address issues that have only been weakly explored, some findings prove to be acquired, while others need more time and deeper investigation to become an integral part of public discourse and

operational land management processes. New challenges in many cases require new approaches to arrive at new solutions. From the operational landscape and the cognitive heritage investigated within the context of the Venice lagoon, it emerges how the land planning process is certainly enriching its design, lexical, and operational vocabulary. This is an evolution that acts on the continuity of knowledge that has traditionally influenced lagoon governance practices and is now being taken up in innovative ways. It is, therefore, possible to say that the increasingly urgent issues regarding climate change are leading urban and territorial planning to a partial updating of disciplinary apparatuses by taking advantage of opportunities such as the research path "Venice 2021 - Scientific Research Program for a Regulated Lagoon." The originality of the approach used for the formulation of the Adaptation Plan lies precisely in the conversion of environmental risk into an opportunity for the transformation and development of the Vast area. That is, it appears that today's environmental crisis offers an opportunity to take a different point of view, a more attentive and far-sighted look at the processes and related consequences that affect urban and territorial transformations while respecting those balances that make the lagoon "a man's environment".

Through the experiences investigated by the research, in addition to the possibility of expanding the concept of climate planning, it was also possible to critically reflect on the very use of emergency planning and decision-support practices, both for research purposes and for spatial planning practice. Learning from practices means, by inductive process, extrapolating key concepts to reformulate methodological approaches, and recognizing the potential for innovation inherent in these processes.

In conclusion, these theoretical-methodological advances allow them to be used again to direct and support the innovation of other practices, thus qualifying the planning process as circular, flexible, and adaptive.

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Image Sources

Fig.1, Fig.2, Fig.5, Fig.7, Fig.8, Fig.9 processed by authors

Fig.3 and Fig.4: Arpa Veneto 2022;

Fig.6: Dr. Gianmarco di Giustino's elaboration for the Plan drafting process

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Analysis of territorial fragilities through GIS_science

A method tested in the Life+ A_GreeNet project to implement urban green infrastructures

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Abstract

This paper presents the results of applied research on the Adriatic linear city (Marche, Abruzzo) aimed at building an innovative cognitive framework through GIScience methods/techniques (geodata processing, remote sensing, and scientific indexes) to support the first analytical phase of the A_GreeNet Life+ project and its aims. In particular, the paper shows the different methodological steps necessary to produce a risk map and multi-thematic geodatabase in a GIS (Geographic Information Systems) environment based on open data. The research results lay the foundations for new ways and different perspectives of investigating the urban landscape in line with the process of renewing cognitive tools for urban planning. Starting with the cognitive framework developed, the project partnership network will be scaled down for the second analysis phase aimed at prefiguring a new scenario for forestation and redeveloping the landscape-vegetation system with the support of the related administrations and in accordance with the current planning framework.

Keywords

GIScience; Urban Green Infrastructure; Risk Maps; Territorial Fragilities; Urban Planning.

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1. The A_GreeNet Project within the Scientific-Cultural Debate

This contribution addresses emerging questions regarding challenges in cities in the 21st century from various directions. Such challenges include ecology and urban health, and most importantly, the climate crisis, which influences the public, academic, geopolitical, and social debate on both an international[1] (IPCC, 2022; EASAC, 2019) and national level[2] (CMCC, 2020). In this sense, the research, while not specifically addressing the two-fold digital and ecological transition, falls within both a process of renewing the cognitive tools of urban planning enabled by the digital geographical progress of GIS and the 'science of where' (GIScience) (Wright and Harder, 2020; van Maarseveen et al., 2019; Adelfio et al, 2019), along with geospatial techniques such as remote sensing (Liu, 2016; Anees et al, 2020; Partheepan, 2023). On the other hand, it reiterates the central role of the Urban green infrastructure (UGI) and nature-based solutions to respond to the social and spatial fragility of the territory (World Bank, 2021; Sturiale and Scuderi, 2019).

It is now well known that the urban climate is closely correlated with the form of urban settlements, building morphologies, and the materials present in the city (Maiullari et. al, 2021; Oke et al, 2017; Rosenzweig et al, 2018) as well as the arrangement/quantity/quality/size of green spaces in their multiple forms and botanical specifics (Salata, Yiannakou, 2016; Shirgir et al., 2019). Various studies have highlighted the benefits of green space for human health and mental-physical well-being, since such spaces provide places for socializing, recreation, and sharing, as well as direct and indirect ecosystem services (UN-Habitat, 2020; WHO, 2020). Other scientific reports and research highlight how natural habitats contribute to protecting the territory, and especially urban areas, from both endogenous (e.g. soil and morphology) and exogenous fragilities (e.g. anthropic and climate impacts). These are aggravated by global weather imbalances due to the climate change currently seen in Italy,[3] with greater severity in duration, intensity, and recursion (torrential rain, storm surges, heat waves, etc.) (Osservatorio Nazionale città-clima, 2022; Brownlee et al., 2021).

This framework is inevitably reflected in the case study, that is, the mid-Adriatic city in Italy, where the mutual relationships — humans/nature, urban form/climate aspects — also interact with i) local socioeconomic dynamics tied to the ageing population (ISTAT, 2020a; ISTAT, 2020b), ii) the intrinsic territorial fragility of the Adriatic side and Italy as a whole (Trigila et al, 2021; Lastoria et al, 2021), as well as iii) the substantial increase in tourist flows on the Adriatic coast of Marche/Abruzzo in summer (Regione Marche, 2023; Regione Abruzzo, 2022).

In this scientific/cultural frame of reference, A_GreeNet Life+[4] investigates the quantity/quality of the UGI of the mid-Adriatic city[5] to increase the availability of green areas through territorial agreements (i.e. 'Intra-Regional Urban Afforestation Agreement for the Middle Adriatic City'[6]) and especially by activating

[1] The international level includes the European Green Deal, a guide to achieve the objectives tied to the transitions and changes in today's society for sustainable development and climate neutrality in Europe: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

[2] In Italy, the direction is dictated by the National Recovery and Resilience Plan, in which Italy is committed to the dual transition, orienting future design towards securing the territory, the climate sustainability of the changes, the socioeconomic recovery of the country and disadvantaged populations, and even more: https://www.italiadomani.gov.it/content/sogei-ng/it/it/home.html

[3] ISPRA report of 17 May 2023 on the 16-17 May 2023 flood in Emilia-Romagna: https://www.isprambiente.gov.it/files2023/notizie/pdf24_merged.pdf. Other infographics on the impacts of extreme events in Italy can be found at: https://cittaclima.it/2022/12/29/bilancio-2022-dellosservatorio-cittaclima/

[4] Project data: budget: €3,631,776, duration: 01/10/2021 (expected start date) – 30/09/2025 (expected end date), partnership: Abruzzo Region (lead partner), Municipalities of Silvi, Ancona, Pescara, San Benedetto del Tronto, Legambiente onlus, Res Agraria srl, University of Camerino – School of Architecture and Design (SAAD/UNICAM); Unicam Team: Rosalba D'Onofrio (scientific coordinator), Elio Trusiani, Roberta Cocci Grifoni, Federica Ottone, Chiara Camaioni, Timothy Daniel Brownlee, Graziano Enzo Marchesani, Giorgio Caprari, Simone Malavolta. Funding: The Life+ AgreeNet Project is funded by LIFE EU Programme, grant number LIFE 20 CCA/IT/001752. More information at: https://www.lifeagreenet.eu/site/.

[5] Urban areas covered by the project fall within the municipalities of Ancona and San Benedetto del Tronto (Marche Region), Martinsicuro, Alba Adriatica, Tortoreto, Giulianova, Roseto, Pineto, Silvi, Pescara (Abruzzo Region).

[6] Contratto Interregionale di Forestazione urbana della città del Medio Adriatico – Abruzzo e Marche (CIdFU)

environmental forecasts internal to current urban plans (D'Onofrio et al, 2023). The project aims to implement coastal UGIs, along with the multiple ecological/functional and aesthetic/recreational services that it provides and which make the infrastructure capable of climate adaptation to protect the health of the urban habitat and people (EC, 2016; Forest Research, 2010).

Within the broader framework of the project, this paper presents a GIScience method applied to the area of study to construct a map of territorial risk and a multi-thematic GeoDataBase (GeoDB) using GIS (Geographic Information Systems) relating to three categories of fragility. The method, which is fully open source, was tested within the project as support for the first analytical phase on the large scale, which is useful for guiding subsequent steps[7] and the specific design solutions to enhance the coastal UGIs that are currently being organized.

As anticipated above, the research is organized around three conditions of territorial fragility/vulnerability that are particularly important today: i) ageing and fragile swaths of the population; ii) land coverage (permeable/impermeable) and the quantity/quality of vegetation; and iii) thermal stress tied to the increase in temperature, heat waves, and the urban heat island (UHI).

These indicators, investigated with scientific indices or aggregates of summary data, fall in line with national research involving similar studies in recent years with respect to area of application, scale, and goals. To cite a few of interest related to this contribution, Gabriele et al. (2023) developed an Environmental Sensitive Area Index (ESAI) to analyse the sensitivity of land to degradation (erosion, loss of biodiversity, etc.), a factor that increases the risk of landslides. Other researchers (Pozzer et al., 2021; Beltramino et al., 2022) have examined spatial correlations among the different risk variables (i.e. sensitivities, pressures, hazards) that contribute to territorial vulnerability. Maragno et al. (2021) proposed a multi-risk climate atlas (thermal stress, risk of flooding) to support local climate-proof planning. In addition, with respect to UHIs, D'Ambrosio et al. (2022) and Todeschi et al. (2023) assessed the territorial vulnerability to heat waves by simulating the impact today and in the future according to scenarios of global warming prepared by the IPCC (2022). These further expanded the area of application, calculating thermal anomalies among urban and periurban areas and considering discomfort for elderly people (Heat-Related Elderly Risks, HERI).

The common thread between this contribution and the research above relates, first, to the technical/operational ambition of the results, i.e. providing decision support systems (DSSs) and innovative analytical frameworks for decision makers and planners with regard to new territorial governance practices, where the climate and green areas are two central issues. On the other hand, it refers to the GIScience approach and the use of GIS-based techniques and methods (e.g. geoprocessing, remote sensing), open geographical data, and a wide range of scientific indices and social and morphological/climate indicators calibrated using case studies.

This state of the art, albeit partial, shows the liveliness of the scientific debate on data-science and GIS used to analyse the various geographies of risk and vulnerabilities in the Italian territory.

The research falls within this disciplinary strand, infusing geo-ICT innovation applied to studies of the city and territory in the era of climate instability with value and scientific features, while highlighting its limits and potential. With regard to the techniques and technologies used, this contribution falls in line — with suitable differences — with the state of the art illustrated above. With respect to theory, the added value of the research consists in systematizing the innovative geospatial knowledge with urban planning techniques and

[7] To situate the contribution within the broader line of research, subsequent evaluations on the large/local scale were carried out as of today and for 2030, and 2050 using the GIS-based open-source 'UMEP – Urban Multi-scale Environmental Predictor' plug-in. The model estimated the mean radiant temperature (Tmrt), converted into the UTCI (Universal Thermal Climate Index). This index assesses thermal stress relative to the impact of climate variables on people. To this end, the meteorological data of the 'representative day' (2019) were projected to 2030 and 2050 according to emission scenarios RCP 10 4.5 (IPCC, 2022). At the end of the workflow, the interpolation of the UTCI with the risk map discussed here definitively highlights the system of the most sensitive areas with which simulations will be made of the state before/after the UGI project as of today, and at 2030 and 2050 (ENVI-Met software).

planning regulations that the research group is working on in synergy with local public administrations (PAs). That is, where areas of discomfort and risk are involved (where social fragility adds to morphological and climate fragilities), actions to mend and improve the environmental system will be planned on different scales, through the application of current regulations where they have not been implemented. According to D'Onofrio et al. (2023), this step is fundamental in situating the planning of nature-based solutions and strengthening UGIs within urban planning, which does not contain specific tools except for voluntary ones (e.g. Piano del Verde [Green Plan]). It is also essential in bridging the gap between the theoretical way in which UGIs are discussed and the practical world in which they are planned and managed (Ferreira et al. 2021; D'Onofrio et al., 2022). In doing so, virtuous practices are instituted to refine and truly enrich the research contributions, aligning them with activities proposed by public departments.

- The specific objectives of this work are summarized as follows:
- spatializing disadvantaged areas (population, housing density, large families) in the 10 municipalities in question, starting with the most up-to-date databases (2020–2021);
- creating a soil atlas using the Soil Adjusted Vegetation Index (SAVI) with respect to permeability and the presence of greenery;
- diachronic mapping of thermal stress through the calculation of Surface Temperature (ST) and Land Surface Temperature-LST;
- structuring a multi-thematic GeoDB for the creation of updatable risk maps.

2. Methodological Steps for Building the Knowledge Framework

Before discussing the technical details of the method, the case study, the reasons for its interest, and the limits of the area of study considered in the A_GreeNet are presented below.

2.1. The Case Study of the Mid-Adriatic City

On the physical/spatial level, the coastal municipalities in the Marche and Abruzzo regions constitute a linear city 355 km long, home to 39% (Marche) and 34% (Abruzzo) of the regional populations (ISTAT, 2020b). The urbanization process has led to a progressive reduction/fragmentation of the green/forested/agricultural lands in the area (Comitato Capitale Naturale, 2018) transforming what was a semi-natural coastal landscape in the second half of the 1900s into a very dense urban landscape. This is particularly evident if one assess the land consumed in the urban/coastal area of Pescara (51.3%[8]) and San Benedetto del Tronto (37.60%), in Abruzzo and Marche, respectively (Munafò, 2019, pp. 65).

Such extensive soil impermeability reduces water absorption, affecting the microclimate on different scales. This is primarily caused by i) the weakness of large-scale planning, ii) the expansive nature of local planning, and iii) the ineffectiveness of governance in activating policies, plans, and measures for multi-level adaptation that integrates UGIs.

The effects of such criticalities are reflected in studies on climate trends in the area. In the Marche region, there has been a significant increase in temperature, rising between 1.6°C and 2.6°C with respect to the 1990s, which is associated with an increase in summer days and tropical nights (Fioravanti et. al., 2016). Furthemore, a study conducted by the European Data Journalism Network[9] (EDJNet) in 2020 highlighted that Pescara (Abruzzo) has witnessed a substantial rise in the average annual temperature over the past fifty years. In the 1960s, the estimated average temperature was +14.2°C, and by 2009–18, it had increased to +16.3°C, indicating a notable temperature increase of 2.1°C.

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[8] Values with respect to the limits of the entire municipality.

[9] The infographic of the research for the City of Pescara is available at: https://climatechange.europeandatajournalism.eu/en/italy/abruzzo/pescara/pescara

Filling in this critical framework, the National Adaptation Plan, as yet lacking approval, defines the macro region of interest as an area with low adaptation capacity, a high risk of desertification by 2050, and a significant increase in summer days (PNACC, Annex 1, 2018). Other studies showed an increase in local mortality in Ancona during the heat wave in 2003 (Condemi et al., 2015) as well as in August 2017 (DEP[10], 2017, Fig. 9, p. 28) with specific reference to people over 65 years of age. Similar increases in mortality were also observed in Pescara in May–June 2022 in correlation with temperature increases (DEP, 2022, Fig. 3, p. 25).
For these reasons, the case study is significant and suitable for testing a methodology that tries to spatially relate social variables, physical-territorial aspects, and climatic dynamics.
In this perspective, three types of analysis were developed on the basis of municipal administrative limits and especially drawing up-to-date urban perimeters as the areas most affected by these dynamics.
The areas of study (Fig. 1) can be identified with the urban expansion of the coastal city characterized by i) the building continuum and ii) the constant presence of anthropic infrastructure (i.e. railway and motorway).
A difference can be seen between a 'restricted perimeter' and an 'expanded perimeter'. This specification relates to the two different purposes of the A_GreeNet project. While the project focuses on the urbanized coastal areas with the highest population density ('restricted'), other areas were identified by the public administration technicians based on trends due to i) ongoing transformations or ii) future transformations based on plans by the individual PAs.

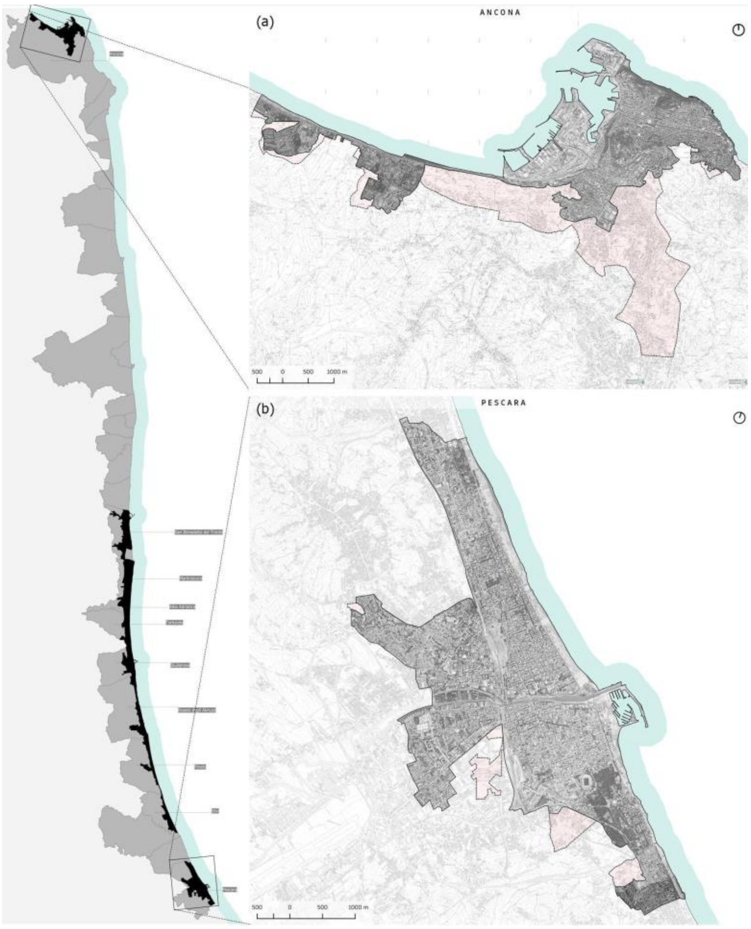

Fig. 1 Limits of internal studies made by municipalities involved in the project (black). The limits of the City of Ancona (a) and the City of Pescara (b), and the related differences between the 'restricted perimeter' (orthophoto) and 'expanded perimeter' (pink). Source: Prepared by the authors using Google Maps ©2022, Marche Regional Technical Map 1:10000 (2000), Abruzzo Regional Technical Map 1:10000 (2007)

[10] The observed data refer to the results of the Heat Health Watch Warning Systems (HHWWS), the Surveillance System of Daily Mortality (SISMG), and A&E admissions in the periods mentioned above. For more information, see: https://www.salute.gov.it/portale/caldo/dettaglioContenutiCaldo.jsp?lingua=italiano&id=408&area=emergenzaCaldo&menu=vuoto

Data and Methods

In line with the research objectives set out above, this section presents the data, methodological process, and geo-based techniques used to construct the map of territorial risk in the area of study (Fig. 2). This was developed using geoprocessing, remote sensing applications, and geospatial analysis tools in the GIS environment (i.e. QGIS software), which rely on open-source geo-spatial hardware/software and libraries (e.g. SAGA-GIS, GRASS ecc.).

The territorial fragilities were analysed with respect to three specific issues deemed important for the area of study, as highlighted above, and around which this section is organized:

- demographic aspects and resident registers;
- soil and green atlas;
- thermal stress.

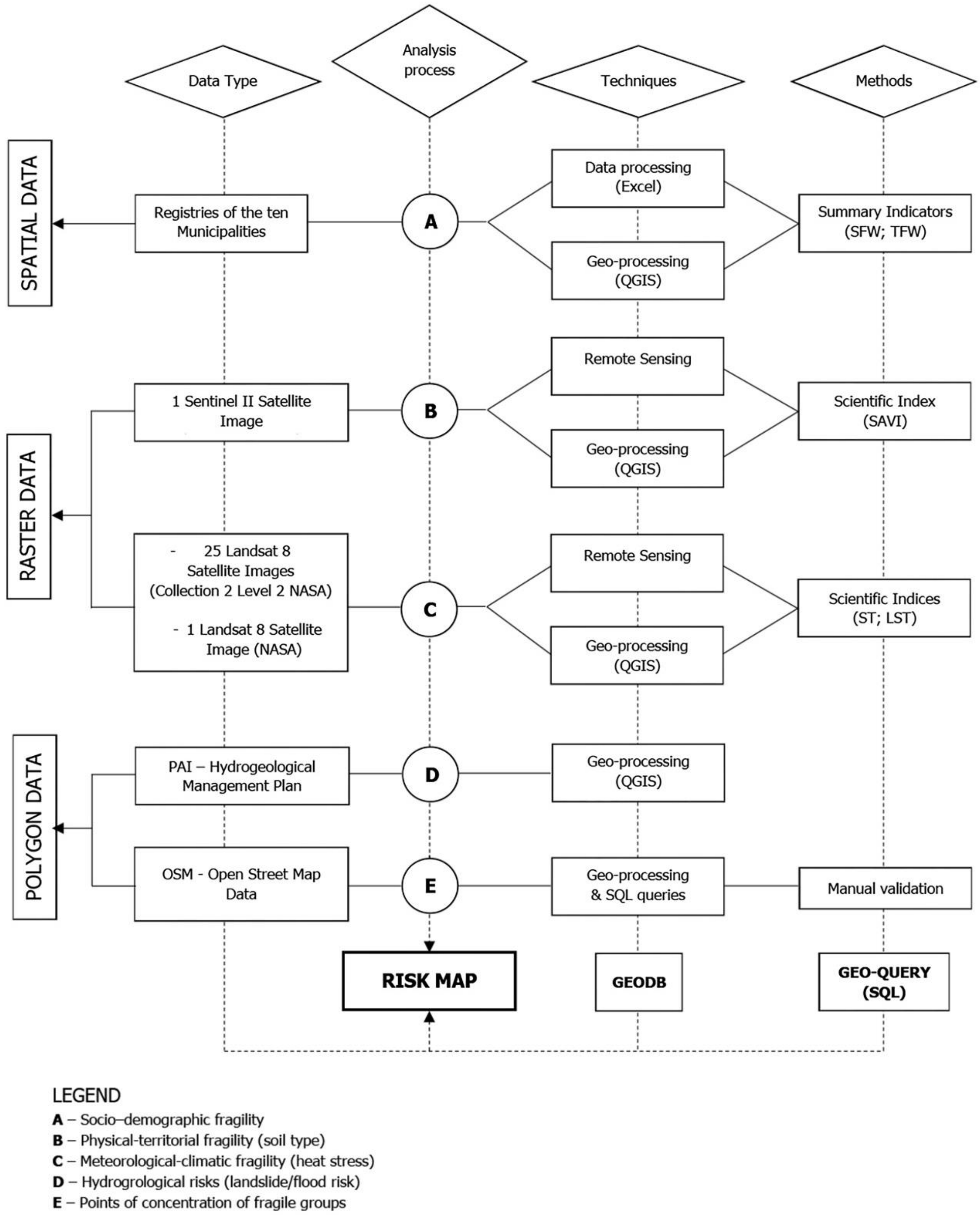

Fig. 2 Research workflow, from the data to the techniques and methods used to develop the risk map for the case study

The Socio-Demographic Analysis

The analysis conducted returns a georeferenced mapping of socio-demographic fragility in the area of study with respect to i) population density, ii) resident age, and iii) presence of large resident families. To this end, the registries of all the municipalities involved (updated to 2020 or 2021) were acquired from the PAs, processed with quantitative mixed methods (data-analysis in Excel and GIS environment) and georeferenced with respect to ISTAT census sections[11]. Given the data availability, the following criteria and data were examined:

- total number of residents;
- number of residents aged ≤ 14 years;
- number of residents aged ≥ 65 years;
- number of households with 4 or more members.

Considering the data acquired thus, two indicators were calculated on the basis of the parameters chosen:

- social fragility weight (SFW[12]);
- total fragility weight (TFW[13]).

The indicators represent both the incidence - i.e. the weight of socio-demographic fragility in relation to the size of the census section (SFW) - and the number - i.e. the quantity-concentration of children under 14, elderly people, families with 4 or more members present in each census section (TFW).

					Indicators			
			Socio-demographic variables					
Census section (no.)	**Square metres (m²)**	**Residents (no.)**	**Residents ≤ 14 years old (no.)**	**Residents ≥ 65 years old (no.)**	**4-5 member families (no.)**	**6+ member families (no.)**	**SFW[11] (0-1)**	**TFW[12] (no.)**
1	481,431.32	6	0	0	1	0	0	1
2	15,298.58	57	4	12	5	0	0.00137	21
3	12,491.04	2	0	0	0	0	0	0
4	9,992.15	1	0	0	0	0	0	0
5	15,453.10	23	2	4	0	0	0.00039	6
6	15,886.20	no data						
7	4,674.00	35	6	8	3	0	0.00364	17
8	6,690.22	95	7	26	4	0	0.00553	37
9	3,511.29	68	4	14	5	0	0.00655	23
10	2,538.91	51	4	19	1	0	0.00945	24
11	7,257.47	53	3	24	1	0	0.00386	28
12	7,255.46	50	4	15	5	0	0.00331	24
13	11,474.65	122	10	33	8	1	0.00453	52
14	4,577.93	93	7	23	2	0	0.00699	32
15	10,145.53	13	0	3	0	0	0.003	3
16	3,720.33	43	3	18	2	0	0.00618	23
17	5,325.89	no data						
18	6,008.53	214	22	44	7	1	0.01232	74
19	2,205.82	33	1	7	0	0	0.00363	8
20	5,980.24	161	15	30	8	0	0.00886	53
Tot.al		99,542	11,530	26,497	6670	533	-	45,230

Tab. 1 Extract from the database of the City of Ancona, processed for the purposes of the socio-demographic fragility assessment

[11] Census sections available for download at: https://www.istat.it/it/archivio/104317#accordions

[12] Social fragility weight is the incidence of demographic fragility aspects (elderly, minors, large families) in relation to census size (SFW/census section in square metres); see Table 1.

[13] Total fragility weight is the sum of the socio-demographic variables for each census section (Residents ≤ 14 + Residents ≥ 65 + 4-5 member families + 6+ member families); see Table 1.

For a better understanding of the indicators, a double graphical layout was chosen (Fig. 3), which enhances the potential of the geo-based representation and notes some limitations of the quantitative data (synthetic indicators) presented later (see Sect. 4). In any case, considering the macro-scalar approach and the large portion of territory investigated, the census section data are sufficiently accurate for the purposes of a general critical evaluation and for identification of the most critical residential areas.

The work as developed was carried out for all 10 A_GreeNet Partner Municipalities and constitutes the first piece and first vulnerability variable for the construction of a socio-morphological and climate risk map useful for pursuing the project objectives. Below is an excerpt of the socio-morphological fragility map and an excerpt of the database developed for the City of Ancona (Table 1).

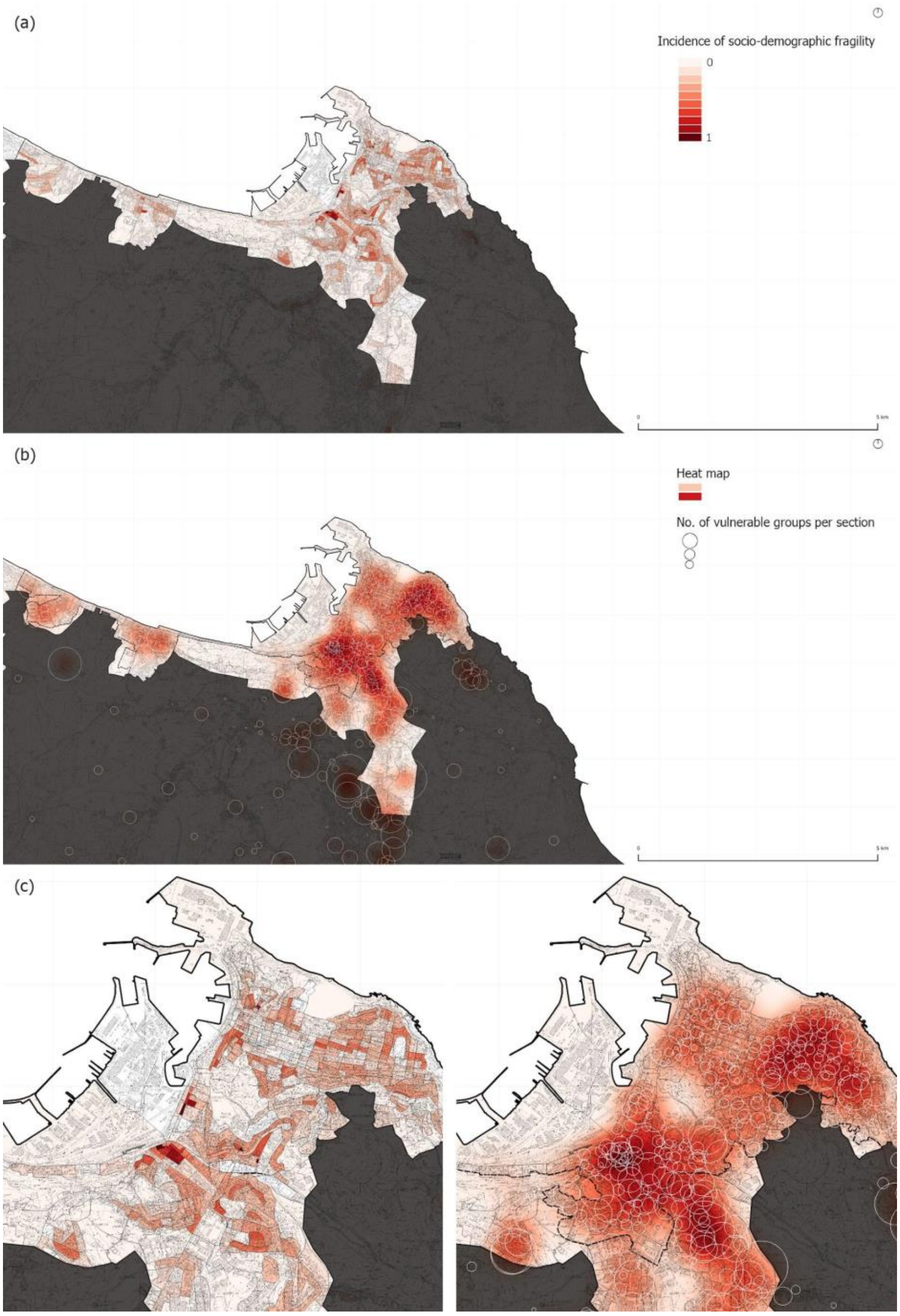

Fig. 3 Incidence of socio-demographic fragility (a) and quantity-concentration of the vulnerable population (b) with respect to individual census sections. Panel (c) shows a detail of the City of Ancona for a comparison of the two graphical representations. Source: Prepared by the authors using the Marche Regional Technical Map 1:10000 (2000)

Morphological Analysis: A Qualitative/Quantitative Survey of Soil and Greenery

Within the scope of research activities aimed at evaluating the condition and health of the UGI in the linear city of the mid-Adriatic region, the analysis of the macro-scale context concentrated on the semi-automated sampling of natural and semi-natural green areas.

This process was developed using remote sensing applications starting with i) open-access multispectral satellite images, ii) the use/calculation of a particularly efficient vegetation index in an urban environment (SAVI), and iii) its critical manual interpretation in order to distinguish artificial and natural surfaces.

This study yielded a spatial mosaic reflecting the degree of vegetation vigour of the land cover based on photosynthesis activity and the presence of chlorophyll in the plants at the time of the satellite shot.

This, in fact, is particularly visible in the red and near-infrared bands, which are two electromagnetic bands in the satellite shots made available by the Sentinel-2 mission of the European 'Copernicus' programme (European Spatial Agency, ESA[14]).

The process involved an initial scan of the satellite images available online covering a recent time period (May–July 2021[15]) that photographed the territory in its current state[16].

Excluding images with high cloud cover, two images[17] were selected from 10 May 2021, taken from the satellite at 10 a.m.

The images, with a square spatial resolution of 10 metres per pixel (10 m/px), were processed geographically in a GIS environment. The raw pixel data in the red (RED, band number 4) and near-infrared (NIR-Near Infrared, band number 8) electromagnetic bands were converted using the following formula (Huete, 1988):

$$SAVI = \frac{(NIR-R)}{(NIR+R+L)} * (1+L)$$

where:

NIR = Near Infrared;

R = Red

L = soil correction/adjustment factor (low vegetation = 0 and high vegetation = 1), which was given an intermediate value of 0.5 by scientific literature (Huete, 1988; Sedlák et al, 2018).

The index defined thus represents an initial qualitative-quantitative survey with respect to the entire survey area, capable of visually and spatially rendering the level of artificial objects/nature in the context. Based on the graphical results, it is easy to identify both the forest cover and/or areas with vegetation and the system of infrastructure, the built area, and vast waterproofed surfaces (Fig. 4).

The individual pixels in the images express a continuous value from less than zero (< 0) to greater than or equal to 1.5 (≥ 1.5), returning the areas with impermeable coverage (built areas, impermeable areas, areas without vegetation, etc.; in red, Fig. 4) and the permeable-natural and semi-natural areas (coastal pine forests, areas with trees, crop vegetation, parks, etc.; in green, Fig. 4).

Finally, in order to sample, capture, and quantify the size of the different areas, a threshold value (0.5) - verified by geoprocessing tests and analogically validated through critical photo interpretation - was identified, with which the permeable and impermeable areas were divided into two classes for the purposes of the risk map.

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[14] Data downloaded from the portal https://scihub.copernicus.eu/dhus/

[15] The effectiveness of semi-automatic processing in surveying the greenery depends on the months in which photosynthesis in the vegetation is most active

[16] This step of the research was conducted in early 2022.

[17] Selected images: S2A_MSIL2A_20210510T100031_N0300_R122_T33TUJ_20210510T115157, Sentinel-2, Level-2A, USGS; S2A_MSIL2A_20210510T100031_N0300_R122_T33TVH_20210510T115157, Sentinel-2, Level-2A - USGS

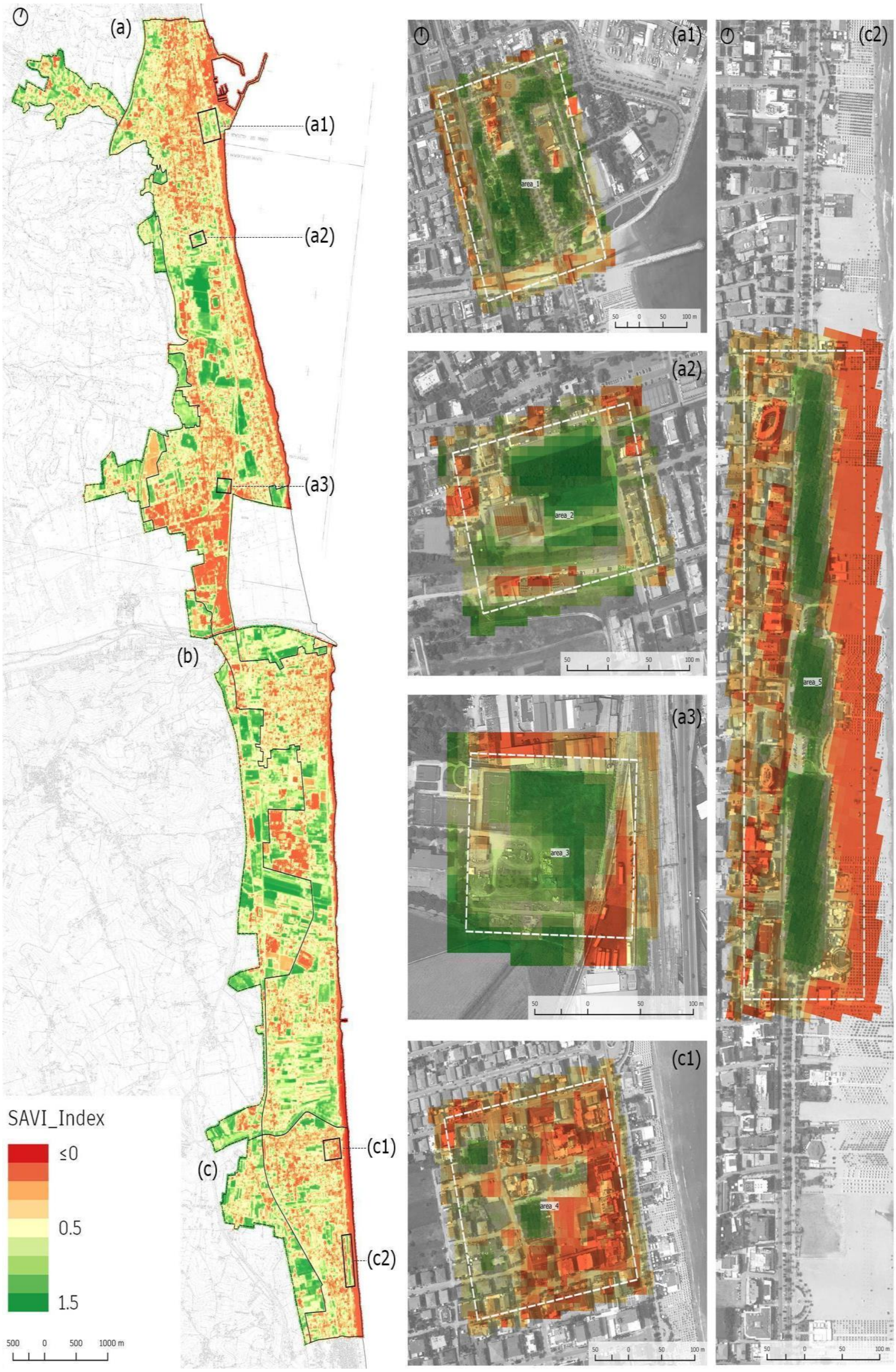

Fig. 4 SAVI Index calculated within the study area of the Municipalities of (a) San Benedetto del Tronto, (b) Martinsicuro, (c) Alba Adriatica, based on the Sentinel II image (Copernicus, ESA) from 10.05.2021. Panels (a1, a2, a3, c1, c2) show details of project pilot areas. Source: Prepared by the authors using Google Maps ©2022, Marche Regional Technical Map 1:10000 (2000), Abruzzo Regional Technical Map 1:10000 (2007)

Thermal Stress: A Diachronic Analysis of Surface Heat

The third vulnerability variable is the analysis of thermal stress using GIScience and remote sensing techniques in a GIS environment. The analysis was carried out through the use of i) multispectral images available via open-access,[18] ii) freely available semi-processed products (NASA – USGS[19]), and iii) the development of indices and mathematical formulas to calculate land surface temperature (LST) based on established methods in the scientific literature.

This analysis, like the others, was conducted on the large scale by photographing the current overheating dynamics in Italy (Spano et al., 2020; Munafò, 2022; Nanni, Minutolo, 2022), with particular reference to temperature trends over the last five years in the project areas obtained by studying regional weather bulletins.[20] As anticipated, the process was carried out on two fronts. On the one hand, various semi-processed images were acquired from the United States Geological Survey (USGS) with regard to provisional surface temperature (ST). On the other hand, the LST index was calculated on an extreme heat day identified using the 'representative day' method[21] (Tirabassi and Nassetti, 1999; Cocci Grifoni et al, 2022).

The huge number of products provided by the USGS — such as ST — are fundamental for the multi-criteria and diachronic monitoring of the Earth's surface temperature (Cook, Monica J., 2014; Cook et al, 2014) through thermal infrared spectral channels placed on geostationary satellites. These scientific indices measure the surface temperature related to the urban boundary layer (Oke, 2006), i.e. the coverage of the urban area above the average height of buildings. The estimate of surface temperature depends on i) the energy-emissivity of individual elements on the ground and systemic factors of an anthropogenic nature (albedo/reflectance of materials, etc.), ii) the degree of artificiality of materials and their intrinsic properties (e.g. light resistance), iii) the level of artificialization/impermeability of soils, iv) the coverage/presence of trees and the type/extent of green areas, and v) humidity, etc. (Caprari, 2021).

With this in mind, the results, which are presented below, were processed in several steps. They provide a large-scale and spatial/temporal overview of the thermal criticality of the study area, i.e. with respect to surface temperature and urban, natural and agricultural habitat elements.

The first step of the method returned a time series of 25 multispectral (pre-processed) images[22] acquired between 2017 and 2022 by the Landsat 8 mission (NASA). The images thus acquired were processed in a GIS environment to obtain the optimized data using the following formula:[23]

$$ST \;\; = \left(\left(img_{B10} * 0.00341802\right) + 149.0\right) - 273.15$$

where:

B10 = BAND 10 thermal infrared satellite image (TIRS);

0.00341802 + 149.0 = pixel scaling and calibration factor;

–273.15 = conversion unit from degrees Kelvin (°K) to degrees Celsius (°C).

[18] https://earthexplorer.usgs.gov/

[19] Specifically, the images are part of the Collection 2 Level 2 'Science Product', containing information pre-processed by an algorithm developed by the Rochester Institute of Technology (RIT) and the National Aeronautics and Space Administration (NASA). More information at: https://www.usgs.gov/landsat-missions/landsat-provisional-surface-temperature

[20] Report acquired from the "'Agenzia per i Servizi nel Settore Agroalimentare della Regione Marche-ASSAM, Centro Funzionale Multirischi della Regione Marche"' http://www.meteo.marche.it/blog/post/2022/07/01/Regione-Marche-Analisi-clima-giugno-2022.aspx) and from "'Centro Funzionale d'Abruzzo, AllarMeteo service'."

[21] This paper does not present the specifics of the process used in the research as it would require a special in-depth study beyond the scope of this contribution.

[22] Images within the summer period (May–August) were selected, with cloud cover between 0-40% and/or taking care that the clouds did not affect the study areas.

[23] Formula suggested in product use guidelines: https://www.usgs.gov/media/files/landsat-8-9-collection-2-level-2-science-product-guide

Once the satellite images had been processed, seven of the most critical temperature images were identified through photo-interpretation, analysis of the image histogram, and mostly using the criterion of frequency, i.e. the number of pixels per thermal degree. This method is useful because the maximum temperature as a selection value might not be representative of the frequency/presence of a given temperature value but rather be limited to a few pixels (areas) in the entire image. In relation to the frequency, the threshold value of 40°C was chosen, which returned the set of images suitable for representing the thermal-critical scenario for the five-year period 2017–2022. An extract is given below (Fig. 5).

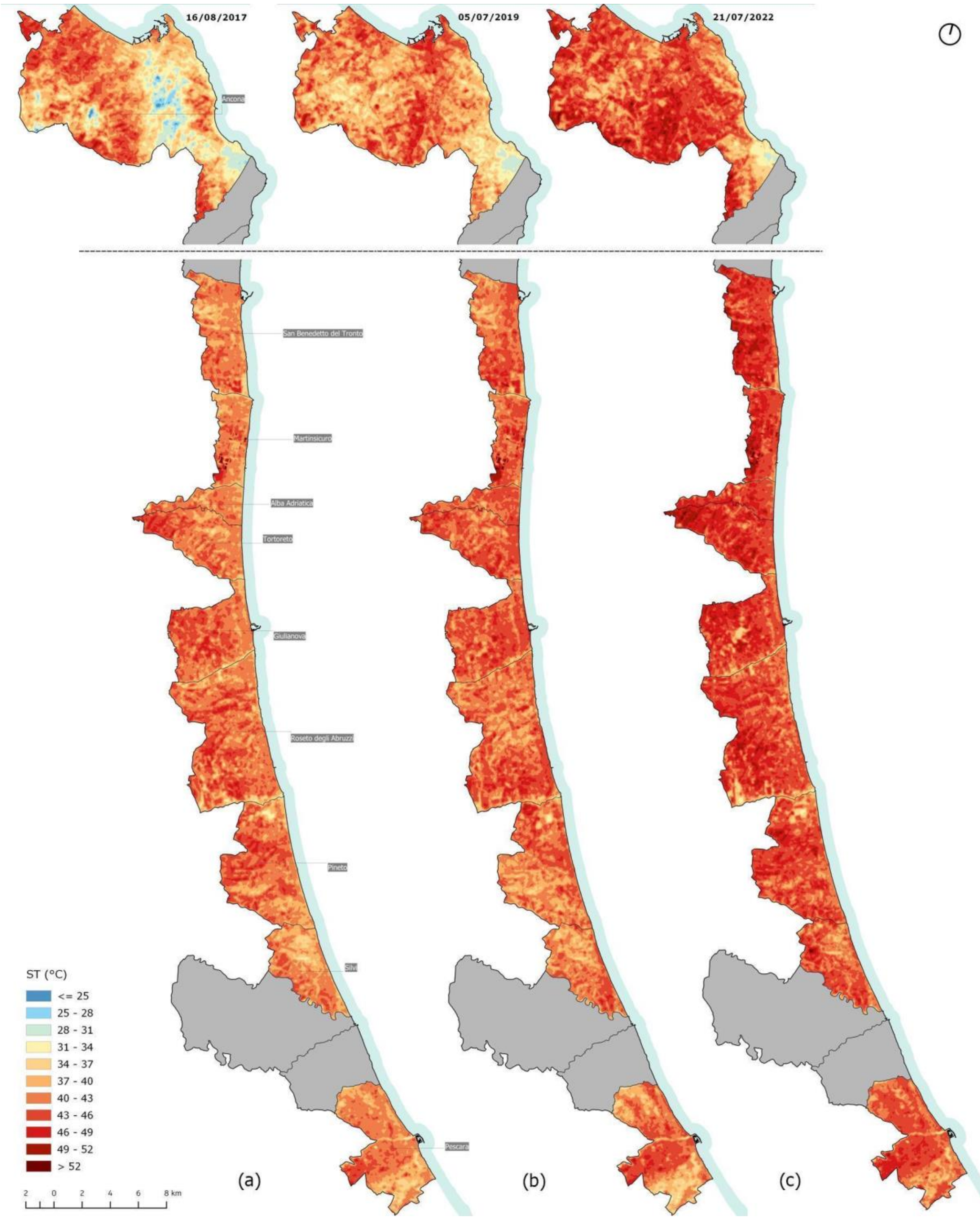

Fig. 5 ST Index developed for 3 days (a) 16.08.2017, (b) 05.07.2019, (c) 21.07.2022 out of the 7 calculated for each partner municipality (additional dates: 03.08.2018, 10.07.2021, 05.07.2022, 29.07.2022). Source: Prepared by the authors using Landsat 8 satellite images, NASA – USGS

Once this first diachronic analysis was completed, a satellite image[24] (Landsat 8 mission) was selected from 21 July 2019[25] (09:46 am) to calculate the LST index. This in-depth study is necessary for several reasons related to the higher spatial resolution of this data (60 m/px, ST; 30 m/px, LST) and the quality of the computation process, which is more detailed, used regularly, and better represented in the literature (Avdan, Jovanovska, 2016; Anandababu et al., 2018; Sandra et al., 2012; Wesley & Brunsell, 2019; Ejiagha et al., 2020). Multiple mathematical formulas were applied to the image to i) calculate the index and convert the raw data to temperature using the relevant electromagnetic bands (in particular B10, B4, B5), as suggested by Avdan & Jovanovska (2016), and ii) calibrate the data with geoprocessing operations to create the graphical output.

The steps for the LST can be summarized as follows:

- Calculation of atmospheric spectral radiance;
- Conversion of radiance to temperature at the sensor;
- Calculation of the NDVI vegetation index for the soil emissivity correction;
- Development of NDVI index;
- Calculation of vegetation ratio;
- Calculation of land surface emissivity;
- Calculation of LST index.

Without detailing the individual calculations for each variable, which have already been presented in the literature, here we highlight some aspects of this process. Like the ST above, this large-scale graphical result (Fig. 6) like the previous ST, does not return the temperature perceived by people at street level (0–2 m), which is left to subsequent micro-scalar simulations, but it does highlight the system of areas most exposed to solar radiation and susceptible to overheating in the urban-territorial area.

In fact, these areas absorb most of the direct radiation during the day and then release heat during the night, thus contributing to the UHI, which is exacerbated locally by the urban form and the rise in heat waves and, globally, by tropicalization of the climate.

Pursuing the aims of the contribution, the last section (Sect. 3) specifically investigates the process of creating a multidimensional GeoDB and risk map capable of highlighting the fragility/healthiness of the territory, depending on the interest — here with respect to the heat stress, UGI quality/quantity, and population vulnerability.

3. Results: An Updatable Geodatabase for Generating Risk Maps

The result of the cognitive framework is a qualitative-quantitative risk map developed through i) spatial correlation of the processed data and ii) querying the GeoDB.

The following are the variables produced, which are combined with other indicators and spatial data of interest. Together, make up the GeoDB dataset:

- socio-demographic fragility;
- soil quality: morphological-spatial vulnerability (SAVI Index);
- multi-temporal thermal stress (ST Index, LST Index);
- hydrogeological Management Plan (PAI[26]), i.e. risk areas;
- educational institutions and health centers.

[24] Selected image: LC08_L1TP_190030_20190721_20200827_02_T1, Landsat 8, Collection 2 Level 1, USGS.

[25] The image selected from among the 7 extremely hot days, was identified through the above-mentioned method of the 'representative day', which returns the recurring thermal condition most representative of the specific area in question.

[26] Piano di Assetto Idrogeologico

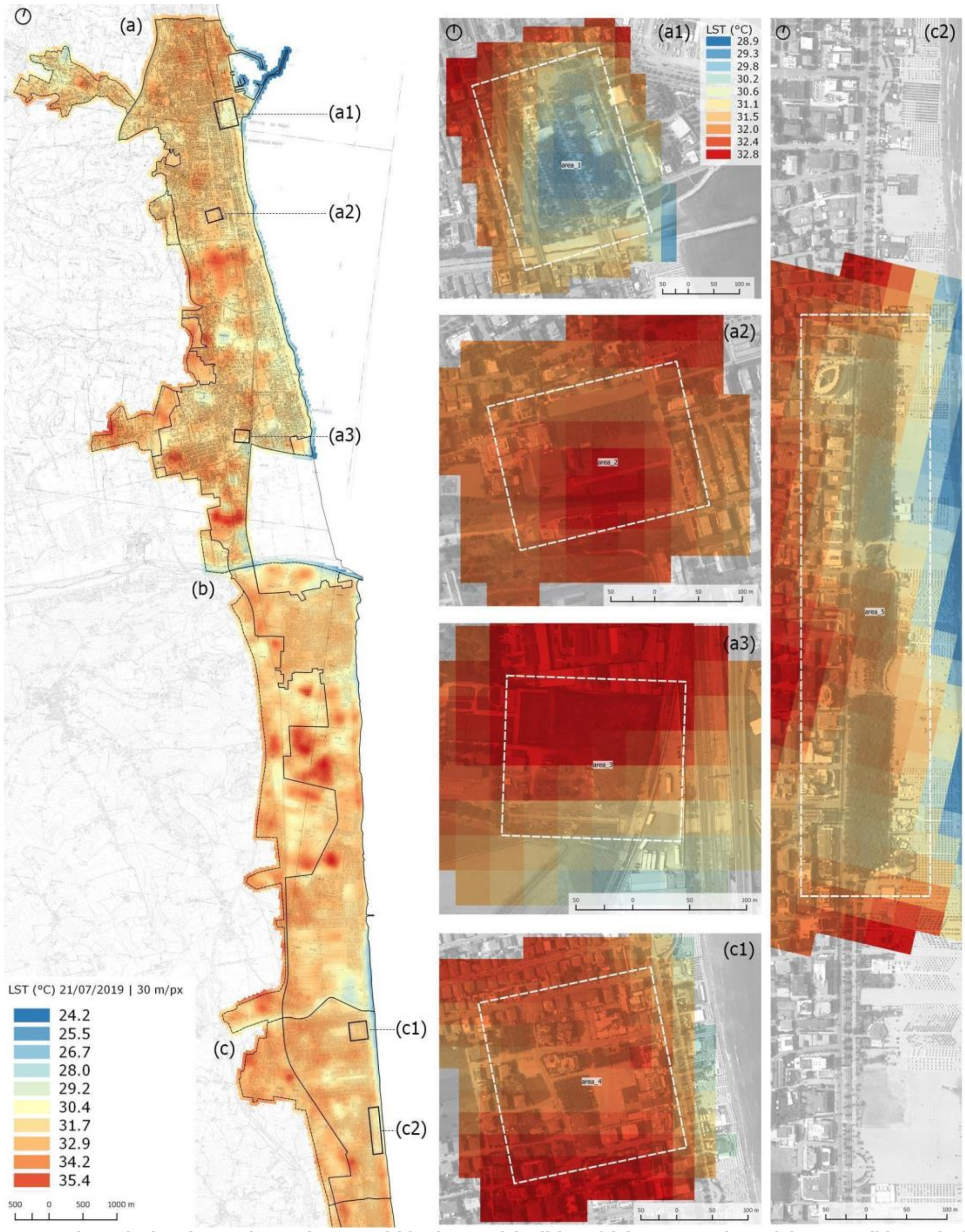

Fig. 6 LST Index calculated over the study area within the municipalities of (a) San Benedetto del Tronto, (b) Martinsicuro, and (c) Alba Adriatica, based on the Landsat 8 image (NASA – USGS) from 21.07.2019. Panels (a1, a2, a3, c1, c2) show details of project pilot areas. Source: Prepared by the authors using Google Maps ©2022, Marche Regional Technical Map 1:10000 (2000), Abruzzo Regional Technical Map 1:10000 (2007)

Points of interest (POIs) and/or places where vulnerable groups aggregate, including schools, nursing homes, hospitals, etc., as well as areas at risk of landslides/flooding, etc., were integrated. The latter are particularly important considering the hydrogeological instability of the central Apennines, which is aggravated by land consumption trends in the coastal area, poor territorial maintenance and care, sealing/artificialization of many areas along rivers, ditches, and streams, etc., as highlighted by thematic studies (Munafò, 2022). In this sense, data on the POIs were acquired from unofficial public databases such as OpenStreetMap[27] (OSM), which relies on contributions from the geographical community and international users on a voluntary basis (Voluntary

[27] Specifically, the 'overpass turbo' search engine was used as a web-based tool to extract OpenStreetMap data by spatial query with SQL (Structured Query Language), e.g. amenity = hospital; amenity = school; etc. Site available at: https://overpass-turbo.eu/.

Geographic Information – VGI). On the other hand, sector planning data (PAI) were downloaded directly from the geoportals of local authorities[28] and official GIS-based open data.

All acquired/produced/measured data were manually validated and integrated into the GeoDB via geospatial processing in the GIS environment. The data were homogenized[29] and spatialized on a uniform polygonal grid (hexagons) - with horizontal and vertical spacing of 30 m and a surface area of 749.42 m^2 - that covers the entire area of study. Each hexagon returns the informational and semantic attributes of the GeoDB, i.e. the geometric base on which the risk map is visualized and spatialized. The aggregation of data into regular shaped grids with uniquely named cells/areas (via IDs) is extremely useful for i) 'normalizing' data from multiple sources, ii) mitigating problems associated with the use of irregularly shaped polygons created for other purposes and with other criteria (i.e. administrative census sections), and iii) having a 'key' to implement the GeoDB over time. As the last step in the whole research process, the GeoDB was spatially interrogated using 'logical operators'[30] in SQL computer language and the discretionary use of quantitative 'threshold limits', between an analogue approach and digital tool. The expression relates the three fragility variables and the added vulnerability data with respect to their presence in and/or level of criticality for each hexagon. As can be seen from the highlighted hexagons (Fig. 7), there are multiple dimensions of risk, since there are several variables that affect their severity, including age, soil morphology, and thermal stress. Red borders are used for areas with socio-demographic fragility, i.e. areas subject to a high concentration of weak population groups with respect to census size or areas with a high number of fragile residents. Orange is used for morphological-climate fragility (soil and heat). Blue and brown, respectively, are the landslide and flooding risk. In order to understand the contents of the resulting risk map, two tabular excerpts of the GeoDB are reported (Table 2[31]) concerning only hexagons subject to risk, i.e. those highlighted in the municipalities of Ancona and Pescara.

	Indicators									
	Socio-demographic				Soil type		Heat		Hydro-geol.	
Hexagon ID (no.)	**Residents (no.)**	**TFW (no.)**	**NFW (0-1)**	**Frag/Res (%)**	**Imp (%)**	**Perm (%)**	**LST mean (°C)**	**ST mean (°C)**	**PAI land-slide**	**PAI flood**
3,305	186	89	0.01231	47.85	100	0	33.47	44.17	no data	
3,341	339	167	0.10654	49.26	100	0	32.81	43.11	no data	
3,342	339	167	0.10654	49.26	100	0	32.84	43.27	no data	
3,343	591	287	0.21538	48.56	100	0	33.02	43.68	no data	
3,344	323	154	0.21538	47.68	100	0	33.46	44.16	no data	
110,739	242	125	0.97512	51.65	100	0	33.17	42.26	no data	
110,740	242	125	0.97512	51.65	100	0	33.45	42.63	no data	
110,745	398	173	0.24337	43.48	100	0	34.64	44.29	no data	
110,746	650	274	0.24337	42.15	100	0	34.63	43.94	no data	
110,747	343	147	0.24337	42.86	100	0	34.41	43.36	no data	

Table 2 Extract of the Risk GeoDB for the Cities of Ancona (above) and Pescara (below)

[28] Specifically, the Flood Risk Management Plan PGRAAC (Directive 2007/60/EC, Article 6 of Italian Legislative Decree 49/2019) prepared by the Central Apennine District Basin Authority of the Marche and Abruzzo Regions and the Hydrogeological Management Plan (PAI) was acquired. Data is available at: http://www.pcn.minambiente.it/mattm/servizio-di-scaricamento-wfs/; https://webgis.abdac.it/portal/home/.

[29] The individual processes for calculating the three fragility variables returned the data in different geographical formats (polygonal, e.g. .shp; raster, e.g. geotiff; etc.). For the purposes of the GeoDB, these were converted into and/or associated with the polygonal data (hexagons).

[30] https://docs.qgis.org/3.28/it/docs/pyqgis_developer_cookbook/expressions.html

[31] Acronyms used in the tables: Hexagon ID: unique hexagon number; Residents: number of residents; TFW: Total fragility weight (see Table 1); NFW: Normalized fragility weight (from 0 to 1); Frag/Res: ratio of vulnerable groups to number of residents; Imp: Impermeable surfaces ; Perm: Permeable surfaces ; LST mean: Land surface temperature, average; ST mean: Surface temperature, average; PAI landslide: hexagons subject to landslide (PAI source); PAI flood: hexagons subject to flood events (PAI source)

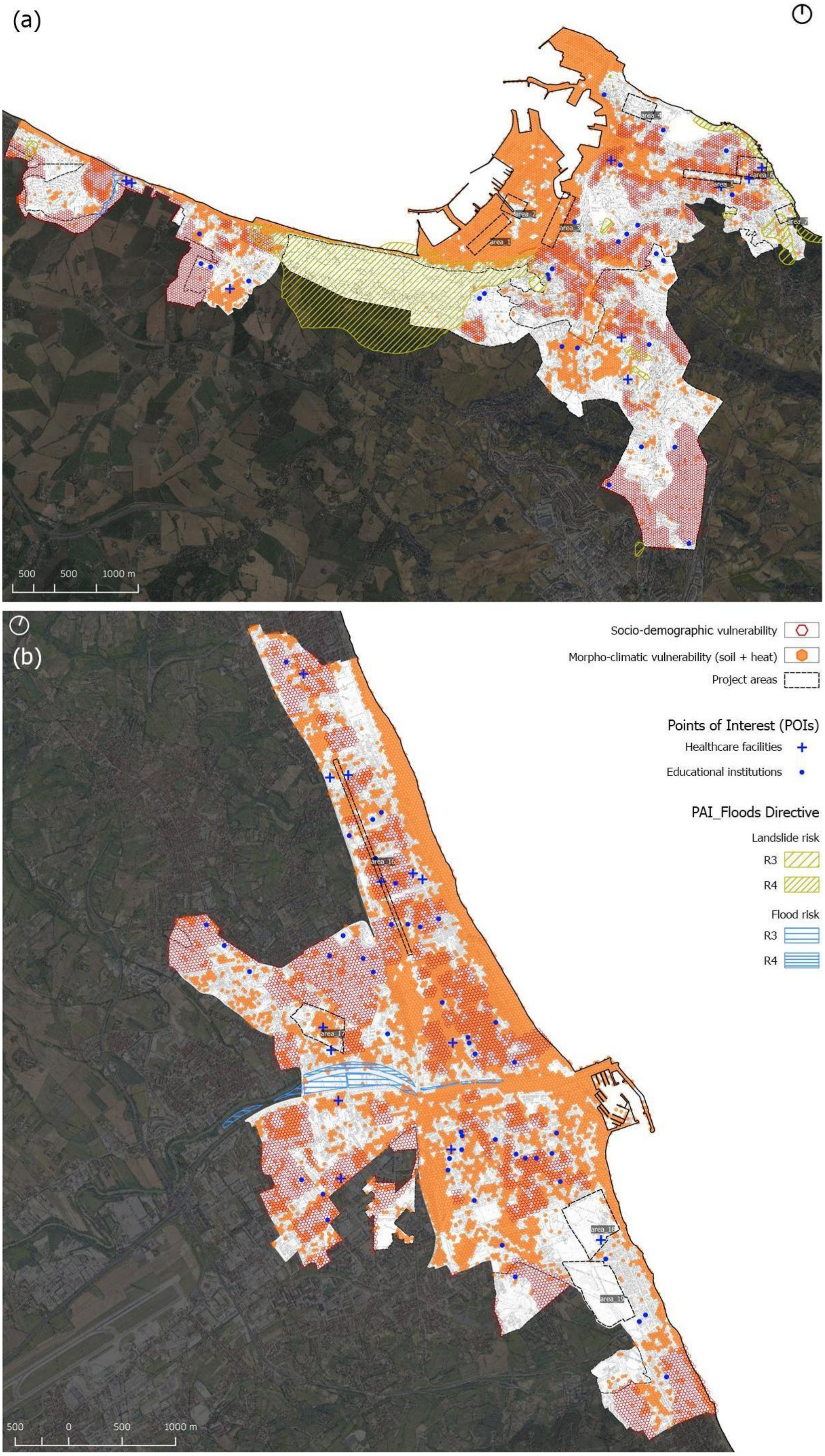

Fig. 7 Risk map of the study area within the Cities of Ancona (a) and Pescara (b). The risk areas/hexagons resulting from the spatial query of the Geo-DB are highlighted. Source: Prepared by the authors using Google Maps ©2022, Marche Regional Technical Map 1:10000 (2000), Abruzzo Regional Technical Map 1:10000 (2007)

4. Discussion: Limitations and Potential of the Method

This work inevitably has some limitations with regard to the quality/quantity of the data acquired and variables developed, but it has outlined an interdisciplinary working method that aims to renew the cognitive framework of the large area of the mid-Adriatic coastal city, supporting the aims of the A_GreeNet project.

Here we briefly discuss the limits and potential of the three data processing steps.

With regard to the first topic (i.e. socio-demographic fragilities), the census sections do not follow the project perimeters but rather the administrative ones. It is possible that a census section may be cut off and/or include only a small extent of the area of study, which would consequently and erroneously receive all the data for the census section. This situation, even if it is small compared to the scale of the survey, could influence the spatial queries of the GeoDB (i.e. hexagons) and the resulting risk map. In this perspective, it is important to emphasize that all the data acquired by the municipalities are affected by the different size of the census (see Fig. 3 a; b) since the data are geo-localized with respect to the limits of the respective sections. The main municipalities and higher-density built areas include a greater number of smaller sections, for which the numerical data are smaller but concentrated with respect to the data for larger, sometimes 'peripheral' sections, which have a considerable number of fragile persons and target-users (see Fig. 3, c). In this sense, knowledge of the places and quality of the source data play a fundamental role in correctly interpreting the data. To partially overcome this problem, demographic and other data were georeferenced onto a uniform hexagonal grid and normalized. Moreover, for a complete overview of social vulnerability, multiple variables should be taken into account, such as per capita income, number of persons suffering from chronic and disabling diseases, hospital admissions, etc., which are currently not available. Anyway, the research made use of the most up-to-date registry data by working in synergy with technicians from the municipalities involved, going beyond open data that is publicly available (i.e. ISTAT census of 2011).

With regard to the second topic of interest (i.e. physical-territorial fragilities), the SAVI index provides fundamental cognitive support for quickly mapping greenery on the urban-territorial scale, but it returns mostly quantitative information. This index was preferred to the other common vegetation index used for a similar aim (NDVI), as it is particularly suitable for reducing the light/reflection effects of the different soil types, especially in areas with lower vegetation density such as the urban areas of the Adriatic city. Further qualitative/quantitative aspects could be provided from i) more detailed multispectral images (not available in open-source), ii) green censuses on a municipal basis (not always present or updated within the municipalities), and iii) a multi-temporal comparison between SAVI and other indexes such us the Normalized Difference Moisture Index (NDMI) and the Vegetation Health Index (VHI) proposed, for instance, in the literature (Maragno et al., 2021; Todeschi et al., 2023).

In our case, it must be emphasized that some permeable and semi-natural areas (i.e. agricultural crops), albeit few in number, appear as artificialized land such as buildings or asphalt surfaces if the soil is bare (i.e. agricultural crops subject to rotation) when the satellite shot was taken. In this perspective, a multi-temporal analysis of satellite images through SAVI would have been appropriate. Finally, for a cross-cutting analysis of the landscape-vegetation component, it would be useful to consider aspects such as the quality/function of the green areas (i.e. types of species present and their environmental/aesthetic value), accessibility, etc., which are difficult to investigate on the large scale and/or summarize as a numerical indicator. These considerations cannot all be addressed due to space/time issues, but will be treated on another scale using other methods during the next phase of A_GreeNet.

With regard to the third topic (i.e. meteorological-climate fragility), the limitations relate to i) the quality of data input (30–60 m/px), ii) the type of information (based on thermal exchanges between materials/elements on the ground and the satellite sensor), and iii) time (satellite image acquired only in the early morning). For a more inclusive critical overview, the data measured using a certain day/time set will be integrated with simulations capable of better understanding the relationship between urban form and climate variables, going

beyond the temperature parameter (wind, humidity, etc.), as established in the next phase of the project. Nevertheless, the LST index is widely used in the current literature for the same purposes, especially on the large scale. Even considering certain limitations, the results obtained from the cognitive framework highlight the areas most subject to thermal discomfort (i.e. Fig. 7) and show a trend of persistent thermal stress in the mid-Adriatic area (i.e. ST, Fig. 5) as also reported in the local meteorological reports.
An assessment of the potential of green infrastructure to investigate hydrogeological risk (Lai et al., 2021) as well as an analysis of the aerobiological risk of trees (i.e. allergenicity) using different GIS techniques and data (Pecero-Casimiro et al., 2019) would be interesting in order to complete such a cognitive framework.
The analysis of flash floods is needed in future research and GIScience can also support researchers in this case (Lin et al., 2019). In this specific case, it was preferable to acquire official, recently updated (2021) hydrogeological data, considering that i) the topic is secondary with respect to A_GreeNet, albeit fundamental with respect to strategy, and ii) the data processing would probably not have implemented the knowledge already developed by the relevant bodies. In this sense, Digital Terrain Models (DTMs), Digital Surface Models (DSMs), and specific tools to identify areas of catchment/flooding should be used, especially where multiple fragilities have been identified. In this specific case, this type of data cannot easily be acquired for all the areas involved in the project due to the time required to request the data and/or differentiate them geometrically.
Finally, from these reflections, it is evident that beyond the quantity of data, the quality of the data (spatially and semantically) and technological tools (algorithm, geoprocess etc.) determine the quality of the geoDB and related maps. This type of map (Fig. 7) is one of 'n' possible geo-spatial queries[32] on the specific dataset. In this sense, data interrogation presupposes i) discretionary validation if scientific thresholds are missing, and ii) a critical interpretation of the data and results associated with an in-depth understanding of site-specific dynamics. This framework gives rise to the need for an integrated dialogue between geo-based instrumental innovation and traditional techniques/approaches used in urban and landscape studies that are not uniquely related to alphanumeric attributes and processes involved in exact sciences. Even with such intrinsic limitations, the benefits of geo-technological progress in developing multi-temporal analyses on different scales, managing and promptly implementing public databases, and understanding of landscape dynamics from a different perspective is unquestionable.

5. Conclusion

This research presents a scientific methodology to critically assess territorial fragilities on the large scale with respect to three important topics. The process was tested in line with the A_GreeNet aims in order to: i) semi-automatically identify urban green areas and the limits/margins of coastal UGI; ii) highlight urban areas subject to social fragility and thermal discomfort; iii) test and improve a current method (Cocci Grifoni et al, 2022; Caprari, 2022) for downscaling such analysis from the macro to micro scale in order to focus on risk areas/subareas to prioritize actions for UGI improvements; iv) disseminate the value of open data to support territorial monitoring; and v) draw the attention of local planning authorities involved in the project to the need for site-specific UGI interventions and their role as a 'health device' for local communities.
The last point especially, i.e. the technical-operational impacts of the project, is still in progress and constitutes the greatest value and ambition of A_GreeNet.
The research presented here and the climate forecasts being developed (UMEP, ENVI-met) are designed to support PAs practitioners in deciding how/where to focus improvements of the UGI (e.g. reforestation, diversifying the agricultural/natural landscape, regenerating green areas, plant health restoration, etc.).

[32] For example, to display the map as shown in Fig. 7, all areas that are completely artificialized and impermeable or those with a high thermal stress were highlighted (see Tables 2, 3) and linked to those with a large number of fragile residents. In this case, the two macro risk categories were highlighted individually with two separate spatial queries for greater clarity considering synergies with the various stakeholders.

Such actions are not general but have considered the local urban plans and the specific legal status of the territory (i.e. prescription), especially where greening has not been implemented as planned and where several risks and critical factors are present (i.e. risk map).
In this context, the purpose of the project is to establish the groundwork for a governance structure that operates across multiple levels and involves various stakeholders. This means enhancing capacities in both administrative-management and technical-operational aspects related to climate adaptation.
It also encompasses the revitalization of knowledge frameworks (i.e. GIScience) and the enhancement of design capabilities for green infrastructure on various scales. This is achieved by contributing to the existing urban planning instruments and building regulations that have already gained approval (D'Onofrio et al, 2023; D'Onofrio et al, 2022). The innovation of the research lies in the generation of a contemporary, adaptable, and incremental evidence-based geo-database that combines the quantitative approach of synthetic data with analogue supervision throughout all stages of the process and a thorough examination of municipal planning regulations. This outcome contributes to the scientific debate on renovating cognitive processes for understanding territorial fragilities, transformations caused by climate change, and socio-demographic dynamics. The initial findings of the on-going research reaffirm the contribution of new technologies, geographical methods, and data that need to be integrated with traditional approaches to urban and landscape analysis. This integration is particularly crucial on larger scales, where geospatial observation reduces time requirements and unveils relationships that are less discernible with analogue instruments. It also enables the activation of a cyclical process of qualitative and quantitative monitoring and verification of the results of UGI policies/interventions. The potential research advancements encompass the inclusion of additional input data pertaining to the variables that have been developed. This may involve integrating data from municipal green censuses, municipal tree health reports, surveys of abandoned buildings or unused public heritage areas, per-capita income, data on individuals with chronic or disabling illnesses, and hospital admissions during specific periods (such as heat waves or the entire summer), along with high-resolution multispectral images. Moreover, the study stands to gain from the use of additional scientific indices, as mentioned earlier, or methods for semi-automatic serial data analysis.
This approach would enable the integration of a more extensive dataset or satellite images. Additionally, the scope of the research could be expanded by incorporating an analysis of urban accessibility to green areas (e.g. network analysis) and/or an assessment of the morphology of open spaces (e.g. slopes and outflows) to identify the areas most susceptible to flooding. Here, we also emphasize that the development of the GeoDB, scientific indexes and cartographies was made possible by Open Data and Open Science (GIS-based tools). In this perspective, the method promotes the spread of transferable open-access methods based on free-access data and portals and an updatable geoDB data that can be downloaded from the official project website. Disparities in public datasets related to both individual geometries and information quality is certainly not uncommon. This shortfall can be ascribed to limitations in the national/local digital transformation process, digital/technological skills, administrative and governmental challenges related to data transparency, the failure to update datasets, or the absence of certain datasets. The transferability of the method is contingent to a significant extent on these factors.
In conclusion, the forthcoming stages of research will consider interconnections between urban planning and the role of green spaces in enhancing the quality of life, supported by a refined understanding and capabilities offered by GIScience. UGI emerges as a structural constant, providing fertile ground for collaborative experimental research between academia and practice, aimed at fostering a more resilient living environment.

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Contributions of native plants to the urban ecosystem: Bursa (Turkey) sample

Native plants in urban ecosystem

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Abstract
In the coming years, it is a potential danger that the ecosystems existing in urban areas will be heavily affected, especially under the pressure of climate change. In the face of this danger, a good understanding of the natural landscape in urban areas and the adoption of local species are of great importance for sustainability. Native plants contribute to the life of their communities by quickly adapting to the environmental conditions in their areas. In this study, the contributions of 72 native woody taxa to the ecosystem were investigated in Bursa (Turkey), which has a rich flora. The relationships that emerged in terms of the criteria examined revealed essential results. The existence of some relationships between the criteria found in the study, like "significant positive correlation was determined at the 5% level between bee attraction and erosion prevention or negative correlation at the 5% level with bee attraction and water demand", shows that the use of native plants is vital for the protection of the ecosystem in urban areas. The primary purpose is to examine the ecological needs of native plants and their contribution to urban ecology to determine whether the existing correlation relationships are meaningful. It is aimed to associate natural areas in cities with the ecological needs of plants.

Keywords
Native plants; Sustainability; Urban ecosystem

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1. Introduction

With the discovery of agriculture in the Neolithic period, the first activities of people on changing nature began, and in this context, planting seeds of plants, taming animals, settling in certain places, and building houses were seen as the first examples of landscaping.

The fact that people started to change the landscape through agriculture has led to the emergence of limited nature destruction (Gül, 2000). It is seen that the "Natural Landscape," which has effects from the Stone Age to the present, has decreased with destruction from prehistoric times to the present (Akurgal, 1998). In the following processes, factors such as rapid population growth, the emergence of the Industrial Revolution, and urbanization caused a rapid increase in the interventions to the natural landscape, which accelerated environmental pollution and started to affect ecosystems negatively.

Due to these negativities that have arisen today, people all over the world have begun to worry about "denaturalizing," that is, breaking away from nature or disappearing (Gül, 2000). In order to address these and similar concerns, Miller, Simonds, and other researchers suggested 100 years ago that the use of native plants in the landscape is a good option, the evaluation of natural conditions in the natural landscape, the realization of "naturalistic" arrangements based on the recreation of nature rather than artificial arrangements in the design approach.

Wilheim Miller, working at the University of Illinois in 1912, published his work called "Designing in the Prairie Spirit" as a series of articles and gave information about the use of native plants in residential gardens, agriculture, parks, roadside design, and rural restoration.

One of the first practitioners of Miller's ideas was landscape architect Ossian C. Simonds, who worked in Chicago (SNR, 2011).

Parallel to these developments, attempts to minimize human intervention and control in landscape design and applications have increased rapidly. The increase in non-native species is unintentionally or intentionally associated with human activities (Richardson et al., 2000; Garcillan and Martorell, 2021).

In particular, natural landscape design and applications, which envisage the promotion of wildlife in cities and the increase of natural areas depending on ecological principles, have started to become popular in Europe and America (Özgüner, 2003).According to Kendle and Forbes (1997), low-cost sustainable landscapes can be created with the natural landscape style, the real meaning of the landscape can be reflected, a significant contrast to the classical style design experiences can be achieved, the value of the area in terms of environmental protection, environmental education, and recreational use can be increased, the public landscape can be valued.

This natural landscape style is characterized by diversity of species, structural complexity in plant communities, absence of uniform structure, maximum use of natural elements, especially native species, minimal use of artificial elements and exotic species, minimal human influence in design and implementation, and environmental control. It has begun to be adopted by many of the modern landscape designers and planners who argue that it should be limited (Özgüner, 2003).

The common point of the studies on the ecosystem integrity of natural vegetation, its contribution to biodiversity, and its contribution to ensuring habitat continuity is the threat posed to biodiversity by habitat fragmentation. This threat reveals the necessity of maintaining ecosystem balance and continuity, creating corridors that will allow transitions between natural vegetation and urban landscape, and disseminating the use of more intense native plant species in urban areas (Deniz and Şirin, 2005; Bianconi et al., 2018).

This situation is extremely important for sustainable plant designs, defined as "planting or vegetation management that preserves and maintains ecological integrity, encourages the use of native opportunities for plant resources and species selection, and foresees the use of minimum energy and physical resources in production." The basis of this approach is closely related to resource protection and management.

The use of native plants in this process is considered more appropriate with considerations such as "the native species' adaptation to the terrain and climatic conditions of the region, providing shelter for many animal species, and their successful performance in problematic areas" (Dunnet and Hitchmough, 1996; Kennedy and Southwood, 1994; Özgüner, 2003).

On the other hand, securing their lives in urban areas where insects and animals have to live as vulnerable to human interactions along with their housing problems requires excellent efforts. However, despite the challenges of existing in urban environments, many wildlife species have adapted to these systems.

It is crucial to understand the natural landscape better and to adopt native species in order to make ecosystems sustainable in urban areas without breaking the chain of life (Flyger, 1974; Atkinson and Shackleton, 1991; Quinn, 1992; Gliwicz et al., 1994; Gustafson, 1998; Burger et al., 2004; Parker and Nilon, 2008; Parker and Nilon, 2012) this is also a critical tool for habitat identification and conservation of wildlife species (Johnson, 1995; Clergeau et al., 1998; Livingston et al., 2003).

Native plants are in mutual interaction with all physical and biotic factors in the areas where they are found, effortlessly adapting to environmental conditions, contributing to the life of natural living communities, requiring less care, being a source of shelter and food for wildlife, landscaping, protection and restoration projects. It also has many features, such as being among the significant alternative sources (Barış, 2002; Deniz and Şirin, 2005; Çorbacı et al., 2017; Eroğlu 2010).

In addition to these contributions, exotic plant species contribute almost nothing to the food web (Anonymous, 2019).

However, the existence of natural vegetation has unlimited direct and indirect benefits to the country's economy.

It is a resource for improving the climatic conditions of a country and preventing soil loss in other rural areas, laying the groundwork for scientific research, and meeting the raw material and fuel needs of forest products, food, and pharmaceutical industry units (Cengiz, 2001).

The use of natural vegetation samples in landscape architecture works is an application that is compatible with ecological, economic, and aesthetic conditions, as well as a landscape design in harmony with nature (Akdoğan, 1972; Atik and Karagüzel, 2007; Altunkasa et al., 2017).

In designs, With the use of native plants, ecological benefits such as protecting biological diversity, providing a habitat for wildlife species, and creating a healthy plant tissue, economic benefits such as reducing fertilization, spraying, and irrigation needs and costs, and aesthetic benefits such as improving environmental quality are provided (Slattery et al., 2003; Atik and Karagüzel, 2007).

In this study, native woody plant taxa in the flora of Bursa province were examined, and their contributions to the ecosystem were tried to be revealed.

As can be expected, many studies have been conducted on natural plants and the aesthetic and ecological properties of plants, and the above examples have been selected only as examples and support for those included in our study. However, there are very few studies in the literature where aesthetic and ecological properties are evaluated simultaneously on natural plants.

In addition, the study area has been determined so that many natural plants with different needs can coexist at the same time.

The aim was to take advantage of both the evaluated features and the ability of the area to provide different geographical and climatic conditions simultaneously.

In this way, the information produced by this study conducted in a specific location will be available to researchers from all over the world.

2. Material and Methods

2.1 Material

The woody taxa (tab. 1), which are found naturally in the flora of Bursa and evaluated as landscape plants and also have the potential to be evaluated by Zencirkıran (2004), Zencirkıran (2009), were utilized as study material.

1. Pinus pinea L.	**25.** Fagus orientalis	**49.** Tilia argentea Desf.ex.DC.
2. Pinus brutia Henry.	**26.** Castanea sativa Mill.	**50.** Tamarix parviflora DC.
3. Pinus nigra Arn. ssp. pallasiana (Lamb.) Holmboe.	**27.** Quercus robur L. ssp.robur	**51.** Cercis siliquastrum L.
4. Pinus silvestris L.	**28.** Quercus frainetto Ten.	**52.** Spartium junceum L.
5. Abies nordmanniana (Stev.)Spach ssp. bornmülleriana Mattf.	**29.** Quercus petraea (Mattuschka) Liebl. ssp. iberica (Steven ex Bieb.)	**53.** Chamaecytisus hirsutus (L.) Link.
6. Juniperus communis ssp. Nana	**30.** Quercus hartwissiana Stev infectoria Olivier ssp. nfectoria (Reut) Schwarz.	**54.** Chamaecytisus austriacus (L.) Link.
7. Juniperus oxycedrus L.	**31.** Quercus pubescens Wild.	**55.** Chamaecytisus pygmaeus (Willd) Rothm.
8. Juniperus excelsa L.	**32.** Quercus ithaburensis	**56.** Vitex agnus-castus L.
9. Taxus baccata L.	**33.** Quercus trojana P.B. Webb.	**57.** Hedera helix L.
10. Acer campestre L.	**34.** Quercus coccifera L.	**58.** Daphne oleoides Schreber
11. Acer platanoides L.	**35.** Quercus hartwissiana Stev.	**59.** Daphne pontica L.
12. Pistacia terebinthus L.	**36.** Laurus nobilis L.	**60.** Daphne sericea L.
13. Rhus coriaria L.	**37.** Fraxinus ornus L.	**61.** Cistus laurifolius L.
14. Alnus glutinosa L. Gaertn.	**38.** Olea europaea L.	**62.** Cistus salviifolius L.
15. Carpinus betulus L.	**39.** Jasminum fruticans L.	**63.** Cistus creticus L.
16. Coryllus avellana L.	**40.** Phillyrea latifolia L.	**64.** Euonymous europaeus L.
17. Cornus mas L.	**41.** Platanus orientalis L.	**65.** Pyracantha coccinea M.J.Roem.
18. Cornus sanguinea L. subsp. sanguinea	**42.** Salix caprea L.	**66.** Rosa gallica L.
19. Arbutus unedo L.	**43.** Salix cinerea L.	**67.** Rosa canina L.
20. Arbutus andrachne L.	**44.** Salix amplexicaulis L.	**68.** Clematis viticella L.
21. Erica arborea L.	**45.** Populus alba L	**69.** Clematis cirrhosa L.
22. Vaccinium myrtillus L.	**46.** Populus tremula L.	**70.** Ruscus aculeatus L.
23. Vaccinium uliginosum L.	**47.** Ulmus glabra L.	**71.** Styrax officinalis L.
24. Vaccinium arctostaphyllos L.	**48.** Celtis australis L.	**72.** Viburnum tinus L.

Tab.1 Native woody taxa evaluated as research material

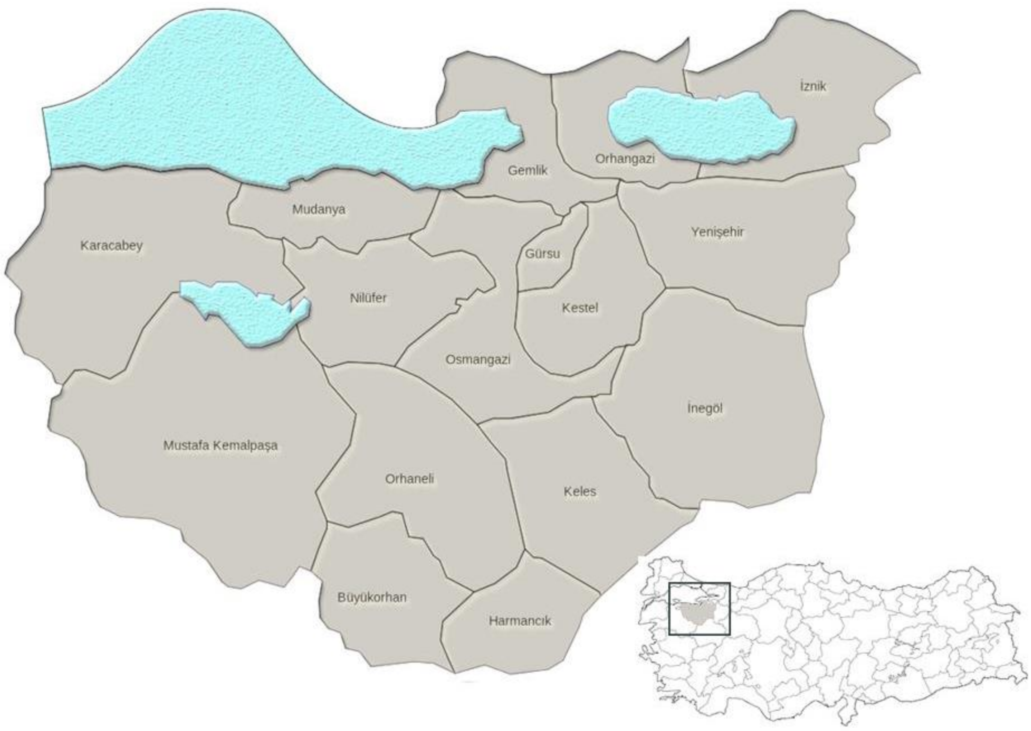

Fig.1 Location of the study area

Bursa, chosen as the study area and the fourth largest city of Turkey in terms of population, is located in the south of the Marmara Region, between 39° 30'-40° 37' north latitudes and 28° 06'-29° 58' east longitudes. It is surrounded by Bilecik and Sakarya in the east, Kocaeli, Yalova, Istanbul, and the Marmara Sea in the north, Kütahya in the south, and Balıkesir in the west (fig. 1) (Zencirkıran et al., 2019). Uludag, which has an altitude of 2543 m and hosts extremely important plant taxa, is located within the borders of Bursa province. On the northwest skirts of Uludağ is the Bursa Plain, where the city spreads. The hottest months of the city are July - August, and the coldest months are February and March. The annual total precipitation is 736.1 mm, and the average relative humidity is around 69%. The Mediterranean climate is dominant in Bursa, which has a coast to the Marmara Sea, with warm and dry summers and mild and rainy winters. Move away from the sea, a semi-terrestrial climate is observed in the interior (Korukçu and Arıcı, 1986; Zencirkıran, 2004; Ender and Zencirkıran, 2017; Zencirkıran et al. 2019).The critical factor in choosing the research area is that it has very different geographical and climatic features. The region includes elevations above 2500 meters, along with areas at sea level. Likewise, although the Mediterranean climate is predominant, examples of mountain climates and semi-terrestrial areas are also encountered in the research area. This ensures that the results of research in the field can be evaluated without being limited to the local area.

2.2 Method

One of the most important criteria taken into consideration when creating the idea of the study was to bring together different perspectives of looking at natural plants.

Therefore, a hypothesis was created that would use as much of the ecological and aesthetic properties of natural plants as possible. However, in the hypothetical preliminary evaluations, some of these factors were eliminated, and a more target-oriented approach was adopted. While doing this, it was also aimed to create a more innovative data set for future research by using features that have yet to be evaluated together in the literature so far.

Using sources such as Davis (1965-1985), Dirr (1998), Hillier (1998), Zencirkıran (2004), Native and Adapted Landscape Plants (2009), Zencirkıran (2009), Gardening with Native Plants (2012), Native Plants for your Landscape (2012), Zencirkıran (2013), Sarah et al. (2014), Florida-Friendly Landscaping™ Guide (2015), Zencirkıran et al. (2019) Akkemik (2020), Mamıkoğlu (2020) the criteria of taxa under the headings of "contributions to the ecosystem" and "ecological demands" were put forward.

The contributions of taxa to the ecosystem were evaluated within the scope of ecological criteria (creation of natural habitat (shelter), a food source for animals, a food source for humans, butterfly attraction, bee attraction (pollination), erosion prevention) and aesthetic criteria (autumn coloration, flowering period, form. Ecological demands of taxa were examined under the headings of water, soil, and light demands.

All data obtained were evaluated using the SPSS 22 for Windows package program (I.B.M. Corp Released 2013). Pearson correlation analysis was performed in order to determine the direction and strength of the relationships that may exist between the criteria (Miles and Banyard, 2007; Öztuna et al., 2008; Choi et al., 2010; Sheskin, 2011). Since all plants have the ability to create a natural habitat (shelter), the criterion of shelter was excluded, considering that it would prevent a statistically significant result in terms of relations between criteria. On the other hand, flower colors were not taken into consideration, considering that misleading results could be obtained regarding bees within the scope of the situations presented by some researchers such as Parker et al. (1987), Arbuckle et al. (2001), Willmer, and Stone (2004); Willmer (2011), Lunau et al. (1996), Spaethe et al. (2001), Manning (1956), Free (1970), Waser and Price (1985), Dafni and Giurfa (1999), Lunau (2000), Lunau, (2006), Hempel de Ibarra and Vorobyev (2009).

3. Findings

Within the scope of the research, it was determined that 38.9% of the 72 woody taxa naturally found and evaluated in Bursa flora were evergreen, and 61.1% were deciduous taxa. It was determined that 42% of the taxa had moderate water demand, 51% clayey-sandy-loam soil demand, and 51% were suitable to be kept in sun-half shade environments (Figures 2, 3, and 4).

Figure 2 shows the water demands of the taxa. The highest rate in these taxa is medium (42%). The lowest rate is high (4%) water demand.

In Figure 3, the highest soil demand rate (51%) is sandy clay loam. The lowest proportions are loam (4%) and sandy (5%).

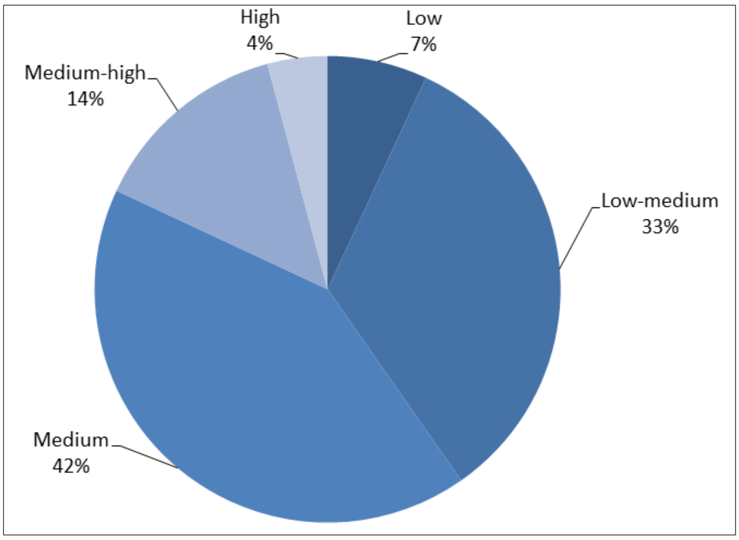

Fig.2 Distribution of the taxa according to their water demands

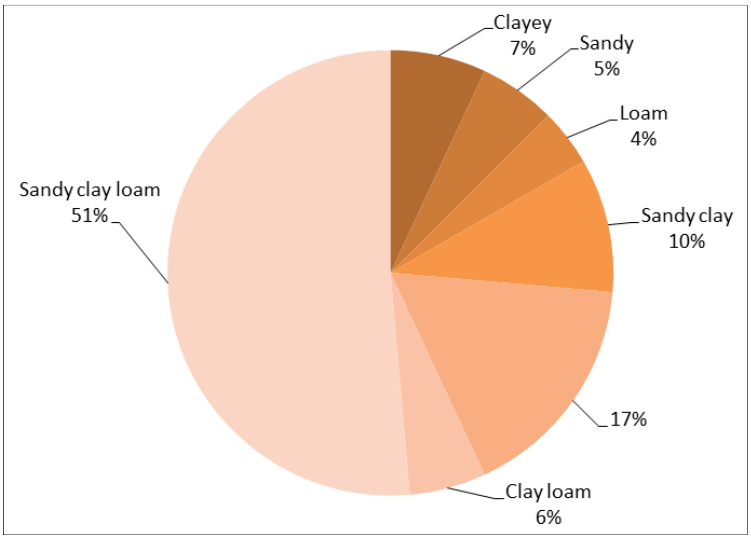

Fig.3 Distribution of the taxa according to their soil demands

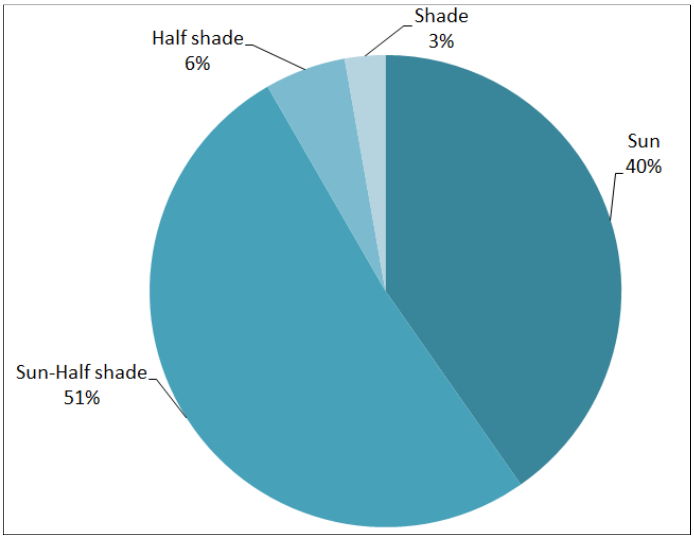

Fig.4 Distribution of the taxa according to their light demands

		Ecological Criteria					Aesthetic Criteria
		Food source for animals	Food source for humans	Butterfly Attraction	Bee Attraction	Erosion Prevention	Autumn coloration
Number	+*	29	19	29	44	36	16
	-	43	53	43	28	36	56
Percent	+	40,3%	26,4%	40,3%	61,1%	50,0%	22,2%
	-	59,7%	73,6%	59,7%	38,9%	50,0%	77,8%

* If the criterion is present in plants, it is +; if it is not - it is.

Tab.2 Distribution of taxa according to ecological and aesthetic criteria

Figure 4 shows the light demands of the taxa. The highest rate in these taxa is sun-half shade (51%). The lowest rate is shade (3%).

Table 2 shows that half of the taxa provide erosion prevention, and more than half attract bees. It has been determined that 19 species are food sources for humans, and 29 species are for animals. Autumn coloration as an aesthetic criterion is seen in 16 taxa.

The findings of the ecological and aesthetic criteria examined in terms of the contribution of taxa to the ecosystem are given in Table 2 and Figures 5 and 6.

In Figure 5, the highest flowering times proportions are one month of flowering (15%) and three months of flowering (15%). The lowest rate is nine months of flowering (1%). The form characters of the taxa are given in Figure 6. Taxa with rounded irregular shapes are the most numerous. The most minor form character is weeping. The mean values and standard deviations of the criteria are given in Table 3, and the relations between the criteria are given in Table 4 as a result of the correlation analyses made in terms of the dendrological characteristics and ecological demands of the taxa and their contributions to the ecosystem within the framework of ecological and aesthetic criteria.

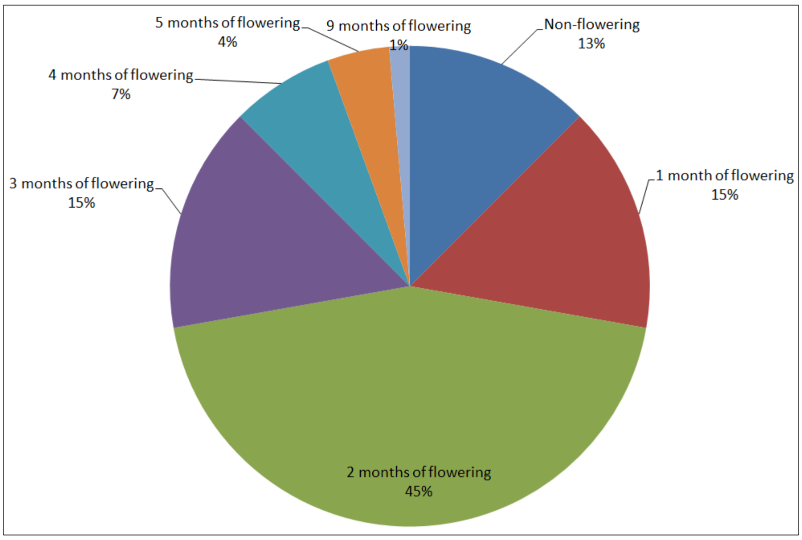

Fig.5 Distribution of the taxa according to their flowering times

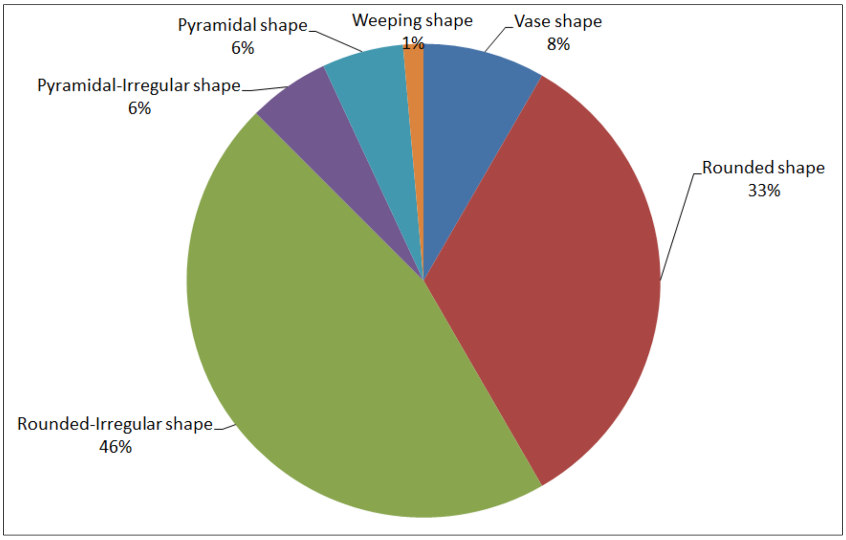

Fig.6 Distribution of the taxa according to their form characteristics

Criterion	Mean	Std.Deviations	Total
Leaf Characteristic	1,61	0,491	72
Water Demand	2,75	0,931	72
Soil Demand	3,38	1,347	72
Light Demand	1,71	0,701	72
Food Source for Animals	0,40	0,494	72
Food Source for Humans	0,26	0,444	72
Butterfly Attraction	0,40	0,494	72
Bee Attraction	0,61	0,491	72
Erosion Prevention	0,50	0,504	72
Autumn Coloration	0,22	0,419	72
Flowering Period	2,11	1,469	72
Form	2,71	0,999	72

Tab.3 The mean values and standard deviations of the criteria

A significant positive correlation was determined at the level of 1% between the leaf characteristics of taxa and their water demands. Also, 1% significant positive correlation was determined between the leaf characteristics of the taxa and the autumn coloration, a significant positive correlation at the level of 5% between the water demand and soil demand of taxa, significant negative at the level of 1% between soil demand and erosion prevention, significant negative at the level of 1% between soil demand and bee attraction feature, 1% significant positive correlation between being a food source for animals and a food source for humans and flowering period, significant positive correlation at the level of 5% between being a source of food for animals and bee attraction, 1% significant positive correlation between being a food source for humans and attracting butterflies and there is significant positive correlation at the 5% level between bee attraction. A 1% positive correlation was determined between attracting butterflies and attracting bees and also between butterfly attraction and flowering time. There is a 1% significant positive between bee attraction and flowering time. A significant positive correlation was determined at the 5% level between bee attraction and erosion prevention. There is a significant negative correlation at the 5% level with bee attraction and water demand. On the other hand, a significant negative correlation at the level of 5% was determined between bee attraction and form.

Criteria	Water Demand	Soil Demand	Light Demand	Food Source for Animals	Food Source for Humans	Butterfly Attraction	Bee Attraction	Erosion Prevention	Autumn Coloration	Flowering Period	Form
Leaf Characteristic	**.493****	0,160	-0,048	0,074	-0,040	0,074	-0,052	-0,228	**.426****	0,041	-0,005
Water Demand		**.289***	0,038	0,100	0,026	0,038	**-.247***	-0,180	0,181	-0,072	0,133
Soil Demand			-0,091	-0,082	0,044	0,193	**-.330****	**-.446****	0,125	0,050	0,124
Light Demand				-0,063	-0,066	-0,103	-0,212	-0,020	-0,016	-0,119	0,058
Food Source for Animals					**.536****	0,134	**.248***	0,142	0,038	**.326****	-0,101
Food Source for Humans						**.344****	**.284***	0,158	-0,017	0,149	0,112
Butterfly Attraction							**.481****	-0,198	-0,098	**.539****	-0,101
Bee Attraction								**.285***	-0,190	**.412****	**-.292***
Erosion Prevention									-0,067	-0,152	-0,042
Autumn Coloration										-0,041	0,022
Flowering Period											-0,218

If a p-value is less than 0.05, it is flagged with one star (*). If a p-value is less than 0.01, it is flagged with 2 stars (**).

Table 4 Relationship between criteria

4. Discussion and Conclusion

As stated in the material section, in choosing the research area, attention was paid to ensuring that the results were applicable to different fields beyond being local. The research area includes coastal areas at sea level as well as mountain areas above 2500 meters. This geographical difference also includes climatically different regions. In this way, the plant stock in the region will be identical to many different areas in the world in terms of its characteristics. At the same time, research parameters such as evaluated ecological and aesthetic criteria are factors that researchers in all parts of the world can benefit from.

In the coming years, it is a potential danger that the ecosystems existing in our urban areas will be affected, fragmented, and even destroyed, especially under the pressure of climate change. It is clear that the form and severity of the impact that this danger may cause will differ on the basis of countries and even cities (Shirgir et al., 2019; Gaglione and Ayiine-Etigo, 2021; Scheiber and Zucaro, 2023). As a matter of fact, Bastin et al. (2019), "Due to the possible effects of global warming in the coming years, more than 77% of the cities in the world may experience a change towards the climatic conditions of another major city by 2050. They also stated that 22% of them could switch to climatic conditions that are not currently available for any major city in the world" and that "the climate of Bursa city will be met with an average temperature increase of 2.4°C".

It is foreseen that this process, which can be experienced, will significantly and intensely affect urban areas and ecosystems. It is of great importance to ensure sustainability without breaking the existing chain of life in these areas. In this context, a good understanding of the natural landscape for sustainable ecosystems in urban areas, the adoption of native species (Flyger, 1974; Atkinson and Shackleton, 1991; Quinn, 1992; Gliwicz et al., 1994; Gustafson, 1998; Burger et al., 2004; Parker and Nilon, 2008; Parker and Nilon, 2012), for urban spaces where native species can easily adapt (Kowarik et al., 2013; Sjöman et al., 2016), the selection of suitable design plants by considering ecological concerns (Zencirkıran and Seyidoğlu Akdeniz, 2017) and the use of natural vegetation samples (Akdoğan 1972, Atik and Karagüzel, 2007) provide significant contributions.

On the other hand, native plants can adjust themselves to various sites, such as wet or dry, sun or shade, high or low fertility soils, and acidic or calcareous soils. If the usage is appropriate, native plants might: 1. be of an added contribution to wildlife, 2. require less maintenance, 3. provide a four-season use, 4. be a good option for irregular landscape planning, 5. preserve the native varieties, and maintain the biodiversity, and 6. add a local touch to the landscape (Sheaffer and Rose, 1998).

It is very rich in native plant taxa and has 1808 vascular plant taxa (Anonymous 2019). In this study, in which the ecological and aesthetic contributions of 72 woody taxa in Bursa flora to the ecosystem were examined, the relationships that emerged in terms of the criteria examined revealed essential results.

The existence of a positive relationship between features such as shelter for animals, being a food source, being a food source for humans, attracting butterflies, attracting bees, and preventing erosion, which are considered among ecological criteria in terms of contribution to the ecosystem, shows that the use of native plants is crucial for the preservation of ecosystem integrity.

Indeed, Shackleton (2016), McFrederick and LeBuhn (2006), and Frankie et al. (2005) emphasized in their studies that enriching the habitats in urban areas with native plants provides a source of food and shelter for more bird species and bees. Pardee and Philpott (2014), Pawelek et al. (2009), and Frankie et al. (2005) stated that the presence of native plants plays a vital role in the preservation of bee presence and diversity in urban ecosystems, while Karin et al. (2007) stated that there are more butterflies in native plants.

However, it has been emphasized that native plants provide critical benefits in preventing erosion and increasing pollination (Darricau, 2018; Elderbrock et al., 2020; Baqi et al., 2021) and contribute to the ecosystem by increasing biodiversity through their critical ecological functions (Kowarik, 2011).

Sustainability of ecosystem integrity, which is tried to be expressed above, is possible with designs made with natural taxa in the flora of that region (Zencirkıran, 2009; Korkut and ark., 2017), where natural resource consumption is minimized. In particular, the sustainability of the designs created with exotic plants, which do not contribute to the wildlife food web (Anonymous, 2019) due to some aesthetic concerns, does not seem possible due to the climate changes and urban pressures that may occur in the coming decades.

Although the study is specific to Bursa, both the characteristics of the region and the native plants found are common to many geographies of the world. For this reason, the points examined by the study are a guide for similar studies by the followers of the journal in their particular regions. Studies to be carried out in different regions will show us how native plants can be used in urban landscapes according to environmental priorities with a more extensive data set.

As a result, it is thought and recommended to pay attention to these issues that ecosystems in urban areas can be sustainable with design approaches in which the idea that they are the habitat of other living things within a system integrity and native plants and natural resources of that region are preferred. It is recommended to pay attention to these issues in designs in urban areas. All kinds of studies are gaining importance today in terms of protecting the environment, which has lost its balance due to the increase in natural destruction, climatic changes, and intensive construction. Demonstrating the relationship between the ecological needs of the plants that make up the natural cover of the regions with the protection and restoration of nature for scientific methodology will create a perspective that goes from local to global.

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Image Sources

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