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THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

Vol.16 n.1 April 2023

print ISSN 1970-9889 e-ISSN 1970-9870
University of Naples Federico II

TeMA Journal of
Land Use, Mobility and Environment

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

1 (2023)

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

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Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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1 (2023)

Contents

REVIEW NOTES

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2023) 47-65
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9736
Received 11th January 2023, Accepted 20th February 2023, Available online 30th April 2023

www.tema.unina.it

Nature-based solution for climate change adaptation and mitigation in urban areas with high natural risk

Proposals of possible measures for a municipality in the Vesuvius area

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Abstract
Nowadays, due to the problematic containment of pollutant emissions worldwide, the process of global warming is inevitable. Moreover, in urban environments, due to the strong anthropisation of the spatial context, these phenomena are often accentuated (e.g. urban heat islands). At the same time, the detrimental effects of the aforementioned process are often combined with other pre-existing risks linked to urbanisation in areas of high natural risk (e.g. hydrogeological and volcanic risk).
In this context, the first examples of the application of measures for adaptation and mitigation of climate change in urban areas are recorded in formulating the latest generation of urban plans. In this respect, natural-based solutions (NBS) are becoming favoured. These measures have a twofold beneficial effect on the urban reality, i.e., adaptation to the effects of climate change and increased renaturalisation of the urban area, with consequent mitigation of other natural hazards.
The present contribution aims to offer an analysis of the main NBSs applicable in an urban context and on different scales (from urban to building) and an applicative example related to their integration into territorial governance tools. In particular, the municipality of Cercola, a territorial context with a high natural risk in the Vesuvian area, has been analysed as a case study.

Keywords
Nature based solution; Adaptation; Urban planning; Sustainable construction techniques; Architectural engineering.

How to cite item in APA format
Mazzeo, G., & Polverino, S. (2023). Nature-based solution for climate change adaptation and mitigation in urban areas with high natural risk. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 47-65. http://dx.doi.org/10.6093/1970-9870/9736

1. Introduction

City and sustainability have become antithetical terms since the industrial revolution. Urban areas have increasingly evolved into an externally dependent ecosystem, i.e., the largest consumer of natural resources and the largest producer of pollution and waste (Mazzeo, 2016; Newman, 2006).

In recent years, global warming has become inevitable, despite numerous international efforts to limit it. The effects and consequences of this process on society and ecosystems can threaten the livability of urban systems, even threatening their survival, e.g. sea level rise in the case of coastal cities (Strauss et al., 2021).

Many phenomena characterise the Mediterranean area, which has become a hot spot of climate change (Lionello et al., 2014). The warming exceeds the global average increase of 20% (Lionello & Scarascia, 2018) and a reduction of precipitation in hot periods (Ulbrich et al., 2006) and sudden and destructive rainfall events (Cramer et al., 2018).

The radicalisation of environmental situations (e.g. climate change, reduction of habitat extent and species quality, modification of ecosystems, etc.) affects urbanised space. The effects are so significant that a rapid change in the planning approaches of cities and territories is required. This process pushes towards a radical rethinking of urban structures (Jenks & Jones, 2008; Mazzeo, 2021).

In this context, planning is thinking in depth about how it has acted in the recent past. The reasoning is also underway on the solutions that can positively affect territories and their ability to change the current paths. Examples of such trends are the fight against land consumption, the renaturalisation of territories, the application of design solutions based on the use of natural practices, the production and use of energy from renewable sources, attention to the natural capital present in territories, and adaptation to the effects of climate change (Balletto et al., 2022; Guida, 2022; Mazzeo, 2013; Pelorosso et al., 2018).

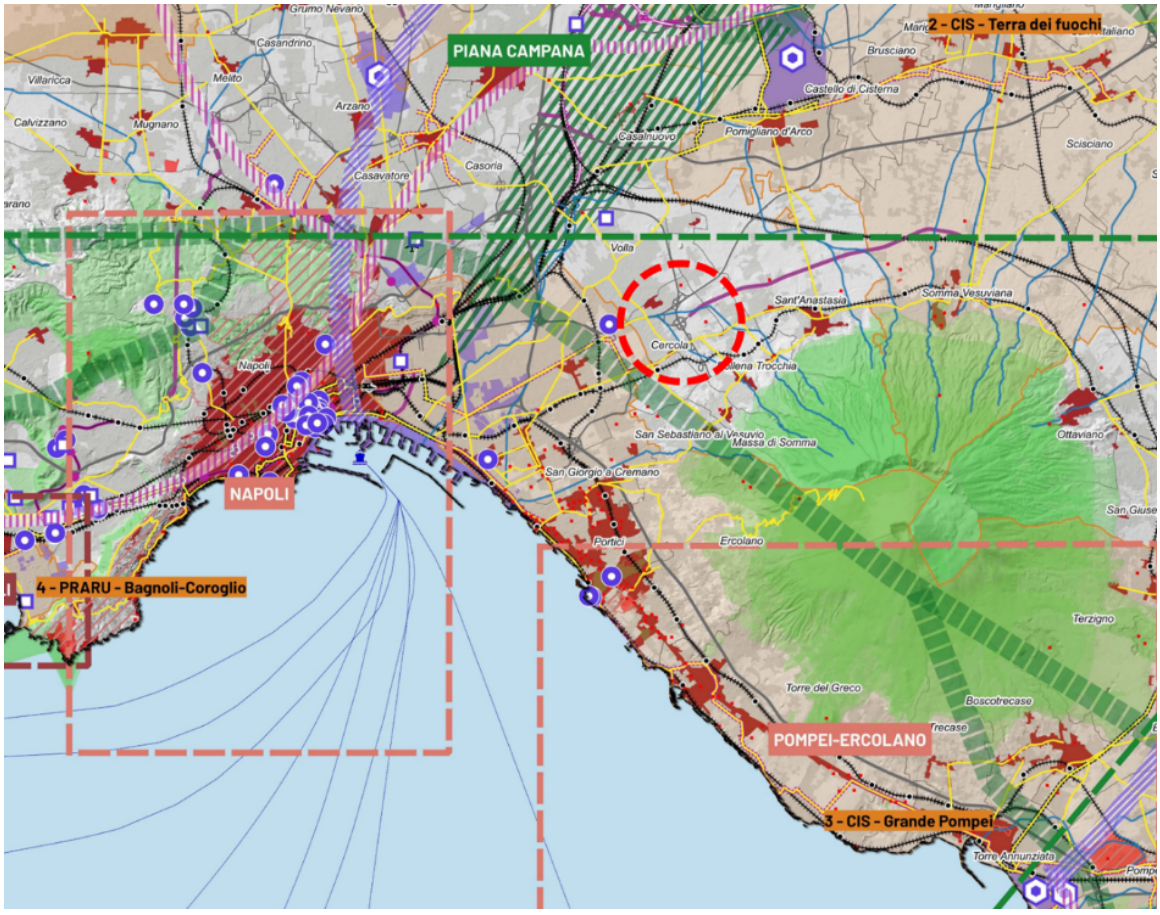

Fig.1 Municipality of Cercola within Metropolitan city of Naples. Extract from Metropolitan Territorial Plan, 2. Preparatory Strategic Scheme (2023)

A significant milestone is transitioning from the theoretical elaboration of principles to their implementation in planning practices.

At the same time, studies on possible applications of NBS for mitigation and adaptation often focus on highly urbanised contexts. As a result, they neglect the small to medium-sized urban realities that form the backbone of the Italian municipal system (ISTAT, 2022).

This paper aims to identify a series of supporting actions for an area at high natural risk in the context of climate change effects, i.e. the Municipality of Cercola located in the Metropolitan City of Naples (Fig. 1). In this respect, a series of actions are proposed to increase the capacity of the urban area to respond to the effects of climate change.

The following sections present the main nature-based solutions compatible with application in the Cercola municipal territory. The relation between applying mitigation and adaptation measures and the strategies outlined in the urban plans is then discussed, highlighting their location in the municipal territory.

2. Methodology

This research aims to present a proposal for applying land naturalisation and climate change mitigation and adaptation measures as an element to be integrated into urban planning (Fig.2).

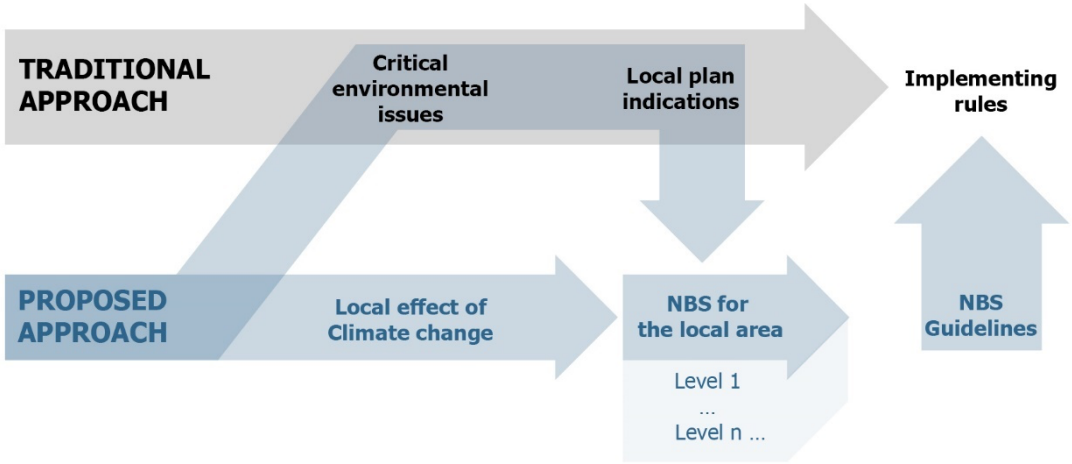

Fig.2 Proposed method for the integration of multiscalar NBSs into Urban plans

In order to achieve this objective, three main stages of research were identified.

In the first phase, the main characteristics of the Cercola territory were identified, and the principal risks and criticalities were analysed. The current territorial plans concerning the municipality and databases on climate and building stock were analysed for a better knowledge of the territory.

Next, the leading Nature-based solutions (NBS) compatible with the territory were analysed. At this stage, there was no intention to carry out a taxonomy of the main measures.

The main NBS measures applicable in the territorial context that can respond to specific criticalities of the territory were selected. The criteria that led to their selection were the following: the size of the intervention, i.e., the interventions range from the building scale to the urban scale; the comparability of the contexts where these measures were applied with the territory studied, i.e., measures were selected whose effectiveness has already been demonstrated in contexts that can be dimensionally compared with the Cercola territory; the feasibility of the intervention, i.e., solutions were selected whose realisation is compatible with the spending capacity of a municipal authority.

Finally, the last phase was formulating guidelines for the location of the identified measures on the analysed territory. The operation was carried out based on the vocational characteristics of the individual areas of the territory in order to define the most compatible and effective solutions.

2.1 Case study

The municipality of Cercola belongs to the Metropolitan City of Naples and is located on its eastern border. It has a population of 17,124 inhabitants (data as of 1 January 2022) with a limited territory (i.e., 4.23 km^2), resulting in a population density of 4,049 inhabitants/km^2. The settlement characteristics are influenced by its proximity to the city of Naples and its position in the metropolitan system. Many specificities characterise the urban area of the municipality of Cercola. The first characteristic consists of a complex system of communication infrastructures formed by medium-speed networks (SS162, SS268) serving the entire metropolitan area and by one of the Circumvesuviana railway lines that crosses the municipal territory from west to east. The intersections of the road networks, in particular, create an infrastructure system that occupies about 10% of the municipal territory.

A second specificity is in the north-western part of the municipal territory, bordering the city of Naples. In this part, there is a system of productive settlements, some of which are currently disused. This feature implies that the area presents significant degradation conditions that negatively affect the remaining urbanised part of the municipal territory. At the same time, there is a potential reserve of urbanised areas strategically located close to an area of Naples where significant transformation projects are underway and planned (Lanzi, 2016).

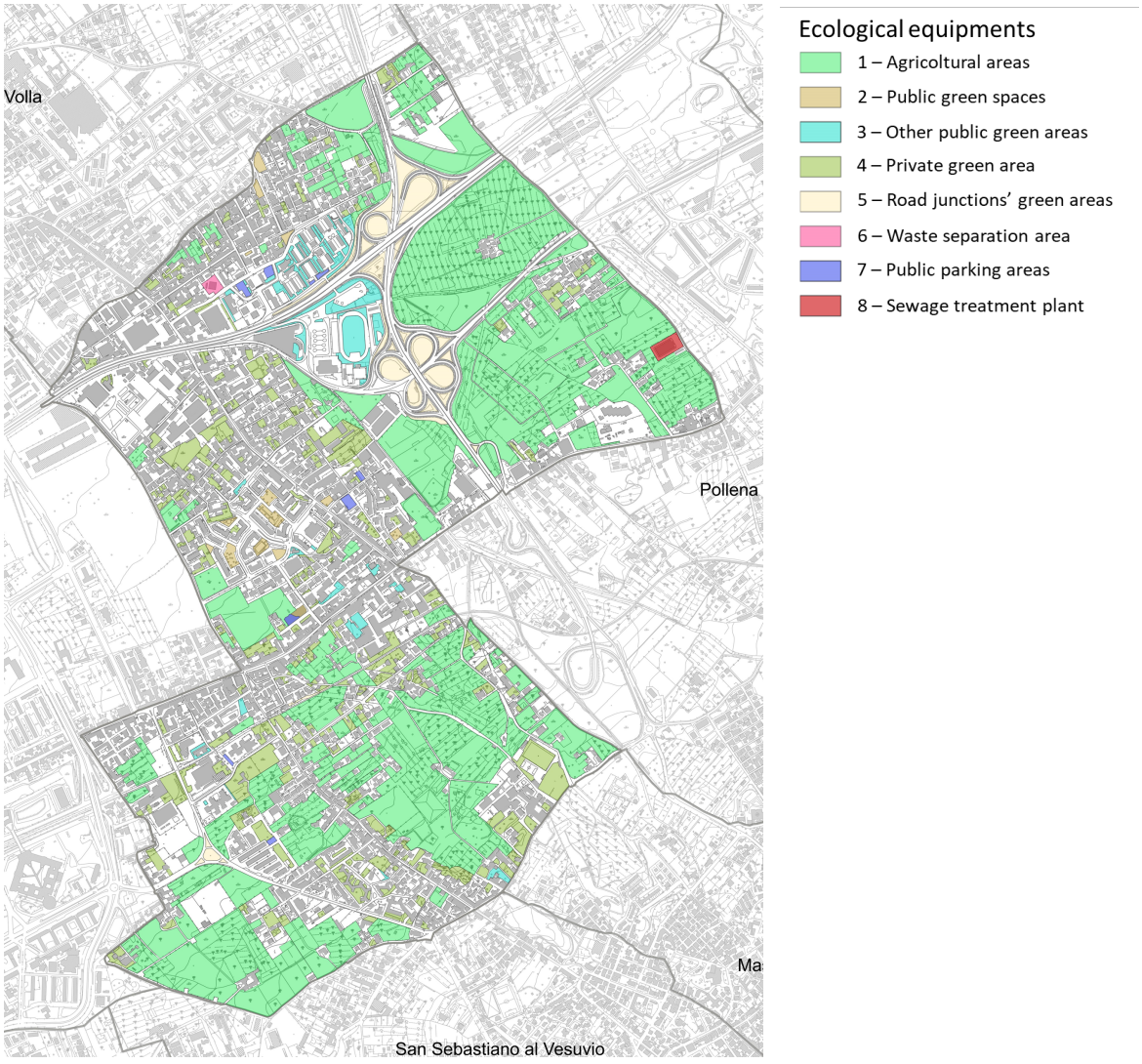

Fig.3 Municipality of Cercola. Ecological equipments present on the municipal territory

A third feature concerns the southern part of the municipality of Cercola, which is placed within the territory of the 'Piano Paesistico del Vesuvio' (Vesuvius landscape plan). Plan restriction should have protected the natural and agricultural characteristics of this part of the territory, which has all the features of the Campania Plain. However, despite the objectives, the protection of the territory has been partial. Diffuse settlement processes have occurred in the area, causing a significant fragmentation of the natural and agricultural fabric and, consequently, an overall loss of environmental quality.

The specificities mentioned above have negatively affected the urbanisation levels of the municipal territory. In this regard, according to ISPRA's 2021 data (ISPRA, 2022), reported by the web mapping of the Regional Environmental Protection Agency of Piedmont, soil consumption in the municipality of Cercola stands at the elevated value of 55.3%, well above the national (7.1%) and regional (10.5%) averages, which are already significantly high (Papa & Mazzeo, 2014).

Considering the critical issues outlined above, drafting the Municipal Urban Plan sought to respond systemically to the main problems in the area. The objectives identified are as follows:

- improvement of urban accessibility;
- increase of urban-territorial service facilities and simultaneous extension-modernisation of productive and tertiary activities;
- implementation of commercial activity;
- regeneration of the historical centre and environmental enhancement of the green system and agricultural parks;
- revitalisation of disused production sites;
- redevelopment, recovery and valorisation of the settlement structure.

A reading of the objectives shows that, although they cover diverse issues, they strongly focus on aspects related to environmental quality (Fig.3). Therefore, their transposition into the plan can have a particular impact on increasing the quality of the settlement fabric and must be coordinated with the indications and forecasts concerning the protection and quality of the natural system and agricultural landscape.

The municipal urban plan has focused on a project to increase the quality of the existing urban fabric, considering that the municipal territory cannot receive additional population; in this regard, it is within the perimeter of the High Volcanic Risk Zone due to its proximity to the volcano Vesuvius. Therefore, the interventions envisioned by the plan are to be implemented using interventions on existing buildings and infrastructures. In addition, another strategy concerns incremental action on specific environmental indicators affecting the adaptive capacity of the municipal territory. Therefore, one of the thematic studies within the Municipal Urban Plan focuses on the types of Nature Based Solutions to be applied in the requalification, regeneration and urban maintenance actions of Cercola's territory. This study, written by the Authors, is presented in detail in the following paragraphs.

3. Climatic/environmental framework of the case study

The analysis of the environmental and climatic peculiarities and criticalities of the Cercola area allowed the outlining of NBSs compatible with the territorial context.

The Cercola territory is closely characterised by the presence of natural and anthropic risks that highlight the territory's high vulnerability (Metropolitan City of Naples, 2013). The main natural criticalities that threaten the Cercola territory are related to volcanic, seismic, geomorphological and hydrogeological risks.

The main natural risk is the proximity of the municipal territory to the volcano Vesuvius. The short distance from the volcanic massif puts the municipality at risk of lava and pyroclastic flows (Red Zone of the Civil

Protection Emergency plan[1]); as a result, the territory is subject to specific sector plans aimed at decongesting the urban fabric (e.g. Strategic Operational Plan - Campania Region, 2006) [2]. Existing volcanic risk plans imply that new constructions for residential purposes are forbidden and that only productive, commercial, and public utility uses are allowed.

Regarding hydrogeological and geomorphological risk (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015), documentation from the basin authorities shows that the municipal territory is not subject to landslide risk but to hydraulic risk. The surface hydrographic network of the municipal territory is characterised by the presence of two 'lagni' (i.e., canals), Pollena and Trocchia.

The hydro-geomorphological risk in the Cercola area is mainly linked to environmental and ecological degradation. Points classified as very high and moderate risk are located near the filled watercourses. In this case, the plans prescribe measures that do not increase the hazard characteristics (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015). In recent years, intervention in the surface water network has been combined with massive soil sealing due to urban expansion. This phenomenon affects groundwater recharge and leads to increased water volumes for sewage disposal systems (Scalenghe & Ajmone-Marsan, 2009). The critical nature of the issue is evidenced by intervention indications in other territorial plans (Campania Region, 2002) that prohibit further sealing of open areas, prescribing filter paving.

Critical issues related to anthropogenic activities are ecological-environmental degradation, weakness of the infrastructure network, morphological-settlement degradation, urban discomfort and loss of agricultural-natural land.

The ecological-environmental degradation concerns the land use of the municipal territory. In particular, there is an evident prevalence of urbanised land (256 ha), while only a small part still has agricultural connotations (148 ha). Moreover, the agricultural land is fragmented throughout the territory and, together with the 19 ha that present natural characteristics represent the only portions of land that have survived the massive urbanisation that began in 1960 (Municipality of Cercola, 2019).

Rapid and uncontrolled urbanisation has triggered critical issues concerning road infrastructure and the built fabric. The road network constitutes the primary source of morphological settlement degradation and the principal source of noise disturbance and pollution from vehicle traffic. However, in recent years, the impact of traffic has yet to be the subject of intervention, as witnessed by the absence of specific measures to mitigate the phenomenon, i.e., buffer strips (Metropolitan City of Naples, 2013). In addition, the urban road system is also affected by the lack of parking areas, which currently fall short of the minimum allocation required by law (Municipality of Cercola, 2019).

The building fabric has been characterised, as in neighbouring municipalities, by intense building growth that has distorted the original agricultural vocation of the area (Metropolitan City of Naples, 2013). According to the age of construction and building characteristics, the urbanised territory can be divided into four types of settlements: the historic "core" city, the linearly dispersed historic city, the newly formed city, and the agricultural city (Municipality of Cercola, 2019). The unevenness of the building fabric is evidence of how the municipality presents, at the same time, peculiarities of a centre in a highly urbanised metropolitan area and of an environment that is still rural (Metropolitan City of Naples, 2013).

Morphological and settlement degradation and urban discomfort are linked to criticalities such as limited access to public facilities, e.g. public green spaces. The criticalities inherent in the built fabric are evidence of the unbalanced nature of the built fabric, the result of a lack of a unitary settlement rule, which has led to the maximum exploitation of building lots. In addition, the speculative logic has led to the construction of

1 Updated by Regional Law no. 21, "Norme Urbanistiche per i comuni rientranti nelle zone a rischio vulcanico dell'Area Vesuviana".

2 Guideline of the President of the Council of Ministers of 14 February 2014 entitled "Disposizioni per l'aggiornamento della pianificazione di emergenza per il rischio volcanico del Vesuvio" (GU n.v108/2014).

buildings of low architectural quality, which are characterised by reinforced concrete and load-bearing masonry structures (ISTAT, 2011).

At the same time, in recent years, there has been a considerable increase in brownfield sites (Municipality of Cercola, 2019), which are portions of territory that can be used as a driving force for economic development.

A fraction of the Cercola municipal territory is still used for agricultural purposes. The rural territory can be subdivided into two main areas: the first is hilly, close to the built-up area in the southern part of the territory, and the second is linked to Monte Somma, an element of the Vesuvius volcanic complex. Due to its peculiarities, agricultural activity is based on orchards, a type that enriches the biodiversity of the area and is less impacting than intensive farming (e.g. wheat, maize, etc.). (Metropolitan City of Naples, 2013). Currently, the loss and fragmentation of the agricultural fabric emerge, which is not linked to a change of use at the planning level but to a progressive abandonment and reduction of agricultural land use.

The current state contrasts with the potential of the sector, which is characterised by territorial excellence that can represent a resource for the economic development of the area (Municipality of Cercola, 2019).

Closely linked to agricultural land are the areas for naturalistic purposes, which cover a total of 19 ha. These are primarily bushes and scattered trees that contribute to the networks of natural connections. The natural areas form a buffer zone between the urban centre (i.e., building fabric and infrastructure networks) and the agricultural areas (Metropolitan City of Naples, 2013). In addition, the Cercola area also lies along the Tyrrhenian corridors for migratory avifauna. These areas are progressively threatened by anthropic actions (fires, groundwater pollution, etc.) that threaten their existence.

The protection and enhancement of natural areas is a priority highlighted by territorial planning (Campania Region, 2008), which can take place through the reconstitution of an ecological network using operations to restore environmental continuity. The protection operation is of primary importance since the municipal territory is on the edge of the Vesuvius National Park and is particularly important in protecting biodiversity and the ecosystem.

Another critical aspect of the territory linked to human activities that threatens the local ecosystem is environmental pollution, which affects the state of air and water. Air pollution in the Cercola area is mainly linked to vehicle traffic and PM10 emissions, the maximum value of which has been exceeded several times in recent years (e.g. 36 times in 2022) (ARPAC, 2022). Air quality is consistent with that characterising the Naples metropolitan area, identified as a 'rehabilitation zone', i.e., a territory where the threshold values of pollutants are exceeded several times during the year (Campania Region, 2005).

Water pollution affects the hydrographic network of the adjacent Campania plain. In particular, like other centres in the Vesuvian area, the pollutants are nitrates from agricultural activities and runoff from urban roads (Campania Region, 2019).

Lastly, in addition to the critical issues highlighted above, there are also meteorological phenomena linked to the effects of climate change. The Cercola territory, like the Neapolitan metropolitan area, will be increasingly affected by rising summer temperatures and heat island phenomena, more prolonged droughts and extreme rainfall phenomena (Metropolitan City of Naples, 2022). The main measures for the municipal area to cope with present and future criticalities are presented in the next section.

4. Identification and classification of the suitable NBSs

The second phase of this work was identifying possible nature-based solutions for climate change adaptation and mitigation for the municipality of Cercola.

As known, among the strategies to cope with the effects of climate change, those aimed at adaptation and mitigation are among the most widely adopted. These two concepts are often confused, but they present different approaches to the same problem; in fact, mitigation involves acting on the causes of climate change in order to avoid worse effects, e.g. interventions to improve energy efficiency in order to reduce the

consumption of the building stock for heating and cooling. On the contrary, adaptation focuses more on effects by defining strategies to limit the potentially destructive consequences of climate change effects, e.g. the use of measures to face cloudbursts due to Mediterranean climate tropicalisation (IPCC, 2022). Recently, measures for adaptation and mitigation defined as nature-based (NB) have been reported in the literature (Johnson et al., 2022). Their name is due to their low environmental impact and contribution to the renaturalisation of the urban territory. Generally, these measures can be classified into mitigation measures (e.g. urban farms that optimise resources by cutting pollutant emissions related to goods transport) and adaptation solutions (e.g. urban green areas that limit UHI). However, often the division into two families is not very clear-cut as some elements can be considered "mixed" and whose beneficial effects of their adoption can be exploited for both adaptation and mitigation. Among these, a significant example is the use of the green envelope of buildings, as it improves the energy performance of buildings and, at the same time, mitigates extreme phenomena such as UHI. As mentioned in section 2, this work does not intend to produce a generic taxonomy of all NBSs, which has already been extensively addressed in the literature (Fan et al., 2017; Zoppi, 2020). Instead, starting from an analysis of the state of the art of the subject and exploring the potential and limitations of the solutions, the main NBSs compatible with the case study were identified and classified according to their effect (e.g. mitigation and/or adaptation). In particular, the scale of intervention, similar PUC objectives and case studies reported in the literature in contexts similar to the municipality of Cercola were considered primary criteria for the choice.

The identified solutions were divided into three main categories according to the scope scale: 'building scale', 'urban public space and efficient water management' and 'natural and rural areas'. The chosen criteria are derived from analysing the PUC's transformation objectives and responding to specific actions.

The NBS solutions for adaptation and mitigation to climate change at the building scale (Tab. 1) selected act mainly on the building envelope, favouring its naturalization, with a re-greening process as highlighted in the territorial plans (Metropolitan City of Naples, 2022).

This category includes green roofs, a widely established solution in the Mediterranean climate that has evolved into solutions such as urban farms and wetland roofs in recent years (Zehnsdorf et al., 2019). Urban farms respond to the need to strengthen social communities in an urban environment and optimise the food production cycle, i.e., the time and impact of transport are reduced (de Oliveira et al., 2021). Wetland roofing, on the other hand, is a system that combines the benefits of a green roof with better rainwater management, i.e., it allows rainwater to be stored and does not overload urban drainage systems (Petreje et al., 2023).

Another intervention at the building scale is the construction of so-called green walls, which involve installing elements employing plant organisms to mitigate phenomena such as the urban heat island (UHI) (Susca et al., 2022) and improve air quality (Ysebaert et al., 2021).

Many green wall systems are currently applicable in the Cercola context: from climatic façades, i.e., the installation of rows with creepers (Chàfer et al., 2021), to more complex systems, e.g. living walls (Susorova, 2015); the latter involve the installation of felts in which tree essences are grown, fed by hydroponic irrigation systems, which allow considerable water savings (Kazemi et al., 2020).

At the building scale, in addition to the measures already shown, there are home gardens, easy-to-implement solutions that have less impact on urban comfort but affect indoor ones (Zhang et al., 2021). Lastly, a further solution working at the building scale is the installation of vertical farms, which can contribute to the reuse of disused production areas (Boganini & Casazza, 2017); this measure has a low environmental impact, i.e., it cuts transport emissions and optimises the necessary water resources (Naskali et al., 2022).

The solutions at the building scale meet the PUC's transformation objectives, e.g. regeneration of the historical centre and redevelopment, recovery and valorisation of the settlement structure. Furthermore,

they are compatible with the specific objectives of the territorial plans, such as improving the quality of the public-private building stock and improving the energy efficiency of buildings (Karimi et al., 2022).
For the population, the presence of green elements also contributes to meeting the plan's objectives concerning the quality of life within the city. They act on the outdoor comfort in case of extreme events and on the psychophysical well-being of citizens (van den Berg et al., 2017). In the agricultural sector, through careful control of their function, vertical farming meets the inherent objective of improving the quality control of production systems (Kozai et al., 2019). Roofing measures, especially wet zone green roofs, meet the objectives of spatial plans regarding the hydrosphere, acting on the desire to reduce water consumption (Lubna et al., 2022).
Nature-based solutions for urban space were selected because they can address present (e.g. lack of public green space) and future (e.g. UHI and drought) problems in the Cercola area.
The measures identified on the urban scale (Tab.2) can act on the naturalisation of the urban environment, mainly increasing the presence of greenery, favouring proper water resource management, or acting on both aspects (Bayulken et al., 2021). Furthermore, the solutions identified can concentrate on specific areas (e.g. gardens) or have a more linear course corresponding to the road axes present (e.g. trees and roadside flowerbeds).
In the first case, we have interventions such as gardens and urban gardens that contribute to the improvement of public services, at the same time naturalising the territory. This criticality is present and highlighted in urban plans (Municipality of Cercola, 2019). Furthermore, there can be composite solutions where several solutions are combined in order to improve their effect on the built-up area. Bioswales, for example, whose primary purpose is the filtration and accumulation of rainwater using proper stratigraphy (Ekka et al., 2021), can be employed in urban or community gardens, also improving soil fertility (Brodsky et al., 2019). Furthermore, the symbiotic use of two identified solutions can lead to developing further nature-based hybrid solutions, e.g. raingardens (Morash et al., 2019).

Field of application	Solution	Typology	Objectives of the urban plan	Reference
Building scale	Green roof	Adaptation Mitigation	Ensuring the quality of living within the city. Improving the quality of the building stock. Increasing energy efficiency. Reducing water consumption.	de Oliveira et al., 2021; Zehnsdorf et al., 2019
	Green wall/ living wall	Adaptation Mitigation	Ensuring the quality of living within the city. Improving the quality of the building stock. Increasing energy efficiency.	Susca et al., 2022; Susorova, 2015
	Domestic gardens	Adaptation	Improving the quality of the building stock. Ensuring the quality of living within the city.	Zhang et al., 2021
	Vertical farming	Mitigation	Improving the quality of the public and private building stock. Regenerate degraded urban areas. Subjecting agricultural production to quality control systems. Increasing energy efficiency.	Boganini & Casazza, 2017; Naskali et al., 2022

Tab.1 Nature-based solutions at building scale for Cercola Municipal territory

Considering the peculiarities of the territory and the saturation of the urban soil, further NBS considered and analysed for their possible use on the territory concerns roads. In this context, naturalisation can take place on different levels. In this respect, this can involve the green system (e.g. tree rows), thus improving the urban microclimate by mitigating the effects of the UHI in the warmer months (Elliott et al., 2020). Another

effect of climate change that can be mitigated with NBS on the street axis is cloudburst management. Indeed, stormwater can be managed by filtering flowerbeds and road surfaces that avoid flash floods and contribute to their storage to cope with dry periods (DeBusk et al., 2010). A further solution that intervenes in urban mobility is the naturalisation of public and private parking areas by combining microclimate improvement with the maintenance of soil permeability (Tong et al., 2022).

The selected NBSs act on individual aspects identified by the PUC. In particular, they contribute to achieving transformation objectives, e.g. the environmental improvement of the green system and indirectly affecting the urban mobility system. The measures identified also impact multiple specific objectives identified by the urban plans. Regarding the population, elements such as the construction of community and urban gardens contribute to the allocation of public green space (Wolch et al., 2014).

Field of application	Solution	Typology	Objectives of the urban plan	Reference
Public space and rainwater management	Bioswale	Adaptation	Ensuring the quality of living within the city. Reducing the hydraulic risk factors.	Ekka et al., 2021
	Roadside trees	Adaptation Mitigation	Regenerate degraded urban areas.	Maher et al., 2013
	Green parking lot	Adaptation	Regenerate degraded urban areas.	Tong et al., 2022
	Community gardens	Mitigation	Ensuring the quality of living within the city. Ensure adequate areas for public facilities and green and collective spaces.	Wolch et al., 2014
	Urban gardens and flowerbeds	Adaptation	Ensuring the quality of living within the city. Ensure adequate areas for public facilities and green and collective spaces.	DeBusk et al., 2010
	Filtering floor	Adaptation	Reducing the hydraulic risk factors. Maintaining aquifer recharge capacity.	Ahmad et al., 2017

Tab.2 Nature-based solutions for public space and rainwater management for Cercola Municipal territory

Including green elements such as gardens and roadside trees can also improve the quality of the urban fabric, acting on the redevelopment of degraded urban areas (Ghose & Pettygrove, 2014). On the other hand, NBSs for avenues meet the objective of increasing the quality of the road network since the use of filtering pavement can contribute to reducing accidents (Tsubota et al., 2018). At the same time, the use of tree planting along roads can contribute to an improvement in air quality by reducing pollutants and traffic noise (Maher et al., 2013).

In addition, bioswales, green parking lots, and filtering floors contribute to the objective of maintaining and improving water resources. As mentioned above, these help limit hydraulic risk elements (Ahmad et al., 2017) and contribute to a reduction in water consumption by favouring the storage of rainwater and its use for irrigation of green and agricultural areas.

Field of application	Solution	Typology	Objectives of the urban plan	Reference
Natural and rural area	Community composting	Mitigation	Turning waste into a resource	Cai et al., 2019
	Phytoremediation	Mitigation	Regenerate degraded urban areas. Reclaiming polluted sites	O'Connor et al., 2019
	Tree/hedges fence	Adaptation	Preserving biodiversity and maintaining ecological connections Enhancing and protecting natural habitats	MacDonald & Johnson, 1995

Tab.3 Nature-based solutions for natural and rural area for Cercola Municipal territory

Finally, thanks to their filtering action, the bioswales also contribute to eliminating pollutants by purifying the first rainwater runoff from urban pavements (Purvis et al., 2018). At the same time, even within the geosphere identified by the PUC, the chosen measures maintain and improve the quality and permeability of soils, preserving the recharge capacity of the aquifer (Oral et al., 2020).

The selected solutions for natural and agricultural areas are measures aimed at re-naturalising the Cercola area and are characterised by limited land consumption. While common effects (e.g. mitigation of the urban microclimate) are identified for the measures on a building and urban scale, the measures for the rural and natural context differ in the object and beneficial effects of their intervention. Indeed, these intervene in a purely rural environment (e.g. trees as fences) or in a peri-urban context (e.g. phytoremediation and composting plant); moreover, they concern anthropised areas (e.g. brownfield rehabilitation and waste cycle), while the benefits of installing trees for fences concern more the animal and plant sphere (MacDonald & Johnson, 1995).

Also, for the natural and agricultural context, selecting suitable NBSs was guided by correspondence with the general and specific objectives defined by the PUC. Moreover, the selected interventions are non-invasive and respect the restrictive indications of the territorial plans for natural and agricultural areas. In particular, the installation of composting facilities is consistent in turning waste into a resource (Mamun et al., 2020). Furthermore, such measures contribute to the circularity of the city's economy as it is possible to obtain both fertilisers for agriculture (Cai et al., 2019), fulfilling another objective of the urban plan.

The use of phytoremediation, on the other hand, acts on disused environments by contributing to the objectives of the redevelopment of degraded landscapes and reclamation of polluted sites, as well as contributing to the renaturalisation of post-industrial spaces (O'Connor et al., 2019). Lastly, planting trees as natural fences for agricultural land works more on the aspects identified by the PUC for the biosphere by enhancing natural habitats and ecological connections (Hinsley & Bellamy, 2000).

5. Selected NBS proposals for the Cercola municipal area

NBS adaptation and mitigation measures, as seen in previous chapters, allow for an increase in the resilience of the anthropised environment concerning the extreme effects of climate change (e.g. UHI, the tropicalisation of the climate in the Mediterranean area, etc.) (Bianchi, 2007).

The application of NBSs in the Cercola municipal territory can affect the evolutionary trajectories identified by the environmental report of the Strategic Environmental Assessment (SEA) of the PUC (Municipality of Cercola, 2019). In this regard, the proposed interventions can impact agricultural land, biosphere and hydrogeological risk zones, contributing to the sustainable development of the Cercola territory.

The peculiarities of the area itself can also be considered NBS measures for adaptation and mitigation. In particular, the presence of the Vesuvius National Park near the urban centre can be categorised as a peri-urban park (i.e., carbon sink) (Marchetti et al., 2012). Moreover, thanks to the wooded area and the provision of a series of measures (e.g. optimising ventilation from the green area towards the built-up area) (Hou et al., 2018), this element can improve the urban microclimate by mitigating excessive urban summer overheating.

The present paragraphs outline the major NB adaptation and mitigation measures to be adopted on "Transformability Areas" identified by the new PUC (Fig. 4), i.e., macro-areas with unitary morphological and functional characteristics and specific transformation objectives.

5.1 Zone 1

In the proposal for the Territorial Coordination Plan (PTC) of the Province of Naples, this portion of the territory is classified as an area of particular agronomic importance. The PTC classification binds the PUC to safeguard current agricultural uses, prohibiting further uses. In particular, the plan requires recovering the

typical elements of the historical agrarian landscape and preserving the environmental value with eco-compatible production systems. In addition, analysing what is indicated in the local basin authority plan (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015), in the territory falling within TA1, there are elements and areas of high and medium criticality from the hydrogeological point of view and a buffer zone according to R.D. 3267/23.

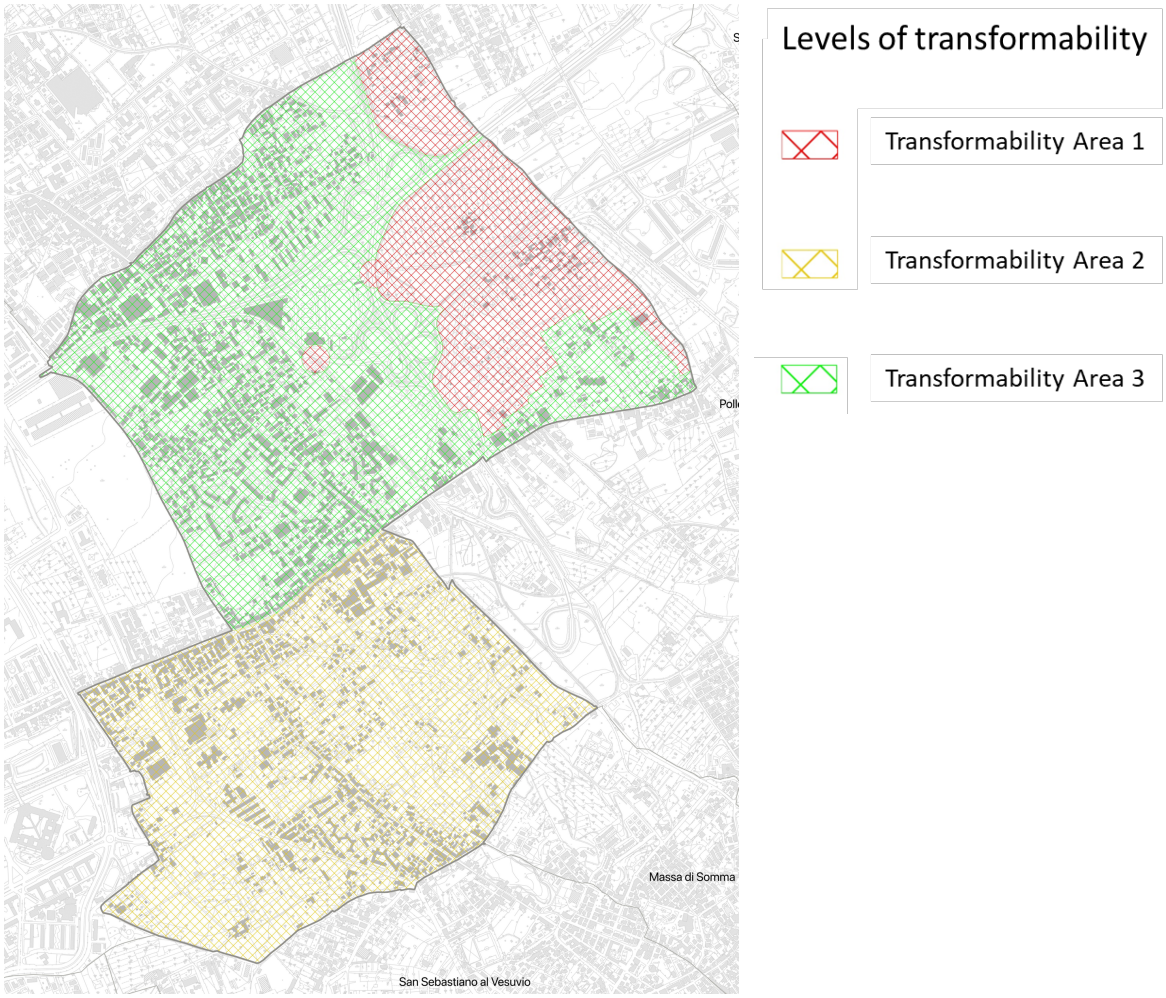

Fig.4 Municipality of Cercola. Transformability areas related to the comprehensive quality of the territory

The mitigation and adaptation interventions applicable to the territory of TA1 mainly concern the agricultural areas and the hydrogeological structure of the territory. Due to the specific characteristics of the area, the only admissible interventions are mainly aimed at the maintenance and conservation of the existing structures in order to enhance and requalify the agricultural landscape.

For agricultural areas, the types of measures that can be adopted are mainly aimed at protecting biodiversity in the rural environment. For example, a first measure may consist of using lot delimitation systems employing natural elements (e.g. trees, shrubs, etc.) that can provide a refuge for local fauna[3]. In addition, measures may concern the end-of-life of agricultural products. These include sites for the installation of community composters in order to use production waste to obtain compost[4].

Another element that emerges is that there are currently no public green areas in TA1 despite the presence of an urban residential fabric. A possible solution is to envisage the reuse of abandoned uncultivated areas

[3] Together with the installation of punctual shelter elements, e.g. beehives and bird houses. The measures contribute to maintaining the naturalness of the Cercola area as an ecological corridor.

[4] To be used as fertiliser in the fields.

for the establishment of community farms, i.e. green spaces serving residents following the territorial vocation of the area.
Other measures that can be implemented in the area concern adaptation to extreme weather phenomena related to hydraulic risk, i.e. cloudbursts. In particular, thanks to the agricultural character of the area, it is possible to make bioswales to collect and filter rainwater. The collected precipitation can be used to irrigate crops and avoid overloading the drainage system. Further intervention may consist of installing filtering soils in areas of maximum hydrogeological criticality to ensure a rapid and efficient flow of rainwater. Furthermore, if water purification is required for irrigation purposes, ponds can also be provided to help eliminate toxic and polluting substances from grey water and first flush rainwater.

5.2 Zone 2

The portion of the municipal territory (North-South Axis) regulated by the Landscape Plan (Piano Paesistico) falls within Transformability Area 2 (TA2) and is characterised by naturalistic value and agricultural-productive character. The interventions allowed for the area with a strictly environmental character are the conservation and maintenance of the existing infrastructure. In particular, the only possible spatial operations concern the extension of the pedestrian and vehicular road network. For the built-up area in TA2, the following actions are identified: restoration and conservative renovation, building refurbishment with volume increases for hygienic and functional adaptation and the construction of new public facilities.
As seen for TA1, in TA2, there are elements of environmental criticality due to anthropic pressure that threaten the biodiversity and naturalness of the area. In this regard, further constraints on the area are due to the indications of the Piano Paesistico dei Comuni Vesuviani, which divides the TA2 into two main areas. The plan defines the following zones: Integral Protection with Environmental Landscape Restoration (PIR) and Urban-Building Recovery and Environmental Landscape Restoration (RUA).
Considering the specific restrictions of the area, feasible climate change mitigation and adaptation measures are limited to non-invasive actions. Regarding works on a building scale, only solutions that do not alter the volume of existing buildings may be applied. Possible actions include the development of home gardens, to be implemented considering the landscape protection criteria present, e.g. respect for panoramic viewpoints. Furthermore, installing green roofs can be a possible intervention on existing buildings, but only by extensive systems or 'wetland' covering. The types of green roofs indicated are limited to encouraging the growth of grass and small shrubs on the surface to improve the urban microclimate and optimised water management without altering the field of vision from panoramic viewpoints. Finally, the installation of urban farms dedicated to cultivating traditional crops can take place, but without the construction of service structures such as greenhouses.
Mitigation and adaptation measures concerning public space are allowed and can be operated in multiple aspects. Planting urban trees in the road network buffer strips can be a valuable resource for buffering the busiest arterial roads. Redevelopment of the road network can be an opportunity to use systems that allow greater soil permeability and better stormwater management in the event of extreme events. The requalification of the road network must take place with self-locking elements to maintain the indications of the territorial plans regarding the use of traditional and stone materials. Finally, a valuable operation for upgrading the roadway can be the installation of flowerbeds, which can be built with layers to absorb rainwater for future use for irrigation and other non-domestic purposes.
The analyses carried out for the urban plans show that Transformability Area 2 lacks public green spaces. The creation of green areas for residential use can be done by improving the urban microclimate. In this regard, urban gardens (e.g. arid gardens, sensory gardens) and community gardens can be realised in TA2 to cultivate tree essences typical of the agricultural tradition of the area. However, interventions in urban green areas are always to be realised by providing nature-based systems that allow rainwater storage.

Besides, in the portions of the TA2 territory that fall within the PIR zones, interventions on public spaces that alter the pre-existing course of the terrain (e.g. bioswales, channels, etc.) are not allowed.
Considering the restrictions of the plans, only natural fences (shrubs, linear trees, etc.) can be built in agricultural areas. Another feasible NBS is the construction of a system for the valorisation of agricultural production waste and part of the wet fraction of urban waste through sites for the collection of material for biomass production. In addition, sites can be provided for installing community composters to obtain fertiliser.
Finally, shelters for insect (beehives, insect farms, etc.) and migratory birds can be installed in the rural context to protect the biodiversity of the site and the existing eco-corridor.

5.2 Zone 3

The PUC identifies Transformability Area 3 (TA3) as the portion of the municipal territory to the northwest, which is characterised by medium transformability. In particular, the interventions allowed are the maintenance and conservation of the existing, urban restructuring and the extension of volumes with new constructions for non-residential purposes. Compared to the other two transformability areas, the greater freedom of action is due to fewer restrictions and a low vocational connotation, i.e., TA3 is made up of uncultivated areas and recently formed residential settlements.
The area includes the urban fabric close to the municipality of Volla and the main roads in the Cercola area[5].
The road network separates TA3 from TA1, which has an agricultural nature. In the vicinity of the road junction, there is a rainwater harvesting basin in TA3 where filled channels of the hydrographic network intersect (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015).
In addition to hydraulically critical issues, the TA3 territory also presents significant issues from an environmental point of view. The area is almost entirely urbanised, with few natural areas for agricultural use threatened by existing anthropic pressure.
The PUC calls for preserving agricultural land in TA3 through maintenance, recovery and redevelopment, which may consist of the ruralisation of urbanised brownfields.
NBS for climate change mitigation and adaptation can contribute to protecting biodiversity threatened by disordered urbanisation in TA3.
Due to less restrictive indications from territorial plans in TA3, acting at the building scale is possible.
In the case of interventions more extensive than building renovation, vertical green systems (e.g. green and living walls) and green roof elements (e.g. extensive, intensive, urban farm) can be used as NBS. In addition to increasing the psychophysical well-being of inhabitants, the proposed interventions are helpful tools for decreasing outdoor discomfort in hot weather.
In the public space, planting urban trees and redeveloping parking areas using green landscaping with filter paving can be provided to ensure maximum permeability of the soil.
Bioswales (alternatively rain gardens) can be placed at the groundwater network, i.e., in areas subject to greater hydrological risk. NBSs can improve the local management of the rainwater cycle without burdening the existing sewage disposal system in case of extreme events.
For the upgrade of the road network, filter beds can be constructed to collect rainwater and its purification. The cleaning of contaminants is achieved through specific types of plants and the installation of natural filters made of gravel and crushed rocks of different granulometry.
A further measure to mitigate anthropic pressure on the environment is the adoption of vegetation noise barriers to act as a filter between the busiest axes (Via Argine) and the urban fabric of Cercola.

[5] The SS162 highway and the Via Argine axis.

In the TA3 area, the reconversion of disused and abandoned areas to green areas can be envisaged through the establishment of community gardens for agricultural purposes; in these green spaces, individual citizens can participate in the management and cultivation of the land as part of an urban farm. Furthermore, the wet fraction of urban waste produced by apartment blocks and agricultural activities can be processed in special neighbourhood composters. These sites valorise waste and give it new life by turning it into fertiliser. Moreover, for the most polluted soils, in the case of disused activities and reconversion of the intended use, phytoremediation systems can be implemented through the planting of plant organisms that can absorb the pollutants present in the soil, reclaiming it; finally, the plant organisms used can then be used for the production of biomass and thus for the production of electrical and thermal energy.

6. Conclusions

The present work deals with the application of measures for mitigation and adaptation to the effects of climate change in an urban context. In particular, it illustrates a multi-scalar approach (e.g. from building to urban scale) that enables mitigation of climate change effects and naturalisation of an area at high anthropogenic and natural risk.

The paper illustrates an operational example of the choice of NBS measures for the Cercola municipal territory as actions and guidelines to be integrated into the implementation rules of the urban plan.

In the first phase, the environmental context of the area subject to intervention was examined in depth. In particular, the main risks were analysed, and the intervention strategies of the territorial and municipal plans were outlined.

Then, starting from a critical analysis of the state of the art, the main NBSs that can be implemented in the Cercola area were outlined. The measures were categorised into three main fields of application: building scale, public space and water management, and rural and natural areas. The solutions identified were chosen based on their correspondence with the transformation objectives of urban planning.

Lastly, for the specific transformation zones outlined in the urban plan, the main NBSs that can be implemented to mitigate and adapt to the effects of climate change were identified. The choice was based on the peculiarities of the zones into which the Cercola territory was divided.

This paper aims to contribute to the ongoing debate on improving the urban territory and built heritage to cope with climate change effects. The work presented here is the first contribution of a structured path leading to the evaluation of the effectiveness of NBS in Italian small urban contexts. The future developments of this work will be the verification through simulations at the urban level of the solutions proposed at the building scale and their effects on the urban microclimate for further scaling down the intervention. In addition, once the first measures are applied in the Cercola area, the actual performance of the NBSs identified for the transformability areas will be monitored.

Authors' contribution

This paper is the result of the joint work of the authors. In particular: § 1 has been written by Giuseppe Mazzeo; § 3, 4, 5 and 6 have been written by Salvatore Polverino; § 2 has been jointly written by Giuseppe Mazzeo and Salvatore Polverino.

Acknowledgement

The paper is based upon a research activity supported by the National Research Council, Institute for Studies on the Mediterranean (CNR-ISMed) in Naples under Grant No. CIG-ZC333560E7 "Identification of urban adaptation measures to include in the municipal urban plan to increase the response capacity of the urban center of Cercola to climate change", February 2022. Authors thanks for the valuable collaboration the Eng. Lorenzo D'Alessandro, manager of technical office of Cercola municipality.

References

Ahmad, K.A., Abdullah, M.E., Hassan, N.A., Daura, H.A., & Ambak, K. (2017). A review of using porous asphalt pavement as an alternative to conventional pavement in stormwater treatment. *World Journal of Engineering*, *14*(5), 355–362. https://doi.org/10.1108/WJE-09-2016-0071.

ARPAC (2022). *Bollettini qualità dell'aria*. Retrieved from: https://arpacampania.clio.it/sito_temporaneo/atto.php?id=350, Accessed: 9/1/2023.

Autorità di Bacino Distrettuale dell'Appennino Meridionale. (2015). *Piano Stralcio per l'Assetto Idrogeologico - Rischio idraulico (PSAI-RI)*. Retrieved from: https://www.distrettoappenninomeridionale.it/index.php/elaborati-di-piano-menu/bacini-reg-nord-occidentali-bacino-reg-sarno-ex-adb-reg-campania-centrale-menu/piano-assetto-idrogeologico-rischio-idraulico-menu. Accessed: 16/02/2023.

Balletto, G., Sinatra, M., Mura, R., & Borruso, G. (2022). Climate variation in metropolitan cities. *TeMA - Journal of Land Use, Mobility and Environment*, *15*(3), 501-516. https://doi.org/10.6093/1970-9870/9265.

Bayulken, B., Huisingh, D., & Fisher, P.M.J. (2021). How are nature based solutions helping in the greening of cities in the context of crises such as climate change and pandemics? A comprehensive review. *Journal of Cleaner Production*, *288*, 125569. https://doi.org/10.1016/j.jclepro.2020.125569.

Bianchi, C.N. (2007). Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia*, *580*(1), 7-21. https://doi.org/10.1007/s10750-006-0469-5.

Boganini, L., & Casazza, C. (2017). Soilless Urban Temporary Agriculture as a Strategy for Brownfield Site Renewal BT. In A. Sayigh (Ed.), *Mediterranean Green Buildings & Renewable Energy.* 729-740. Springer International Publishing. https://doi.org/10.1007/978-3-319-30746-6.

Brodsky, O.L., Shek, K.L., Dinwiddie, D., Bruner, S.G., Gill, A.S., Hoch, J.M., Palmer, M.I., & McGuire, K.L. (2019). Microbial Communities in Bioswale Soils and Their Relationships to Soil Properties, Plant Species, and Plant Physiology. *Frontiers in Microbiology*, *10*, 1.10. https://doi.org/10.3389/fmicb.2019.02368.

Cai, X., Tan, J., Chen, H., Huang, M., & Huang, X. (2019). The Application of the Solid Waste Compost Products in Garden Plant Planting. *IOP Conference Series: Materials Science and Engineering*, *688*(3). https://doi.org/10.1088/1757-899X/688/3/033044.

Campania Region (2002). *Piano Territoriale Paesistico dei comuni vesuviani*. Retrieved from: http://cercola.asmenet.it/ Accessed: 22/01/2023.

Campania Region (2005). *Piano Regionale di Risanamento e Mantenimento della qualità dell'aria*. Retrieved from: https://www.regione. campania.it/assets/documents/Piano_regionale_di_risanamento.pdf. Accessed: 22/1/2023.

Campania Region (2006). *Piano Strategico Operativo dell'area vesuviana*. Retrieved from: https://www.cittametropolitana.na.it/ pianificazione_territoriale/piani_settore/piano_strategico_operativo. Accessed: 22/1/2023.

Campania Region (2008). *Piano Territoriale Regionale (PTR)*.
Retrieved from: http://www.regione.campania.it/regione/it/tematiche/piano-territoriale-regionale-ptr Accessed: 24/1/2023.

Campania Region (2019). *Piano di Tutela delle Acque (PTA)*. Retrieved from: http://www.regione.campania.it/regione /it/tematiche/acque/piano-di-tutela-delle-acque-2020-2026-j872?page=1. Accessed: 22/12/2023.

Chàfer, M., Pérez, G., Coma, J., & Cabeza, L.F. (2021). A comparative life cycle assessment between green walls and green facades in the Mediterranean continental climate. *Energy and Buildings*, *249*, 111236. https://doi.org/10.1016/j.enbuild.2021.111236.

Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J.P., Iglesias, A., Lange, M.A., Lionello, P., Llasat, M.C., Paz, S., Peñuelas, J., Snoussi, M., Toreti, A., Tsimplis, M.N., & Xoplaki, E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change*, *8* (11), 972-980. https://doi.org/10.1038/s41558-018-0299-2.

de Oliveira, R.L.M., Santos, I.V., Graciano, G.F., Cunha Libânio, A.A., Kelli de Oliveira, L., & Bracarense, L. dos S.F.P. (2021). A sustainable approach for urban farming based on city logistics concepts for local production and consumption of vegetables. *Research in Transportation Economics*, *87*, 101038. https://doi.org/10.1016/j.retrec.2021.101038.

DeBusk, K., Hunt, B., & Sydorovych, O. (2010). Watershed retrofit and management evaluation for urban stormwater management systems in North Carolina. *World Environmental and Water Resources Congress 2010: Challenges of Change - Proceedings of the World Environmental and Water Resources Congress 2010*, 3911-3920. https://doi.org/10.1061/41114(371)398.

Ekka, S.A., Rujner, H., Leonhardt, G., Blecken, G.T., Viklander, M., & Hunt, W.F. (2021). Next generation swale design for stormwater runoff treatment: A comprehensive approach. *Journal of Environmental Management*, *279*, 111756. https://doi.org/10.1016/j.jenvman.2020.111756.

Elliott, H., Eon, C., & Breadsell, J.K. (2020). Improving city vitality through urban heat reduction with green infrastructure and design solutions: A systematic literature review. *Buildings*, *10*(12), 1-30. https://doi.org/10.3390/buildings10120219.

Fan, P., Ouyang, Z., Basnou, C., Pino, J., Park, H., & Chen, J. (2017). Nature-based solutions for urban landscapes under post-industrialization and globalization: Barcelona versus Shanghai. *Environmental Research*, *156*, 272-283. https://doi.org/10.1016/j.envres.2017.03.043.

Ghose, R., & Pettygrove, M. (2014). Urban Community Gardens as Spaces of Citizenship. *Antipode*, *46*(4), 1092-1112. https://doi.org/10.1111/anti.12077.

Guida, C. (2022). Energy saving and efficiency in urban environments: integration strategies and best practices. *TeMA - Journal of Land Use, Mobility and Environment*, *15*(3), 517-531. https://doi.org/10.6093/1970-9870/9549.

Hinsley, S.A., & Bellamy, P.E. (2000). The influence of hedge structure, management and landscape context on the value of hedgerows to birds: A review. *Journal of Environmental Management*, *60*(1), 33-49. https://doi.org/10.1006/jema.2000.0360.

Hou, C., Hou, J., Kang, Q., Meng, X., Wei, D., Liu, Z., & Zhang, L. (2018). Research on urban park design combined with the urban ventilation system. *Energy Procedia*, *152*, 1133-1138. https://doi.org/10.1016/j.egypro.2018.09.139.

IPCC (2022). Annex II: Glossary [Möller, V., R. van iemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (Eds.)]. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://doi.org/10.1017/9781009325844.029.2897.

ISPRA (2022). *Il consumo di suolo in Italia*. Retrived from: https://geoportale.arpa.piemonte.it/. Accessed: 5/1/2023.

ISTAT (2011). *Censimento della popolazione e abitazioni*. Retrieved from: https://www.istat.it/it/censimenti-permanenti/censimenti-precedenti/popolazione-e-abitazioni/popolazione-2011. Accessed: 12/2/2023.

ISTAT (2022). *Principali statistiche geografiche sui comuni*. Retrieved from: https://www.istat.it/it/archivio/156224. Accessed: 12/2/2023.

Jenks, M., & Jones, C. (2008). *Dimensions of the sustainable city*. Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-8647-2.

Johnson, B. A., Kumar, P., Okano, N., Dasgupta, R., & Shivakoti, B. R. (2022). Nature-based solutions for climate change adaptation: A systematic review of systematic reviews. *Nature-Based Solutions*, *2*, 100042. https://doi.org/10.1016/j.nbsj.2022.100042.

Karimi, K., Farrokhzad, M., Roshan, G., & Aghdasi, M. (2022). Evaluation of effects of a green wall as a sustainable approach on reducing energy use in temperate and humid areas. *Energy and Buildings*, *262*, 112014. https://doi.org/10.1016/j.enbuild.2022.112014.

Kazemi, F., Rabbani, M., & Jozay, M. (2020). Investigating the plant and air-quality performances of an internal green wall system under hydroponic conditions. *Journal of Environmental Management*, *275*, 111230. https://doi.org/10.1016/j.jenvman.2020.111230.

Kozai, T., Niu, G., & Takagaki, M. (2019). *Plant factory: an indoor vertical farming system for efficient quality food production*. Amsterdam: Elsevier Academic Press. https://doi.org/10.1016/C2014-0-01039-8.

Lanzi, M. (2016). Drosscape e reti di nuova urbanità nell'area orientale di Napoli. In G. Punziano (Ed.), *Società, economia e spazio a Napoli. Esplorazioni e riflessioni.* L'Aquila: GSSI Social Sciences.

Lionello, P., Abrantes, F., Gacic, M., Planton, S., Trigo, R., & Ulbrich, U. (2014). The climate of the Mediterranean region: research progress and climate change impacts. *Regional Environmental Change*, *14*(5), 1679-1684. https://doi.org/10.1007/s10113-014-0666-0.

Lionello, P., & Scarascia, L. (2018). The relation between climate change in the Mediterranean region and global warming. *Regional Environmental Change*, *18*(5), 1481-1493. https://doi.org/10.1007/s10113-018-1290-1.

Lubna, F.A., Lewus, D.C., Shelford, T.J., & Both, A.J. (2022). What You May Not Realize about Vertical Farming. *Horticulturae*, *8*(4), 1-9. https://doi.org/10.3390/horticulturae8040322.

MacDonald, D.W., & Johnson, P.J. (1995). The Relationship Between Bird Distribution and the Botanical and Structural Characteristics of Hedges. *Journal of Applied Ecology*, *32*(3), 492-505. https://doi.org/10.2307/2404647.

Maher, B.A., Ahmed, I.A.M., Davison, B., Karloukovski, V., & Clarke, R. (2013). Impact of roadside tree lines on indoor concentrations of traffic-derived particulate matter. *Environmental Science and Technology*, *47*(23), 13737-13744. https://doi.org/10.1021/es404363m.

Mamun, A. Al, Hayat, N., Malarvizhi, C.A.N., & Zainol, N.R.B. (2020). Economic and environmental sustainability through green composting: A study among low-income households. *Sustainability*, *12*(16), 6488. https://doi.org/10.3390/su12166488.

Marchetti, M., Sallustio, L., Ottaviano, M., Barbati, A., Corona, P., Tognetti, R., Zavattero, L., & Capotorti, G. (2012). Carbon sequestration by forests in the National Parks of Italy. *Plant Biosystems - An International Journal Dealing with All Aspects of Plant Biology*, *146*(4), 1001-1011. https://doi.org/10.1080/11263504.2012.738715.

Mazzeo, G. (2013). City and Energy Infrastructures between Economic Processes and Urban Planning. *TeMA - Journal of Land Use, Mobility and Environment*, *6*(3), 311-324. https://doi.org/10.6092/1970-9870/1929.

Mazzeo, G. (2016). *La città leggera: Smart City e urbanistica attuativa*. Napoli: FedOA Press. https://doi.org/10.6093/978-88-6887-008-9.

Mazzeo, G. (2021). *Sulla pianificazione territoriale in Italia. Cronache, testimonianze, prospettive*. Milano: FrancoAngeli.

Metropolitan City of Naples (2013). *Piano Territoriale di Coordinamento (PTC)*. Retrieved from: https://www.cittametropolitana.na.it/ pianificazione_territoriale/ptcp Accessed: 21/01/2023.

Metropolitan City of Naples (2022). *Piano Territoriale Metropolitano (PTM)*. Retrieved from: https://www.cittametropolitana.na.it/ documenti2. Accessed: 21/01/2023.

Morash, J., Wright, A., LeBleu, C., Meder, A., Kessler, R., Brantley, E., & Howe, J. (2019). Increasing sustainability of residential areas using rain gardens to improve pollutant capture, biodiversity and ecosystem resilience. *Sustainability*, *11*(12), 3269. https://doi.org/10.3390/SU11123269.

Municipality of Cercola (2019). *Piano Urbanistico Comunale*. Retrieved from: http://cercola.asmenet.it/. Accessed: 15/12/2023.

Naskali, A.T., Pinarer, O., & Tolga, A.C. (2022). Vertical Farming: Under Climate Change Effect BT. In C.M. Galanakis (Ed.), *Environment and Climate-smart Food Production*. 259-284. Berlin: Springer International Publishing. https://doi.org/10.1007/978-3-030-71571-7_8.

Newman, P. (2006). The environmental impact of cities. *Environment and Urbanization*, *18*(2), 275-295. https://doi.org/10.1177/0956247806069599.

O'Connor, D., Zheng, X., Hou, D., Shen, Z., Li, G., Miao, G., O'Connell, S., & Guo, M. (2019). Phytoremediation: Climate change resilience and sustainability assessment at a coastal brownfield redevelopment. *Environment International*, *130*, 104945. https://doi.org/10.1016/j.envint.2019.104945.

Oral, H.V., Carvalho, P., Gajewska, M., Ursino, N., Masi, F., van Hullebusch, E.D., Kazak, J.K., Exposito, A., Cipolletta, G., Andersen, T.R., Finger, D.C., Simperler, L., Regelsberger, M., Rous, V., Radinja, M., Buttiglieri, G., Krzeminski, P., Rizzo, A., Dehghanian, K., … Zimmermann, M. (2020). A review of nature-based solutions for urban water management in European circular cities: A critical assessment based on case studies and literature. *Blue-Green Systems*, *2*(1), 112-136. https://doi.org/10.2166/bgs.2020.932.

Papa, R., & Mazzeo, G. (2014). Characteristics of Sprawl in the Naples Metropolitan Area. Indications for Controlling and Monitoring Urban Transformations. In B. Murgante, S. Misra, A.M.A.C. Rocha, C. Torre, J.G. Rocha, M.I. Falcão, D. Taniar, B.O. Apduhan, & O. Gervasi (Eds.). *Computational Science and Its Applications – ICCSA 2014*. 520-531. Berlin: Springer International Publishing. https://doi.org/10.1007/978-3-319-09129-7_38.

Pelorosso, R., Gobattoni, F., Ripa, M.N., & Leone, A. (2018). Second law of thermodynamics and urban green infrastructure - A knowledge synthesis to address spatial planning strategies. *TeMA - Journal of Land Use, Mobility and Environment*, *11*(1), 27-50. https://doi.org/10.6092/1970-9870/5326.

Petreje, M., Sněhota, M., Chorazy, T., Novotný, M., Rybová, B., & Hečková, P. (2023). Performance study of an innovative concept of hybrid constructed wetland-extensive green roof with growing media amended with recycled materials. *Journal of Environmental Management*, *331,* 117151. https://doi.org/10.1016/j.jenvman.2022.117151.

Purvis, R.A., Winston, R.J., Hunt, W.F., Lipscomb, B., Narayanaswamy, K., McDaniel, A., Lauffer, M.S., & Libes, S. (2018). Evaluating the water quality benefits of a bioswale in Brunswick County, North Carolina (NC), USA. *Water*, *10*(2), 134. https://doi.org/10.3390/w10020134.

Scalenghe, R., & Ajmone-Marsan, F. (2009). The anthropogenic sealing of soils in urban areas. *Landscape and Urban Planning*, *90*(1-2), 1-10. https://doi.org/10.1016/j.landurbplan.2008.10.011.

Strauss, B.H., Kulp, S.A., Rasmussen, D.J., & Levermann, A. (2021). Unprecedented threats to cities from multi-century sea level rise. *Environmental Research Letters*, *16*(11), 114015. https://doi.org/10.1088/1748-9326/ac2e6b.

Susca, T., Zanghirella, F., Colasuonno, L., & Del Fatto, V. (2022). Effect of green wall installation on urban heat island and building energy use: A climate-informed systematic literature review. *Renewable and Sustainable Energy Reviews*, *159*, 112100. https://doi.org/10.1016/j.rser.2022.112100.

Susorova, I. (2015). *5 - Green facades and living walls: vertical vegetation as a construction material to reduce building cooling loads*. In F. Pacheco-Torgal, J.A. Labrincha, L.F. Cabeza, & C.-G.B.T.-E.-E.M. for M.B.C.N. Granqvist (Eds.), *Eco-efficient Materials for Mitigating Building Cooling Needs. Design, Properties and Applications*. 127-153. Cambridge: Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-1-78242-380-5.00005-4

Tong, P., Yin, H., Wang, Z., & Trivers, I. (2022). Combining Stormwater Management and Park Services to Mitigate Climate Change and Improve Human Well-Being: A Case Study of Sponge City Parks in Shanghai. *Land*, *11*(9), 1589. https://doi.org/10.3390/land11091589.

Tsubota, T., Fernando, C., Yoshii, T., & Shirayanagi, H. (2018). Effect of Road Pavement Types and Ages on Traffic Accident Risks. *Transportation Research Procedia*, *34*, 211-218. https://doi.org/10.1016/j.trpro.2018.11.034.

Ulbrich, U., May, W., Li, L., Lionello, P., Pinto, J. G., & Somot, S. (2006). The Mediterranean climate change under global warming. In P. Lionello, P. Malanotte-Rizzoli, & R.B.T.-D. in E. and E.S. Boscolo (Eds.), *Mediterranean*. *4*, 399-415. Amsterdam: Elsevier. https://doi.org/https://doi.org/10.1016/S1571-9197(06)80011-X.

Van den Berg, A.E., Wesselius, J.E., Maas, J., & Tanja-Dijkstra, K. (2017). Green Walls for a Restorative Classroom Environment: A Controlled Evaluation Study. *Environment and Behavior*, *49*(7), 791-813. https://doi.org/10.1177/0013916516667976.

Wolch, J.R., Byrne, J., & Newell, J.P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*, *125*, 234-244. https://doi.org/10.1016/j.landurbplan.2014.01.017.

Ysebaert, T., Koch, K., Samson, R., & Denys, S. (2021). Green walls for mitigating urban particulate matter pollution. A review. *Urban Forestry and Urban Greening*, *59*, 127014. https://doi.org/10.1016/j.ufug.2021.127014.

Zehnsdorf, A., Willebrand, K.C.U., Trabitzsch, R., Knechtel, S., Blumberg, M., & Müller, R.A. (2019). Wetland roofs as an attractive option for decentralized water management and air conditioning enhancement in growing cities-A review. *Water*, *11*(9), 1845. https://doi.org/10.3390/w11091845.

Zhang, X., Zhang, Y., & Zhai, J. (2021). Home Garden With Eco-Healing Functions Benefiting Mental Health and Biodiversity During and After the COVID-19 Pandemic: A Scoping Review. *Frontiers in Public Health*, *9*, 1-13. https://doi.org/10.3389/fpubh.2021.740187.

Zoppi, C. (2020). Ecosystem services, green infrastructure and spatial planning. *Sustainability*, *12*(11), 10-13. https://doi.org/10.3390/su12114396.

Image Sources

Fig. 1: Metropolitan City of Naples. Metropolitan Territorial Plan, Preparatory Strategic Scheme (2023). Retrieved from: https://www.cittametropolitana.na.it/documents/10181/9998654/27_Tavola+PP2+Schema+strategico+preliminare.pdf/885def70-2560-4db6-b56c-299c2308dda4;

Fig. 2: Author's elaboration;

Figg. 3 and 4: Preparatory studies for the drafting of the municipal urban plan of Cercola.

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