INTERREG IPA-ADRION
PROGRAMME 2021 – 2027

Nature-bAsed soluTions for a jUst Resilience in thE Adriatic-Ionian cities - NATURED

Project ID: IPA-ADRION00445

Narrative report on the complex interactions between climate and cities

Project partner: CORILA/IUAV

Reporting period: December 2024

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Executive summary

Climate change and extreme weather events are already affecting people, livelihoods, ecosystems, and economies. For example, heatwaves and floods are among the major climatic concerns in many territories worldwide, including Europe. With the climate crisis projected to continue and worsen in the next decades, there is an urgent need to adopt and scale up action and investment into climate resilience across and within different sectors and geographical areas.

In this context, nature-based solutions are seen as a promising tool to address climate-related challenges, since they can improve the economic, social and environmental resilience of communities while providing many co-benefits to people. Urban areas and, consequently, urban populations are particularly vulnerable to climate-related hazards and hence in need of such cost-effective, resource efficient, multi-purpose, and multi-beneficial nature-based solutions.

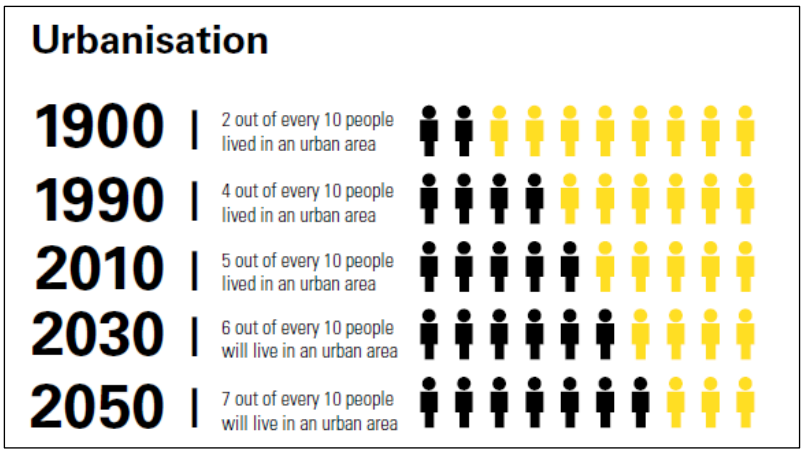
This narrative report provides readers with key information to understand how cities react to critical climate stimuli and how solutions based on nature can enhance their resilience, by examining:

i) the main implications of climate change and extreme weather events in cities, disentangling the complex interactions between climate and urban environments with a particular focus on heat- and flood-related issues;

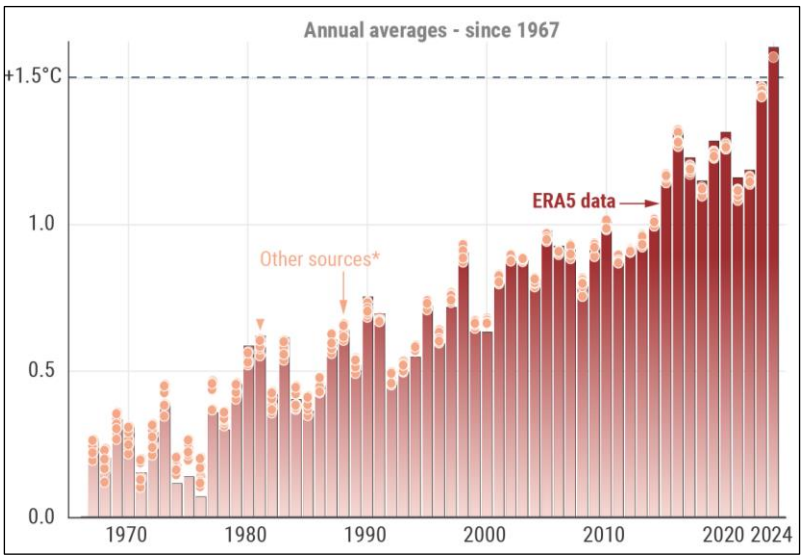
ii) the role that nature-based solutions may have in promoting climate adaptation and urban resilience, also showcasing real-life examples;

iii) key planning aspects and considerations that are relevant for promoting the implementation and scaling up of nature-based solutions in cities, to enable a more widespread and systematic implementation while addressing more effective and just outcomes.

Setting the context



Despite cities cover just 2% of the earth's surface, the future of most of the world's population is urban. For many people the urban environment already is the norm, and cities will continue to attract people and grow over time also in the next decades. According to future projections, around 70% of the population will be living in urban areas by 2050.



The most recent data on global temperatures had confirmed that 2024 was the warmest year on record going back to 1850. It also was the first calendar year in which average global temperatures exceed 1.5 degrees Celsius above the 1850-1900 pre-industrial period, with a temperature of around 1.6°C higher than the average. The previous warmest year on record was 2023, and each of the past 10 years (2015-2024) was one of the 10 warmest years on record.

How these two facts relate to each other? What are the consequences? How to sustainably address them?

LET'S DISCOVER IT.

Climate change and cities

Climate change – which is caused by global warming – is already occurring, is projected to persist, and presents significant challenges for societies and cities across Europe and the globe. These include rising temperatures, shifting precipitation patterns, rising sea levels, and more frequent and intense extreme weather events, such as heatwaves, floods, wildfires, and droughts.

Given that many environmental challenges are exacerbated in cities and other highly artificialized environments, climate-related ones do not escape this rule. According to EEA (2012), although urban areas face the same general climate risks as their surrounding regions, their unique environments can magnify or alter them. Variations in urban design and management make cities vulnerable in different ways, even when located in the same geographic area.

"Although urban areas face the same general climate risks as their surrounding regions, their unique environments can magnify or alter them"

Replacing natural vegetation with artificial surfaces and buildings creates distinct microclimates, influencing temperatures, humidity, wind patterns, and precipitation (Oke et al., 2017). In cities where much of the ground is sealed by impermeable surfaces, excessive rainfall cannot infiltrate the soil, exacerbating flooding. Similarly, artificial surfaces retain heat, causing urban areas to experience higher temperatures compared to their surroundings.

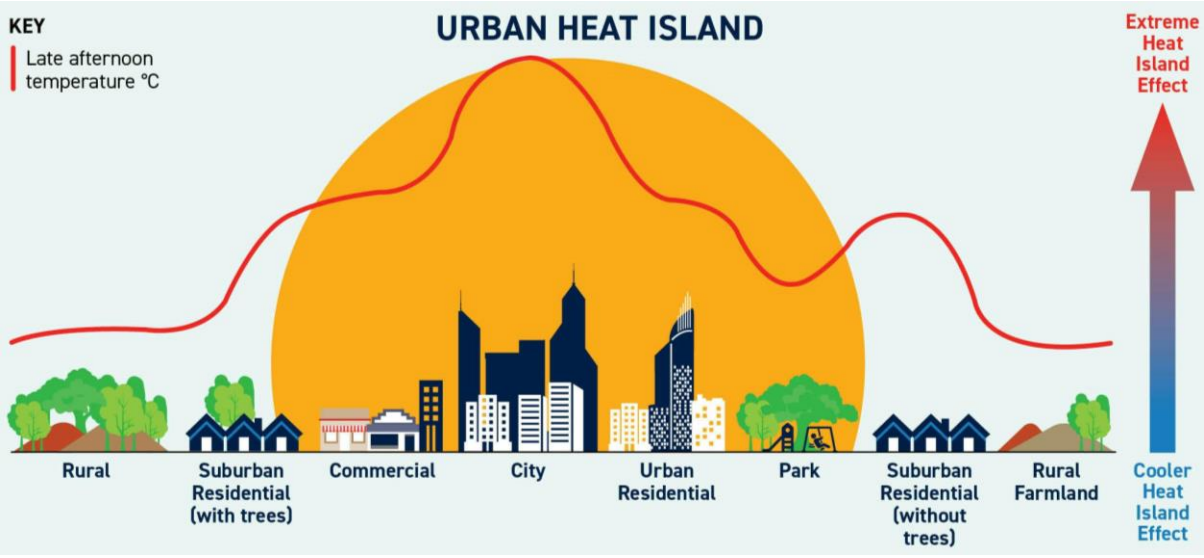
Focus #1: Heat island effect in cities

The impact of heatwaves is particularly strong in cities and towns. The so-called "Urban Heat Island" (UHI) effect describes the increased urban air temperature, or urban overheating, compared to the rural surroundings. The difference is particularly stark at evening and night, even in relatively small towns (Steigerwald et al., 2022). Climate change essentially increases the number of hot days by a similar amount for both urban and rural situations. However, the number of additional hot nights is larger in cities than in the countryside (EEA, 2012).

"The so-called "Urban Heat Island" (UHI) effect describes the increased urban air temperature compared to the rural surroundings"

UHI is influenced by the urban fabric and design of cities. Urbanisation and human activities essentially alter the balance between the energy from the sun absorbed by the surface, then stored in the building mass and later released to the surrounding air (Yu et al., 2020). Most notably, the cooling effect of vegetated surfaces is replaced by the storage of heat in surfaces such as concrete, asphalt and stone. Since the urban fabric shows large amounts of variation, the intensity of the UHI would reflect this (e.g., Longato & Maragno, 2024). This can cause spatial variations of UHI effects within cities as well as between cities. The hottest parts in cities and towns are generally those with dense urban settings, without green spaces and including areas generating large amounts of anthropogenic heat (EEA et al., 2008).

UHI exacerbate the heatwave's impacts on urban populations, increasing the risk of cardiovascular disease, heat stroke, and heat-related deaths, among others (Reiners et al., 2023). This is because people exposed to UHI are likely to experience more prolonged heat stress/thermal discomfort conditions since this phenomenon occurs especially during night-time, maintaining high temperatures even when they should naturally decrease to more tolerable levels, consequently limiting people's ability to cool off and reducing the recovery time for the body (Logan et al., 2020). Particularly vulnerable groups are the elderly, infants, or people with chronic illnesses. Moreover, UHI may also result in higher costs for people living in cities, since the longer the time with high ambient temperatures, the longer the time artificial air conditioning systems are required to function leading to more energy consumption and energy bill increase (Santamouris, 2020).



Focus #2: Flood in cities

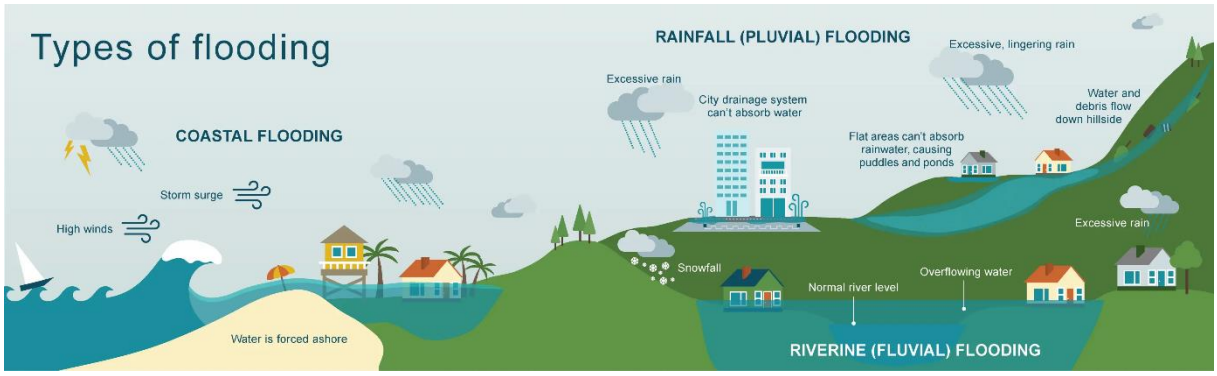
Flooding in urban areas can result from several types of floods, which intensity and frequency are expected to increase due to changing climate. These include:

- River floods that occur when urban areas near rivers (especially highly artificialized ones) experience river overflows, mainly because of excessive rainfall in the river catchment area.
- Flash floods, as a result from rapid runoff accumulation and release from upstream regions in cities within mountainous settings.
- Coastal floods that may affect coastal cities during storm surges, when sea levels temporarily rise above the usual tidal range.
- Urban drainage floods, which arise during extreme rainfall events concentrated in a short time when urban drainage systems are overwhelmed.

Flood is considered among the climate-related hazards that provoke the highest economic losses in Europe (EEA, 2012), affecting buildings, infrastructures, and economic activities, among others, both directly (e.g., submerging lower floors of buildings and their content) and indirectly (e.g., interrupting transport corridors).

"Flood is considered among the climate-related hazards that provoke the highest economic losses in Europe, affecting buildings, infrastructures, and economic activities"

Flood-related economic damages are likely more impactful for lower income populations, since they have less resources to prepare for, respond to, and recover from flood events and related impacts (e.g., low-income populations typically may not afford flood insurances and may not have enough financial resources to repair damages to their homes (Tesselaar et al., 2020)).



The most typical flood type in cities

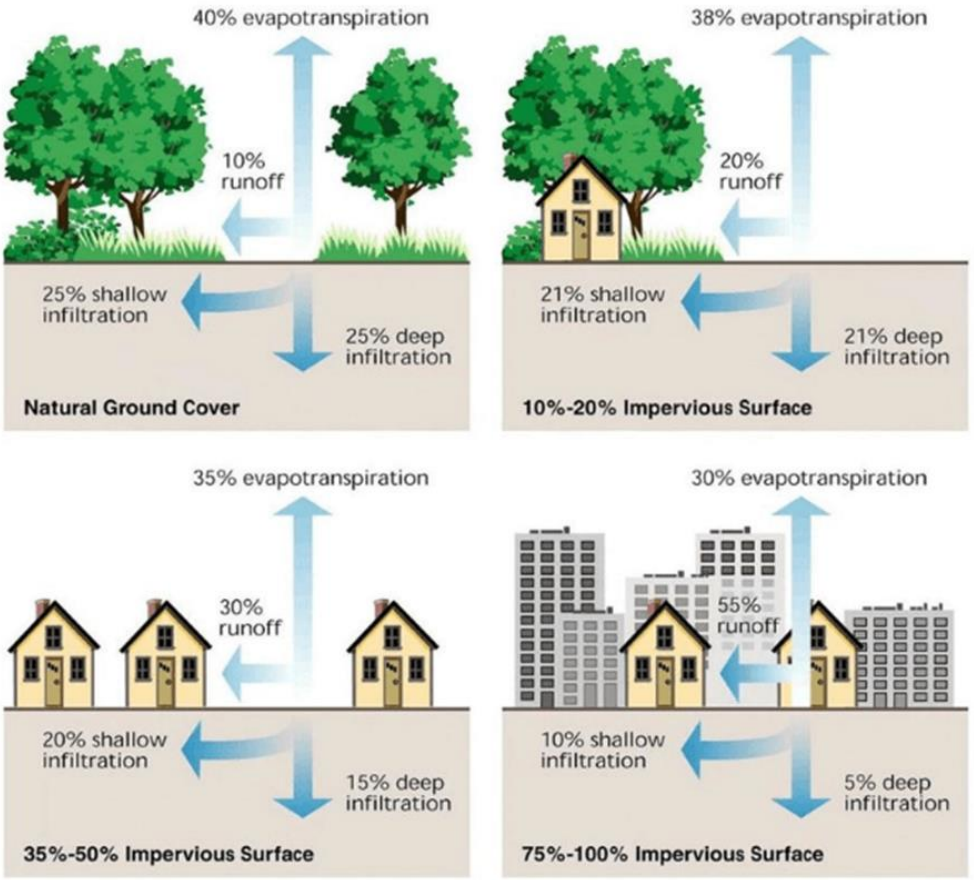
Urban drainage flood is a type of flooding that is typical of cities, and one of the most common. It happens due to insufficient drainage system capacity to manage stormwater during intense rainfall events, leading to flooding in low-lying areas and sewer overflows. Urban areas with high densities of impervious surfaces exacerbate this issue by generating large volumes of runoff that cannot infiltrate the soil.

"Urban drainage flood happens due to insufficient drainage system capacity to manage stormwater during intense rainfall events"

According to EEA (2012), urban vulnerability to flooding is not only tied to soil sealing but also to how rainwater is managed. For decades, drainage systems have been designed to handle storms with specific return periods and to quickly channel rainfall and wastewater through underground pipes.

Combined sewer systems, common in older urban areas, are especially vulnerable as they carry both sewage and rainfall to treatment plants, struggling to cope during heavy rain. With climate change and rapid urbanization, these systems are proving to be inadequate in many cities.

The figure below (FISRWG, 1998) showcases the indicative stormwater interaction with natural ground cover and impervious surfaces.



Climate adaptation in cities with nature-based solutions

The challenges of climate change force drastic modifications in city management so that innovative adaptation solutions are required alongside traditional measures (see BOX 1), with nature-based solutions being a promising option to counteract climate-related effects and impacts (Iwaszuk et al., 2019).

Actually, urban adaptation truly relates strongly to using and expanding green infrastructure and nature-based solutions such as parks, forests and trees, wetlands, green walls and roofs, and sustainable urban drainage systems, among others, wherever feasible and sustainable.

BOX 1 - Categories of climate adaptation measures

According to the taxonomy also used by the EU (Leitner et al., 2020), climate adaptation measures can be described using three main categories: (i) grey, (ii) green and (iii) soft. **Grey measures** refer to technological and engineering solutions to improve adaptation of territories, infrastructures and people. **Green measures** are based on ecosystem-based (or nature-based) approaches and make use of the multiple services provided by natural ecosystems to improve resilience and adaptive capacity. These can also be implemented through hybrid approaches that integrate both grey and green infrastructures into the design of adaptation solutions. **Soft measures** (non-infrastructural) include policy, legal, social, management and financial measures that can alter human behaviour and styles of governance, contributing to improving adaptation capacity and to increasing awareness about climate change.

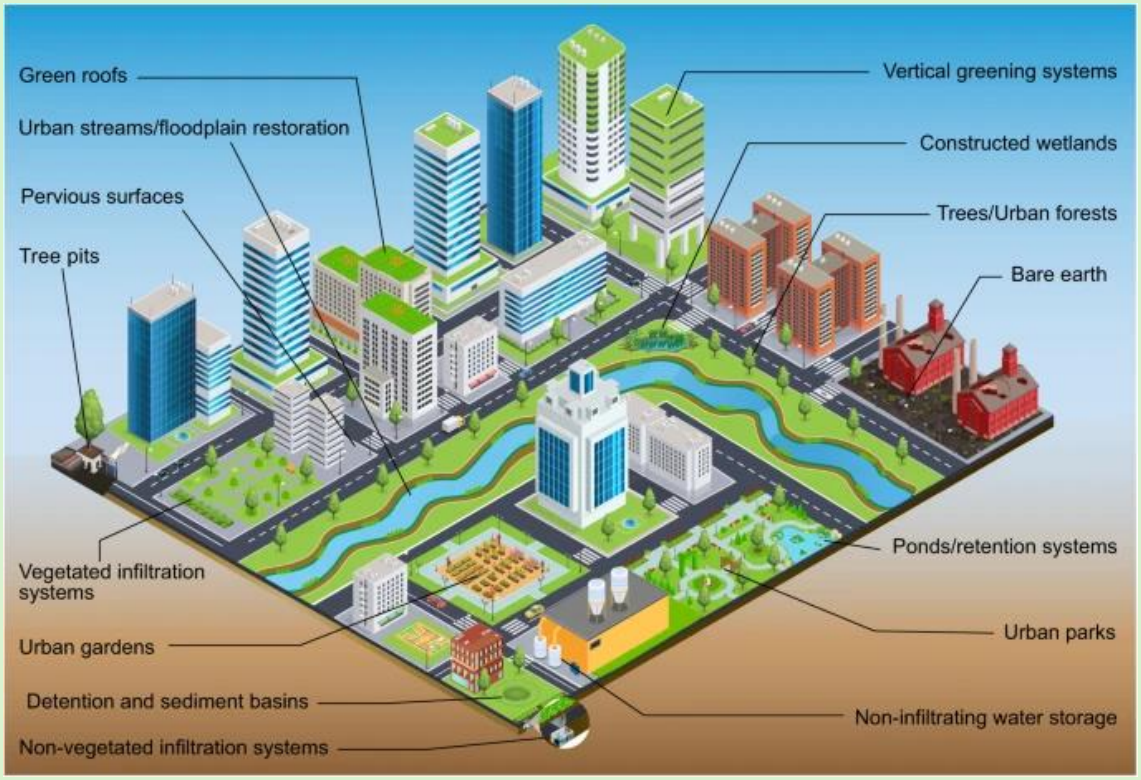
Such solutions serve to cool down temperature in cities as well as they play a key role in managing stormwater and reducing flood risks and impacts. Measures which combine grey and green infrastructures also have the potential to provide robust and flexible adaptation solutions (EEA, 2012).

"Urban adaptation truly relates strongly to using and expanding green infrastructure and nature-based solutions"

Unlike traditional approaches, nature-based solutions often perform multiple functions simultaneously. By adopting nature-based solutions, cities can aid in mitigating climate change by improving carbon sequestration, while delivering further social, economic, and environmental co-benefits, such as higher energy efficiency due to lower cooling needs, attractive areas for nature, wildlife and recreation, and air purification (see BOX 2 for a more detailed presentation of the nature-based solutions concept). However, the establishment of green infrastructure and nature-based solutions requires thoughtful planning and maintenance efforts (e.g., City of Boston, n.d.). As an example, plant selection should take into account native species, local water availability and the risk of potential shortages. In areas prone to water scarcity, opting for drought-resistant species that remain visually appealing as part of urban green spaces is crucial. Additionally, these plants should be watered using domestic grey water or collected rainwater to ensure sustainable water management. Finally, introducing invasive alien species or replacing natural habitats with artificial green spaces may negatively affect biodiversity (EEA, 2012).

BOX 2 – What are nature-based solutions?

Among the various definitions proposed, the IUCN defined **nature-based solutions** as "actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016), while the European Commission (2015) as "living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits". Apart from these consistent definitions, nature-based solutions can be considered as a catch-all term for all those human actions that involve the deployment, enhancement or conservation of nature with the aim to deliver desired **ecosystem services** (e.g., Kabisch et al., 2016; Raymond et al., 2017), namely the benefits people derive from ecosystems. Examples of nature-based solutions that deliver multiple co-benefits include green roofs built to prevent/alleviate flooding thanks to their benefit in runoff peak reduction that may simultaneously cool down temperatures, and constructed wetlands that besides reducing flood risk by storing excess water and enhancing water quality by phytodepuration can be designed to support local biodiversity and pollinators (Aronson et al., 2017; Pianella et al., 2016). All these solutions may additionally provide a more pleasant environment for human health and wellbeing and recreational opportunities. To understand their functioning and added value with respect to alternative solutions, nature-based solutions can thus be described as actions that utilize ecosystem processes of **green and blue infrastructure** in order to safeguard or enhance the delivery of ecosystem services that contribute to alleviate societal challenges, simultaneously providing economic, social/cultural, and ecological co-benefits, in spite of technical alternatives which target the challenge without providing additional benefits (Albert et al., 2019). The figure below (Cook et al., 2024) shows different typologies of nature-based solutions in urban areas.



Focus #3: Heat adaptation with nature-based solutions

Conservation and improvement in existing green and blue infrastructure (i.e., terrestrial and water natural and seminatural ecosystems) and the creation of new ecosystems in cities to alleviate the UHI effect is hugely important and can have a number of additional benefits such as creating areas for recreation, biodiversity, filtering air and draining and storing stormwater (Longato & Maragno, 2024).

In general, vegetation provides cooling through shading and evapotranspiration (Park et al., 2021). Specific solutions such as green roofs lower temperature in buildings during the summer through enhanced insulation and evapotranspiration by the newly installed vegetative elements. Afforested areas and parks have a significant effect on the local climate as they provide fresh and cold air, particularly at night, and have a thermally balancing effect during the day due to a high percentage of trees.

"Vegetation provides cooling through shading and evapotranspiration"

Focus #4: Flood adaptation with nature-based solutions

The ability of soils and vegetation to retain water plays a crucial role in preventing floods, as it helps to lower peak discharges across river basins and, on a smaller scale, in urban drainage piped systems (EEA, 2012). River and coastal flood adaptation is typically managed at the supralocal scale (e.g., regional or basin/catchment area), while urban drainage flood at the city/local scale.

"The ability of soils and vegetation to retain water plays a crucial role in preventing floods, as it helps to lower peak discharges"

Actually, the management of agricultural and forestry land significantly impacts flood risk at a regional level. Flood prevention measures in river landscapes (e.g., river restoration and renaturation, creation of natural detention areas and constructed wetlands, implementation of green corridors in floodplains) in combination with agri-environmental practices may contribute to flood prevention by improving water retention in areas upstream of flood-prone cities. Natural or hybrid protection measures along coastal landscapes (e.g., dune systems) contribute to alleviate the impacts of storm-surge-driven coastal floods.

Within urban settings, by using nature-based solutions such as green roofs, parks, bioretention areas, and sustainable drainage systems, stormwater can be kept out or diverted away from closed piped networks, directing it to surface and subsurface systems capable of storing and/or infiltrating water into the ground, thus reducing the risk of surface water accumulation (Oral et al., 2020). Most of these nature-based solutions not only can manage stormwater locally but also support groundwater recharge. If combined with other storage practices, such as rain barrels and cisterns, these solutions can also help facilitate rainwater reuse (City of Boston, n.d.). For instance, collected rainwater can be used for lawn and garden irrigation, or toilet flushing, contributing to reduce depletion of existing water resources.

BOX 3 – A public space renovation project with nature-based solutions

Piazza Savelli is a public space of about 6,800 sqm mainly destined to car parking in the city of Padua (Italy). A renovation project involved the complete redesign of the space that originally was completely sealed with asphalt. The two figures below show the before and after implementation situation, respectively.

Nature-based solutions to mitigate urban heat island and floods were installed, including new vegetated and tree-covered areas, and rain gardens that are designed to collect surface runoff water, which is then discharged to an underground drainage system and reused for irrigation purposes. In the remaining space that continues to function as a car parking, the original asphalt was substituted with a specific type of concrete pavement that can absorb, to a certain extent, rainwater and reduce the ground temperature thanks to the light-coloured surfaces that reflect the sun's rays more than the darker ones. Finally, the renovated square was also equipped with new pedestrian and cycle paths and street furniture. For more information visit (in Italian): https://www.comune.padova.it/progetto-di-riqualificazione-urbana-di-piazza-savelli.

Planning nature-based solutions in cities

Urban/Spatial planning can promote the implementation and scaling up of nature-based solutions through the adoption of specific policy instruments, as already done by several frontrunner cities worldwide (e.g., Naumann et al., 2020). According to Longato et al. (2024), these instruments encompass mandatory regulations (regulatory instruments), financial and non-financial incentives that are usually applied on a voluntary basis (incentive-based instruments), and instruments providing information and knowledge transfer (information-based instruments) (see BOX 4 for more information). They can be applied to different typologies of nature-based solutions, depending on the transformations allowed by the urban plans/policies and the property regime of the target areas.

"Urban/Spatial planning can promote the implementation and scaling up of nature-based solutions through the adoption of specific policy instruments"

Regulatory instruments can be especially used to mandate the integration of nature-based solutions early on in new development areas, while incentive-based instruments are suitable to promote nature-based solutions in retrofitting and renovating the existing built environment. Information-based instruments can communicate relevant information and knowledge for nature-based solutions planning, design, and implementation.

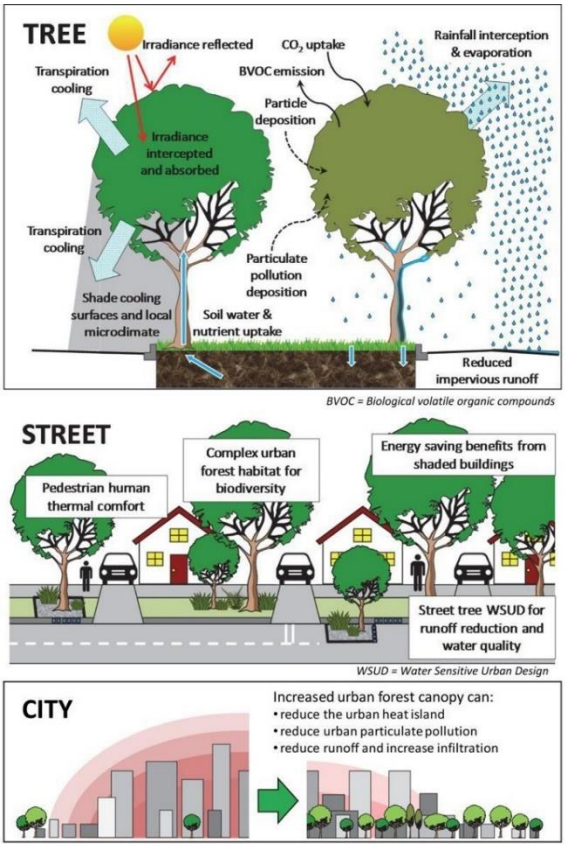
BOX 4 – Policy instruments to promote nature-based solutions (Longato et al., 2024)

Regulatory instruments are usually legally binding and entail mandatory actions through prescriptions or prohibitions, to protect land from or to mitigate development impact through nature-based solutions. Main typologies include the definition of targets/standards, technological/performance requirements, or compensation measures to achieve by creating new green spaces; the definition of land to be protected from development, also through land acquisition programs; and the use of detailed masterplan setting specific rules for green space.

Incentive-based instruments are usually applied on a voluntary basis (i.e., the target groups are free to react or not) to encourage and promote or discourage and restrain certain activities. They are non-legally binding until agreement. These instruments often provide financial/budgetary support, or other types of incentives, to stakeholders for adopting nature-based solutions/alternatives which can reduce the impact of their activities. Main typologies include a series of instrument to stimulate privates to voluntarily install nature-based solutions in their properties in exchange of economic (e.g., tax reductions, subsidies/grants) or other benefits (e.g., density bonuses, expedited project approval processes); development right programmes (transfer or purchase) to prevent development in an area already granted with development rights; and conservation easements to restrict the development, management, or use of the land.

Information-based instruments (also known as knowledge-based or soft instruments) are not legally binding and mostly focus on the transfer of knowledge and meaningful information. They include guidelines, manuals, best practice handbooks, inventories of green spaces, and other types of documents that can raise awareness on nature-based solutions and support private developers or public officials in their planning, design, installation, and/or maintenance.

Policy instrument mixes and combinations are key to secure effective scaling up of nature-based solutions in cities (Kabisch et al., 2017), meaning that they may support changes in planning laws, policies, or norms based on promising lower-level practice (e.g., demonstrative nature-based interventions) to allow for moving from pilot projects to everyday practice in planning for a more widespread and systematic implementation (Sarkki et al., 2024). This would enable a broader uptake and scaling out (i.e., geographically replicating from highly localized solutions to wider application) of multiple nature-based solutions in cities, thus achieving those cumulative benefits that really have a tangible effect in addressing urban challenges.



The figure above (Livesley et al., 2016) shows the benefits provided by trees from the local street to a more widespread scale to demonstrate how cumulative benefits obtained from diffuse tree planting can effectively target citywide climate-related challenges (e.g., mitigating the UHI effect, alleviating the pressure on the urban drainage system during intense rainfalls).

"Policy instrument mixes and combinations are key to secure effective scaling up of nature-based solutions in cities"

Policy instrument combinations can include instruments of the same category (e.g., different incentive-based instruments) or different ones (e.g., regulatory and incentive- and/or information-based instruments). Another policy mechanism type to implement nature-based solutions that does not require the enforcement of policy instruments consists in the direct realization of nature-based projects by the public administration (e.g., in public land, infrastructure, and buildings) (Bush & Hens, 2018).

Moreover, decision-making processes for the planning and implementation of nature-based solutions (Geneletti et al., 2020) should properly consider: i) the possible trade-offs among the ecosystem services provided (i.e., maximizing the delivery of one or more services at the expenses of others), as well as with biodiversity, and ii) the potential beneficiaries of the benefits provided by a solution. The former aspect especially depends on the solution typology and specific design of (i.e., a solution designed to maximizes stormwater retention may not be accessible for recreational purposes), while the latter especially on its localization that influences the distribution of the benefits – the ecosystem services – across the urban area (e.g., Longato et al., 2023). For instance, a new urban park can be localized in a densely populated area currently lacking public greenery in order that a high number of new beneficiaries can have access to a public green area and benefit from the delivered services, such as recreation, improved mental health, or cooling.

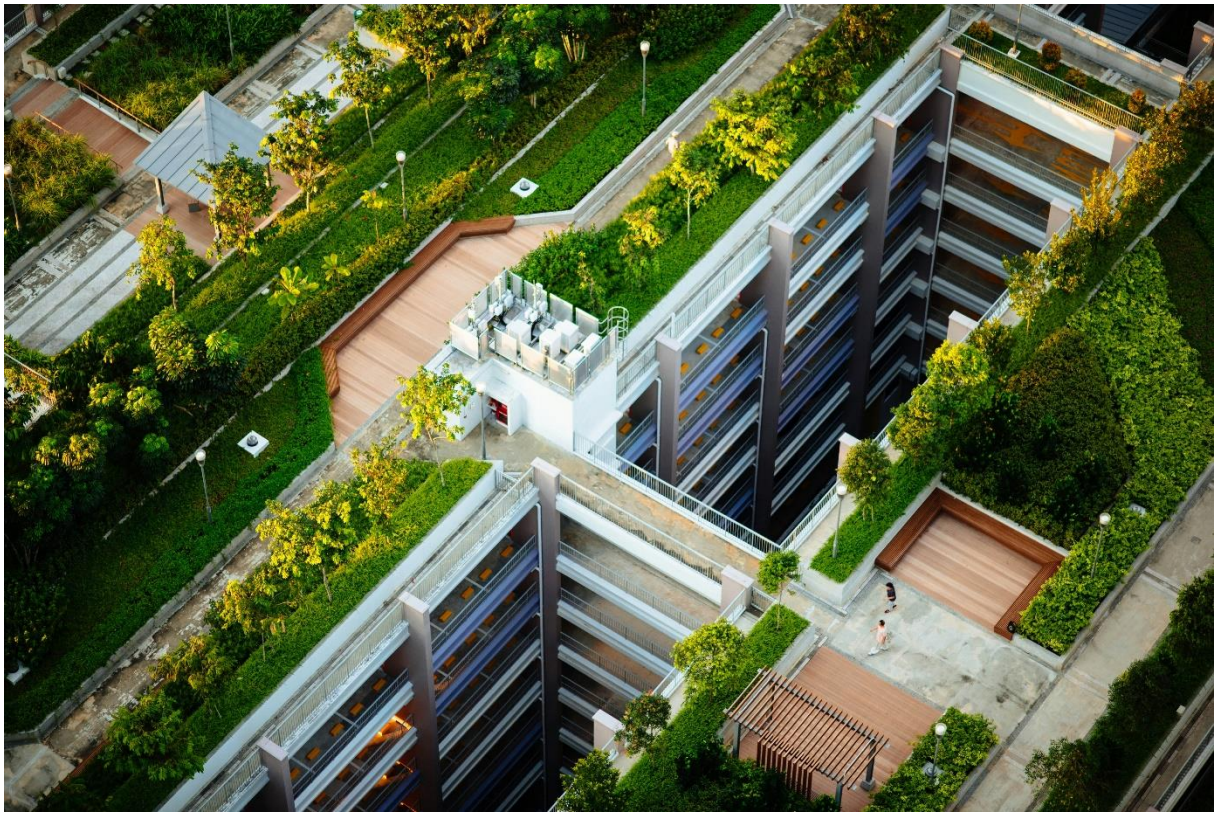
Conclusions

This narrative report provided an overview of the main interrelations between climate and cities in the context of climate change, with a particular emphasis on the risks and impacts associated with urban heat islands and floods. Urbanized environments in fact tend to alter or magnify environmental risks, including climate-related ones, and hence are in urgent need of solutions that can enhance their climate resilience and foster adaptation to changing climate and increasing extreme weather events. For example, the ability of soils and vegetation to retain water and prevent floods, as well as to cool down temperatures, play a crucial role in mitigating the impacts of heatwaves and intense rainfalls. For this reason, nature-based solutions such as green roofs, bioretention areas, urban parks and forests, among others, are seen as a promising option to achieve more resilient cities. An urban area well equipped with such solutions is certainly more efficient in both better managing stormwater by reducing the amount of surface runoff reaching the drainage system and decreasing people's exposures to the urban heat island effect.

The added value of these solutions in spite of alternative (grey) adaptation interventions stands on the fact that, if properly planned and designed, they can additionally provide a wide range of co-benefits for urban communities and the society in general, including carbon sequestration, increased human health and wellbeing, regulation of water cycles with enhanced groundwater recharge, recreational opportunities for citizens, air and water purification, and biodiversity support, among others.

To promote a more systematic implementation of nature-based solutions at scale, cities can define and adopt a range of policy instruments and mechanisms, including various typologies of regulations and incentives, that can force or stimulate their integration along with new development or refurbishment projects in different spaces, spanning from buildings to ground open spaces and transport infrastructures, among others. Only through this systematic integration and widespread replication, cumulative benefits can be achieved that have a tangible effect in truly addressing urban climate-related challenges.

However, attention should be paid when designing and distributing nature-based solutions in cities. The design aspect has important implications for the trade-offs among the ecosystem services delivered by a solution, and with biodiversity. The distributional aspect influences the distribution of and access to their benefits and, consequently, whom may take advantage from them and whom is instead somewhat excluded.



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