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Master’s Thesis

Green Infrastructure and Climate Change
Preliminary Insights for the City of Novara (Italy)

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Abstract

This thesis investigates the function of green infrastructure (GI) in reducing the effects of climate change with an emphasis on its implementation in Novara, Italy. The study looks at the theoretical underpinnings of GI, how it fits into environmental policies in Italy and Europe, and how it can be used practically in urban planning to address issues related to climate change, like flood hazards and urban heat islands (UHI). A thorough examination of the literature, a policy analysis, and an in-depth case study of Novara form the framework of the study. An overview of the theoretical underpinnings of GI and its many uses, such as its advantages in the social, ecological, and economic spheres, is given in the literature review. Policy analysis discusses the frameworks in Europe and Italy that support GI, emphasizing best practices and laws that encourage its growth. In the Novara case study, maps of flood risk and UHI are created through empirical research utilizing geospatial data. HEC-RAS software and Landsat 8 satellite imagery are two methods used to guarantee the dependability and accuracy of these maps. The results highlight the efficiency of green infrastructure (GI) solutions in improving climate resilience, including permeable pavements, urban green spaces, and green roofs. The findings suggest that by improving stormwater management and lowering surface runoff, GI can be incorporated into urban planning to significantly reduce the UHI effect and mitigate flood risks. The socioeconomic advantages of GI, such as better air quality, more biodiversity, and more recreational opportunities, are also examined in the study. The thesis concludes by highlighting how crucial it is to incorporate GI into urban planning and policy making in order to develop resilient and sustainable urban environments. To ensure the effective implementation and upkeep of GI initiatives, Novara is advised to incentivize GI development, encourage community engagement, and cultivate interdisciplinary collaboration. This study offers insightful information about the function of GI in mitigating and adapting to climate change, offering a model for other cities dealing with related issues.

Key words: Green Infrastructure, Climate Change, Urban Heat Island, Flood Risk, Sustainable Urban Planning, Novara, Italy.

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List of Acronyms and Abbreviations

1. ALGG - All London Green Grid
2. CAP - Common Agricultural Policy
3. CBD - Convention on Biological Diversity
4. CSOs- Combined Sewer Overflows
5. EN- Ecological Network
6. ES- Ecosystem Service
7. EU- European Union
8. GHG- Green House Gas
9. GI- Green Infrastructure
10. GISS- Geographical Information System Specialist
11. HEC-RAS- Hydrologic Engineering Centre- River Analysis System
12. IPCC- Intergovernmental Panel on Climate Change
13. NBS- Nature-Based Solution
14. NDC- Nationally Determined Contribution
15. PPR- Piano Paesaggistico Regionale
16. PTR- Piano Territoriale della Regione Piemonte
17. REN- Regional Ecological Network
18. RTP- Regional Territorial Plan
19. SREX- Special Report on Managing the Risks of Extreme Events
20. TAPE- Turin Action Plan for Energy
21. TEEB- The Economics of Ecosystems and Biodiversity
22. TFEU- Treaty on the Functioning of European Union
23. UHI- Urban Heat Island

24. UNFCCC- United Nations Framework Convention on Climate Change

25. UWWTD- Urban Wastewater Treatment Directive

1. Introduction

1.1 Introduction to the context

In the face of unprecedented global climate change, urban environments are grappling with escalating challenges, from rising temperatures and extreme weather events to heightened flood risks. The imperative to develop sustainable and resilient urban landscapes has led to increased attention on green infrastructure as a transformative approach. This thesis endeavors to delve into the intricate relationship between green infrastructure and climate change, focusing specifically on its role in mitigating Urban Heat Island (UHI) effects, reducing flood risks, and exploring nature-based solutions as adaptive measures.

Cities are at the forefront of climate change impacts, with rapid urbanization exacerbating vulnerabilities and intensifying the urban heat island phenomenon. The Urban Heat Island effect, characterized by elevated temperatures in urban areas compared to their non-urban surroundings, is a complex interplay of impervious surfaces, altered land use patterns, and heat-retaining materials. Concurrently, the escalating frequency and intensity of extreme weather events pose a substantial threat, amplifying the risk of urban flooding. Green infrastructure emerges as a multifaceted strategy that not only addresses these challenges but also enhances overall urban resilience.

Green infrastructure, encompassing a network of strategically planned natural and semi-natural elements, offers a holistic approach to climate resilience. By integrating elements such as urban forests, green roofs, permeable surfaces, and wetlands, green infrastructure provides a mechanism to mitigate Urban Heat Island effects, reduce flood risks, and concurrently enhance urban ecosystems. The interconnectedness of these components presents a compelling opportunity to address climate change challenges comprehensively.

Green infrastructure's role in Urban Heat Island mitigation is multifaceted. The incorporation of green spaces, tree canopies, and reflective surfaces not only provides shade and lowers ambient temperatures but also contributes to enhanced air quality. This thesis will explore the mechanisms through which green infrastructure influences microclimates, with a focus on temperature regulation and its subsequent impact on urban heat-related vulnerabilities.

With changing precipitation patterns and increased susceptibility to flooding, urban areas face a critical need for adaptive strategies. Green infrastructure, through its capacity to absorb and slow stormwater runoff, acts as a natural buffer against floods.

Nature-based solutions, a subset of green infrastructure, represent an innovative approach inspired by natural processes. This thesis will explore various nature-based solutions, including their design, implementation, and effectiveness in enhancing urban climate resilience. Case studies and empirical analyses will be employed to illustrate the real-world impact of these solutions on mitigating the impacts of climate change.

1.2 Thesis objectives, research questions and hypotheses

Within the framework of a master thesis, the research aims to evaluate a more in-depth planning process of Green Infrastructure Plans in Novara, Italy. Novara is capital city of the province of Novara in the Piedmont region in Northwest Italy. Italy, a southern European nation, has defined a series of national regulations and directives on topics related to green infrastructure, such as protected areas, biodiversity protection and ecosystems, and the Natura 2000 sites.

Moreover, in compliance with the European framework on Biodiversity Protection, Italian Regions integrate green infrastructure in the definition of their Regional Ecological Networks. In certain Regional Territorial Plans (RTPs), RENs are recognized as priority infrastructures, and they represent a key tool to orient spatial planning at the regional and local level.

This research seeks to provide a comprehensive understanding of the interconnections between green infrastructure, Urban Heat Island, flood risk reduction, and nature-based solutions in the context of climate change. Through empirical investigations, case studies, and a synthesis of existing literature, the aim is to contribute valuable insights that can inform urban planning, policy development, and community initiatives for creating resilient and sustainable cities in the face of an evolving climate.

The main research objective and challenges are in further details as following:

Main aim of thesis:

- To explore the process of development and implementation of the Green Infrastructure Plans in Novara, Italy and to identify best practices and lessons that can be useful for the Italian context.

Specific objectives:

- To analyze the contents of Green Infrastructure Plans in Italy.
- To analyze the development process of Green Infrastructure in Italy.
- To investigate how Green Infrastructure and Climate Change incorporated in the country spatial governance and planning system.
- To identify best practices and lessons that may be useful to drive Green Infrastructure and Nature Based Solutions (NBS) a Just and Green in the Italian context in terms of contents, development process, integration in the spatial governance and planning system.

Research questions

Four key research questions guide the study:

- How can the implementation of green infrastructure contribute to mitigating urban heat island effects in densely populated urban areas, and what are the associated socio-economic benefits?
- What role do nature-based solutions play in enhancing urban resilience to climate change-induced flood risks, and how can these solutions be integrated into urban planning and development strategies?
- To what extent does the presence of green spaces and urban vegetation influence the reduction of urban heat island effects, and how can city planners optimize the distribution of such green spaces for maximum impact?

- What is the most effective nature-based strategies for managing flood risks in coastal urban areas, and how do these strategies align with broader climate adaptation and mitigation goals?

1.3 Structure of the study

This thesis is divided into eight chapters to address the mentioned research questions. After an introduction outlining the main goals and concerns surrounding the topic, the research delves deeply into the concepts of climate change, green infrastructure (GI), and pertinent materials. In Chapter 2, it also lays out the theoretical foundation for the thesis. An overview of green infrastructure in Europe and Italy is given in Chapters 4 and 5, which also include case studies and a summary of the plans and strategies implemented in various European cities. In order to answer the research questions, the research design and data collection methodology are described in detail in Chapter 5. The chosen case study city, the factors that went into choosing it, and the techniques employed are all described in this chapter. In Chapter 6, the case study-related documents and maps are used to interpret the research findings. Chapter 7 provides a conclusion relevant to theoretical discussions and policy making. It also addresses the thesis's limitations and recommends future research directions. All the cited literature is listed in the final chapter.

2. Literature review

2.1 Introduction

The safeguarding of our environment emerged as a major focus in the latter part of the previous century and is expected to persist as a prominent concern in the current century. While environmental protection was not neglected in earlier periods, its significance in our societal context has heightened significantly. This is particularly relevant as populations grow, and the importance of resource management continues to escalate.

To put it another way, when it comes to land management, environmental protection has historically focused on protecting wildlife and natural or semi-natural habitats, as well as natural and cultural landscapes, frequently on a site-by-site basis and frequently isolated from neighbouring land uses.

To maintain economic and social stability in the modern world, societies and economies have made significant investments in housing, industry, and transportation infrastructure. Although society benefits from these investments in "grey" infrastructure, the less obvious but no less significant advantages that the environment offers to people have been somewhat downplayed.

This "other" infrastructure, which is hidden away among the more recognisable grey infrastructure of development, has rarely drawn the same level of attention or investment in the past, at least not at the strategic level. Instead, local-level investment has typically focused on a site-by-site basis, taking into account the aesthetic requirements of evolving development design trends over time or the needs of recreation. It makes sense that the strategic value of this "other" infrastructure has remained a secondary concern as settlements grow and alter (Christopher Marrs .et al, 2019).

As our understanding of our reliance with the environment grows, there is a great deal of discussion and study surrounding its importance and the advantages it offers to society. It is now evident that the spaces and regions outside of protected areas may and do offer us necessities for our economies, cultural identities, and general health and well-being. In addition, by acting as linkages between them, these areas help assist the protected areas.

By adding an additional, more tangible value to our green places, the science of ecosystem services presents a chance to maximise the benefits that the "other" infrastructure may offer. Applying ecosystem services, however, does not always solve the strategic imbalance or the best ways to arrange green areas and parks at the local or regional level. As a result, we were left with an inherited scenario in which few of our urban and peri-urban regions are planned strategically and our significant natural areas are not (Gavrilidis et al. 2019).

Green infrastructure is this "other" type of infrastructure. Green infrastructure is an approach that combines the science of ecosystem services with the need for strategic planning of green and open spaces. It encourages the versatility of space and the advantages that proper management techniques can provide. It acknowledges the necessity of planning land use for particular uses, such as farming, conservation, and development, but it also offers the instruments and techniques to pinpoint opportunities and requirements to improve the environment and all of its aspects.

The term "green infrastructure" is not new; it was first used in the United States in the mid-1990s (Firehock 2010). Even though there has been a supporting theory that ecosystems ought to be viewed as infrastructure since the 1980s (da Silva & Wheeler 2017).

The idea was born out of the recognition that natural systems are just as, if not more, crucial to the health of society and the economy as what is referred to as "grey infrastructure." Even though it may seem apparent that society needs the goods and services that green infrastructure offers, the phrase was first used in relation to spatial planning in the US in the 1990s, when it was first used. Over time, a variety of terms have been used to refer to different aspects of infrastructure, depending on context, professional level, or academic background. However, the term "green infrastructure" has emerged as the most used term in academic literature (da Silva & Wheeler 2017).

Since then, many have pushed for the development of green infrastructure as a counterpart to grey infrastructure, though few have done more to define and advance the idea than Benedict and McMahon of the US-based Conservation

Fund. This collaboration, which began in the early 2000s and culminated in their publication "Linking Landscapes and Communities," helped to establish the concept's global understanding (Benedict & McMahon 2006). The realisation that most planning techniques, especially in the urban setting, were, at best, reactive in terms of designing green spaces with little strategic planning was crucial to the concept's development.

Over time, green space policies and strategies have been developed throughout Europe as a result of the recognition that green infrastructure, in all its forms, is an essential factor in planning. However, the term "green infrastructure" is rarely used directly; instead, concepts like "ecological networks," "green wedges," and "green networks" are frequently employed instead (Grădinaru & Hersperger 2018). In their report on 20 European case study cities, the GREEN SURGE project also noted that while other concepts like "green system" or "ecological networks" were used, very few cities specifically mentioned "GI" (Hansen et al. 2015). Ecological networks and the components that make them up are typically recognised by the planning system and protected by current national legislation; green infrastructure does not replace these elements. Nonetheless, the larger network of green infrastructure includes those ecological networks.

A strategically planned network of natural and semi-natural areas with additional environmental features, as defined by the European Union, is called "green infrastructure." Its purpose is to provide a variety of ecosystem services, including air quality, water purification, recreation areas, and climate mitigation and adaptation. The network of green (land) and blue (water) spaces has the potential to enhance the quality of life and health of the populace by improving environmental conditions. Additionally, it improves biodiversity, generates employment opportunities, and supports a green economy. The foundation of the EU's green infrastructure is the Natura 2000 network (European Commission, 2016). The EU GI Strategy gets its definition of GI from this definition, and the MaGICLandscapes project has built its work around it as well.

The functions and scales of the various elements of green infrastructure differ, but they all contribute to the larger network of green infrastructure. The core of the EU

GI network, as previously mentioned on a transnational scale, is the Natura 2000 network, which includes vast forested and mountainous areas typical of border regions in Central Europe, such as the Giant Mountains separating Poland and the Czech Republic. Big rivers can also be transnational GI elements; the Danube River is an excellent example of one. As we prepare for future sea-level rise, the coast should not be overlooked as a transnational GI resource. Its diverse network of dunes, marshlands, lagoons, forests, and grasslands could become more interconnected.

Large, wooded areas like the Dübener Heide Nature Park in Saxony, protected areas like the Fiume Po - tratto vercellese alessandrino Special Protected Area in Northern Italy, and large bodies of water like the Neusiedler /Fertő tó UNESCO and Ramsar wetland on the Austrian/Hungarian border are examples of regional green infrastructure.

Of the three scales, local scale green infrastructure is typically the most diverse. Its location and local conditions greatly influence its form and function. It should be designed to adapt to local needs and take on a range of shapes and roles. Ponds, hedgerows, and artificial features like green walls and roofs can all be considered parts of the local green infrastructure (GI) (Christopher Marrs .et al, 2019).

Table below describes various green infrastructure elements and demonstrates that the concept is applicable at all scales.

Green infrastructure Elements	
Core Areas	Areas of high biodiversity value, often having protected status such as Natura 2000 sites, large habitat patches such as woodland, grasslands and water
Restoration Zones	New areas of habitat created for specific species and/or restored ecosystems for service provision
Sustainable Use/Ecosystem Service Zones	Land managed in a sustainable fashion for economic purposes whilst retaining and maintaining ecosystem services, examples include multi-use forestry and High Natural Value (HNV) farmland
Green Urban and Peri-Urban Features	Parks, gardens, small woodlands, grass verges, green walls and roofs, Sustainable Urban Drainage Systems (SUDS), school fields, cemeteries, allotments, street trees, ponds
Natural Connectivity Features	Ecological corridors such as hedgerows, rivers, wildlife strips and stone walls. Includes 'stepping stone' habitats to enable movement of species
Artificial Connectivity Features	Man-made features with the purpose of easing the movement of species through a landscape, includes green bridges over road corridors, tunnels underneath transport corridors and fish passes where natural migration/movement is hindered by development

Table 1: Green Infrastructure Elements and Examples, adapted from Mazza et al. (2011)

2.2 Overview over the conceptual aspects of Green Infrastructure

To provide a comprehensive knowledge of the concept based on previous studies, this section will especially discuss the fundamental and key aspects of Green Infrastructure.

2.2.1 Introduction and definition of Green infrastructure

The functioning of human society relies on the advantages offered by nature, including provisions like food, resources, clean water, fresh air, climate control, flood prevention, pollination, and recreational opportunities (COM (2012). However, many of these advantages, commonly known as ecosystem services, are often used as if they are in endless supply and are treated as free resources whose true value is not fully recognised. This can lead public authorities to make use for constructed infrastructure, often referred to as grey infrastructure, instead of natural solutions to address issues like flood prevention. In Europe, this ongoing trend results in the ongoing depletion of our natural resources, jeopardising our long-term sustainability and undermining our ability to withstand environmental shocks. The failure to safeguard our natural resources and properly appreciate the value of ecosystem services needs to be tackled as part of the efforts to achieve intelligent, sustainable, and inclusive growth, which is the primary focus of the EU's Europe 2020 initiative (COM (2010). The roadmap recognises that investing in Green Infrastructure (GI) is a vital step in safeguarding our natural resources. Numerous definitions of GI have been developed.

Green Infrastructure (GI) has proven to be an effective tool in delivering ecological, economic, and social advantages through natural solutions. It aids in recognising the value of the benefits nature offers to human society and encourages investments to preserve and improve these benefits. Additionally, GI helps us to avoid expensive infrastructure development when more cost-effective and resilient natural solutions are available. Moreover, many of these solutions generate local employment opportunities. The core principle of Green Infrastructure lies in the deliberate integration of protecting and enhancing nature, as well as the associated benefits for human society, into spatial planning and territorial development. In comparison to single-purpose, conventional infrastructure (often referred to as grey infrastructure), GI offers a multitude of advantages. It doesn't hinder territorial development but rather promotes natural solutions when they prove to be the optimal choice. In some cases, it can even serve as a viable alternative or complement to traditional grey infrastructure. Numerous definitions of GI have been formulated, and the following are considered the most accurate ones.

To be more specific, we need to have the definition of Green Infrastructure. Green infrastructure (GI) is a designed system of natural and semi-natural zones, along with various environmental elements, intentionally organised and maintained to provide a diverse array of ecosystem services. It encompasses green areas (or blue if pertaining to aquatic ecosystems) and other tangible characteristics found in both terrestrial (including coastal) and marine environments. On land, GI is present in rural and urban settings.

According to Benedict and McMahon (2002), Green Infrastructure (GI) is characterised as a connected system of green spaces that preserves the inherent values and functions of natural ecosystems, while also delivering advantages to human communities. They argue that GI represents the essential ecological framework for achieving environmental, social, and economic sustainability. It sets itself apart from traditional methods of open space planning by combining conservation values and actions seamlessly with land development, growth management, and the planning of built infrastructure.

Weber and colleagues (2006) define Green Infrastructure as the presence and arrangement of natural elements within the environment. These natural features not only facilitate ecological processes but also have a positive impact on human health and overall well-being, as highlighted by Tzoulas et al. (2007). Moreover, Ewers et al. (2009) and Lafortezza et al. (2010) acknowledge that Green Infrastructure is evolving into a lasting strategy for providing vital resources and services to communities while also addressing issues like landscape and habitat fragmentation.

Green Infrastructure is also described as the fusion and interplay of diverse services and advantages within a given region, primarily through the concept of "multi- functionality," which illustrates the various roles fulfilled through effective land management (Davies et al., 2006). Ortega-Álvarez and MacGregor-Fors (2009) depict Green Infrastructure in structural dimensions as a collection of elements collaborating to uphold a network of sites that facilitate ecological and social processes. These elements can vary in size and configuration, tailored to the specific function or service they are meant to deliver.

The term Green Infrastructure (GI) is becoming increasingly prevalent in discussions related to land and urban planning in various areas and at multiple scales, ranging from city-level planning to supranational contexts (Mell, 2010). However, it's important to note that the term can carry varying interpretations for different individuals, and there are numerous approaches to defining and evaluating it (Davies et al. 2006).

The National Planning Policy Framework for England in 2012 (issued by the Department of Communities and Local Government in the UK) emphasizes the importance of considering climate change in long-term planning. It specifically suggests that Local Plans should factor in the effects of climate change and, in areas susceptible to its impacts, new developments should incorporate adaptation measures, including the utilisation of Green Infrastructure, to manage and mitigate risks (Bonan, 2008).

At the European level, Green Infrastructure (GI) has been defined as a comprehensive concept that addresses the connectivity of ecosystems, their preservation, and the provision of ecosystem services, all while addressing mitigation and adaptation to climate change (EEA, 2011). It also encourages the integration of spatial planning by identifying multifunctional zones and incorporating habitat restoration measures and other connectivity elements into various land-use plans and policies. This includes linking peri-urban and urban areas, as well as implementing these principles in marine spatial planning policy, as highlighted by Lafortezza et al. (2013).

Those conceptualising Green Infrastructure including Benedict & McMahon (2002), Weber et al. (2006), Davies et al. (2006) and Tzoulas et al. (2007) all see the link between ecological and social factors as crucial to the Green Infrastructure approach.

2.2.2 Introduction of climate change

The term "climate change" describes notable and long-lasting variations in Earth's climate patterns that are mostly caused by human activity. The planet has seen unparalleled shifts in temperature, precipitation, and weather patterns over the last century. The increase in greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in the atmosphere is primarily responsible for these changes. GHGs trap heat, raising the Earth's surface temperature—a phenomenon known as global warming. The concentrations of these GHGs have increased dramatically since the pre-industrial era due to human activities, specifically the burning of fossil fuels and deforestation, according to the Intergovernmental Panel on Climate Change (IPCC), a preeminent authority on climate science (IPCC, 2021). Since the late 19th century, the amount of CO2 in the atmosphere has increased by over 40%. This increase is mostly attributable to changes in land use and the burning of coal, oil, and natural gas.

One of the most significant effects of climate change is the increase in global temperatures. NASA's Goddard Institute for Space Studies (GISS) reports that the average global temperature has risen by about 1.2 degrees Celsius (2.2 degrees Fahrenheit) since the late 19th century, with the last decade being the warmest on record (NASA, 2020). This temperature rise has caused numerous environmental impacts, such as the melting of polar ice caps and glaciers, rising sea levels, and more frequent and intense weather events like hurricanes, heatwaves, and heavy rainfall (NOAA, 2021).

The impacts of climate change are extensive and profound, affecting ecosystems, biodiversity, and human societies. Changes in temperature and precipitation patterns have disrupted habitats, causing shifts in species distributions and increasing the risk of extinction for many plants and animals (Parmesan & Yohe, 2003). Moreover, climate change poses significant threats to human health, food security, water resources, and economic stability. The World Health Organization (WHO) has identified climate change as one of the greatest global health threats of the 21st century, linking it to higher incidences of heat-related illnesses, vector-borne diseases, and food and water shortages (WHO, 2018).

Addressing climate change requires a comprehensive and coordinated global effort to reduce greenhouse gas emissions and enhance resilience to its impacts. International agreements like the Paris Agreement aim to limit global warming to well below 2 degrees Celsius above pre-industrial levels, with efforts to cap the temperature increase at 1.5 degrees Celsius. Achieving these targets necessitates substantial emission reductions through the adoption of renewable energy sources, increased energy efficiency, and sustainable land management practices (UNFCCC, 2015).

2.2.3 Introduction and definition of Urban Heat Island (UHI)

The core of most major cities is generally observed to have a higher temperature than the surrounding area or the suburbs. Urban Heat Island (UHI) effect is the term used to describe the phenomenon (Adinna et al. 2009; Synnefa et al. 2008). More specifically, the term "Urban Heat Island effect" refers to the phenomenon wherein the central part of a city exhibits a higher temperature than the surrounding rural areas (Yamamoto 2006). The effect creates a temperature differential between the cities and the surrounding suburbs, which makes city dwellers uncomfortable (Yamamoto 2006). It develops when a significant portion of natural land is replaced with man-made surfaces that absorb heat or solar radiation from the sun and reradiate it at night.

As Yamamoto (2006) notes, the phenomenon is real and present in nearly every major city. This effect is attributed to a multitude of factors, such as air pollutants, surface cover, climate conditions, and human-generated heat release (Yamamoto 2006). According to Oke, T.R. (1982), UHI can reach up to 10-150C in the right circumstances. The UHI creates a microclimate, which increases the need for energy to cool buildings (Adina et al. 2009). Additionally, in order to meet demand, more electricity must be generated, which raises greenhouse gas emissions and contributes to climate change. The vast number of built-up surfaces, such as asphalt and concrete, which have a high heat capacity, is one of the main causes of UHI formation (Akbari et al. 2001). Low albedo materials are exacerbating the phenomenon further. According to Taha (1997), an urban heat island is produced when natural vegetation is replaced with non-reflective, water-resistant, impermeable materials at the surface. It's a procedure that changes depending on the built environment and surrounding geography of a city (Grimmond & Oke 1999). Inadequate city planning is another factor contributing to the Urban Heat Island effect (Li, K. et al.). According to Taha, H. (1997), anthropogenic heat, vehicle exhaust fumes, power plants, and industrial processes can all increase the intensity of the UHI effect. The demand for electricity increases by 2-4% for every 10C increase in temperature, according to Akbari et al. (2001). Generally speaking, urban areas have less vegetation and darker surfaces than their surroundings. In a warm summer's day, the temperature difference between a typical city and its surrounding rural areas can reach 2.50C, which could result in an extra 5–10% of the municipal peak electricity demand (Akbari et al., 2001).

2.3 Overview over the relation of Green Infrastructure and Climate Change

- **Climate change and disaster risk management**

Ecosystem-based approaches refer to strategies and actions that leverage the natural adaptive capabilities of ecosystems. They are recognised as some of the most broadly applicable, economically feasible, and efficient methods for addressing the consequences of climate change. In suitable circumstances, these approaches incorporate Green Infrastructure (GI) solutions, as they utilise biodiversity and ecosystem services as integral components of a comprehensive adaptation strategy to assist communities in adapting to or mitigating the adverse impacts of climate change. The recent EU Strategy on Adaptation to Climate Change (COM (2013) is focused on assessing the necessity for further guidance to assist authorities, decision- makers, civil society, private enterprises, and conservation practitioners in fully harnessing ecosystem-based adaptation approaches. Green Infrastructure (GI) projects in the agricultural and forestry sectors that positively influence carbon stocks and greenhouse gas balances in Member States will be considered within the framework of LULUCF (Land Use, Land Use Change, and Forestry). This action aligns with the practical implementation of climate policies set forth by the EU and the United Nations Framework Convention on Climate Change (UNFCCC). Green Infrastructure (GI) will play an essential role in complementing efforts to reduce the carbon footprint associated with transportation and energy provision. It will aid in mitigating the adverse impacts of land consumption and fragmentation, while also enhancing the prospects for more effectively integrating land use, ecosystem preservation, and biodiversity considerations into policy and planning processes. GI solutions can make substantial contributions to the establishment of Green Transport Corridors, utilising the capacity of healthy ecosystems, for instance, to sustainably offset carbon emissions.

The Directive on the energy performance of buildings is designed to encourage the advancement and adoption of novel materials and innovative design elements in the construction of buildings. This is part of the broader initiative to decrease the substantial volume of greenhouse gas (GHG) emissions generated by this sector. Green Infrastructure (GI) solutions, like green roofs and walls, can play a crucial role in lowering GHG emissions. This is because they demand less energy for heating and cooling, while also offering additional advantages such as water retention, air purification, and enhancement of biodiversity.

The impact of such events on both human society and the environment can often be mitigated through the application of GI solutions. These include functional floodplains, riparian woodlands, protective forests in mountainous regions, barrier beaches, and coastal wetlands, which can be effectively combined with disaster reduction infrastructure, such as river protection works. GI also contributes to reducing vulnerability to risks by supporting local livelihoods and economies. Investments in ecosystem-based disaster risk reduction and GI, therefore, offer numerous advantages for innovative risk management strategies, adaptation to climate change-related risks, the maintenance of sustainable livelihoods, and the promotion of green growth (COM (2009)).

Given that cities and local authorities are typically the first to address the immediate aftermath of such disasters, they have a crucial role in implementing preventive measures like GI.

- **Land and Soil**

Land and soil constitute essential elements of the European Union's natural resources. However, each year, over 1000 Km2 of land are subject to urban expansion for housing, industrial purposes, roads, and recreational areas (State of the Environment Report 2010). In many regions, soil faces irreversible erosion or possesses a low organic matter content, with soil contamination emerging as a significant issue (COM (2012).

To address these challenges, it is crucial to systematically incorporate Green Infrastructure (GI) considerations into the planning and decision-making processes. This approach can help mitigate the loss of ecosystem services resulting from future land development and contribute to the enhancement and restoration of soil functions.

The management of agricultural and forestry land profoundly influences the state of the EU's natural resources. In acknowledgment of this connection, the Common Agricultural Policy (CAP) and rural development offer tools and measures to promote GI and improve areas with high ecological value in rural areas. This encompasses substantial direct support for farmers in the first pillar of the CAP, designed to prevent land abandonment and fragmentation. Additionally, smaller-scale initiatives are supported through rural development programs in the second pillar. These include non-productive investments, agro-environmental actions such as farmed landscape conservation, maintenance and enhancement of hedgerows, buffer strips, terraces, dry walls, payments to ensure the cohesion of Natura 2000, cooperative efforts to preserve valuable field boundaries, and the conservation and restoration of rural heritage features.

- **Water**

Incorporating Green Infrastructure (GI) considerations into the management of river basins can make a significant contribution to achieving high water quality, mitigating the impacts of hydro-morphological pressures, and minimising the consequences of both floods and droughts (COM (2012). Additionally, Green Infrastructure provides cost-effective alternatives, as emphasised by The Economics of Ecosystems and Biodiversity (TEEB), for more effectively implementing the Drinking Water Directive and the Groundwater Directive. There is ongoing development of innovative, multifaceted, highly efficient, and cost-effective green solutions for wastewater treatment.

In the context of the marine environment, GI can facilitate the practical implementation of existing strategies for marine spatial planning and integrated coastal zone management, particularly strategies aimed at the sustainable management of coastal areas and the enhancement of coastal defences (COM (2013). Furthermore, the further advancement of blue carbon approaches, which benefit fish populations, can also gain from the application of GI principles to promote various ecosystem services in the marine environment.

To sum up, Ecosystem-based approaches and Green Infrastructure (GI) solutions are among the most effective and economical strategies for addressing climate change and disaster risk management. By utilizing the adaptive capabilities of natural ecosystems, these methods mitigate climate impacts and enhance community resilience. The EU Strategy on Adaptation to Climate Change highlights the need for guidance to fully implement these approaches. GI projects in agriculture and forestry are crucial for enhancing carbon stocks and reducing greenhouse gas emissions, aligning with EU and UNFCCC policies. They also reduce the carbon footprint of transportation and energy sectors and integrate biodiversity into planning processes.

In construction, the Directive on energy performance promotes GI solutions like green roofs and walls, which lower greenhouse gas emissions and offer benefits such as water retention and air purification. GI solutions also mitigate natural disaster impacts. Examples include functional floodplains and coastal wetlands, which support local economies and reduce vulnerabilities.

Effective land and soil management, crucial in the EU, can be achieved by incorporating GI into planning to prevent ecosystem service loss and improve soil functions. The Common Agricultural Policy and rural development programs support GI to prevent land abandonment and fragmentation.

In water management, GI improves water quality, mitigates hydro-morphological pressures, and minimizes flood and drought impacts. It also supports marine spatial planning and enhances marine ecosystem services.

Overall, investing in ecosystem-based disaster risk reduction and GI promotes innovative risk management, climate adaptation, and sustainable livelihoods. Local authorities and cities play a key role in implementing these measures, ensuring a resilient and sustainable future for communities.

3. Green infrastructure and Climate change in Europe

3.1 Introduction

The concept of Green Infrastructure encompasses a network of green spaces and other environmental features that are strategically planned and managed to provide ecosystem services, such as air and water purification, flood management, carbon sequestration, and recreational opportunities (Benedict & McMahon, 2006). GI includes a variety of elements such as parks, green roofs, wetlands, urban forests, rivers, and coastal areas.

The European Commission approved the EU Green Infrastructure Strategy in 2013 (European Commission 2013a). It is regarded as essential to achieving the goals of the EU 2020 Biodiversity Strategy. Though all the targets relate to and/or benefit in some way from the implementation of Green Infrastructure (GI), Target 2 of the Biodiversity Strategy specifically highlights the use of GI to maintain and enhance ecosystems and their services (European Commission 2011a and b). The EU Directorate-General for Environment identified four "broad roles" for green infrastructure in its report "The Multi-functionality of Green Infrastructure" (European Commission's Directorate-General Environment 2012): Protecting ecosystem state and biodiversity, improving ecosystem functioning and promoting ecosystem services, promoting societal well-being and health and supporting the development of a green economy, and sustainable land and water management (Figure 6).

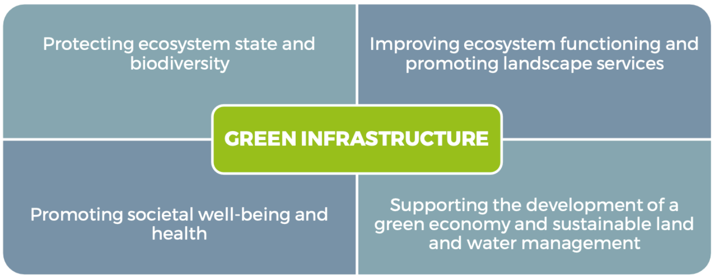


Figure 1: Roles of Green Infrastructure (adapted from European Commission's Directorate-General Environment 2012)

Natural Capital/ Natural Heritage

"Real or financial assets possessing a monetary value, accumulated wealth and goods" is how the Oxford English Dictionary defines capital (OED, 2018). The term "natural capital" refers to the inventory of natural resources or assets that humans use to produce goods and services, including materials, food, water, recreation, and other things. Some of these resources are renewable, while others are not (NCC, 2016). Landscape services derive their benefits from this natural capital (Figure 7).

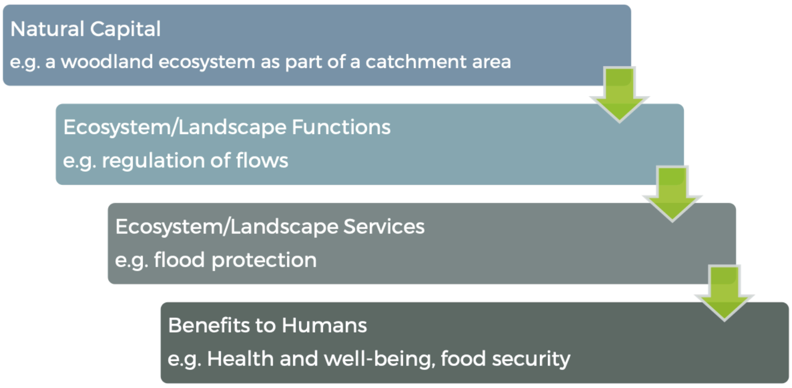


Figure 2: Relationship between Natural Capital, Ecosystem/Landscape Functions and Services and Benefits of Green Infrastructure (adapted from Potschin & Haines-Young 2011)

According to Ekins (1992), there are four distinct types of capital stock: manufactured capital, social and organizational capital, human capital, and natural capital. According to Ekins et al. (2003), natural capital serves four purposes from the perspective of humans:

- Provision of resources for production
- Absorption of waste (production waste and disposal of goods)
- Life support (water, air)
- Amenity

Overusing natural capital, a limited resource, without replenishing it is unsustainable, in a similar way to how it is not sustainable to withdraw money from a bank account on a regular basis without adding to it. The following quote from 2009, which emphasises the need for a more sustainable use of natural capital, says it all: "From an economic point of view, nature is an asset which should be preserved." According to the 2009 Initiative "Memorandum: Economics for Nature Conservation," we must live off interest rather than capital.

We are able to evaluate nature's value to economies and society by treating it as capital in a manner similar to that of manufactured or human capital. This allows us to include nature in decision-making processes where it has historically not been given the same weight as factors like housing, jobs, and transportation infrastructure.

3.2 Ecosystem Services

Ecosystem services are the products and services that nature, our natural capital, offers and that humans depend on. Since ecosystem services are essential to the long-term preservation and restoration of Europe's natural capital, it is critical to comprehend the services that ecosystems offer (European Union 2017). Ecosystem services are given more attention in the EU Biodiversity Strategy 2020, and the strategy lays out several steps intended to preserve and restore ecosystems and the services they provide (European Commission 2011a). These steps include increasing our understanding of ecosystems and the services they provide, prioritising the restoration and upkeep of green infrastructure, and making sure that there is no net loss of biodiversity or ecosystem services (European Commission 2011b).

Ecosystem services are often grouped into four main categories: Provisioning, Regulatory and Maintenance, Cultural and Supporting Services/Functions.

3.3 Landscape Services

In the fields of landscape ecology, landscape planning, and spatial, regional, and urban planning, the term "landscape functions" or "services" can be used interchangeably with "ecosystem services" because landscapes are thought to be multifunctional and subject to a variety of land uses. Landscape services can be found to varied degrees in a range of natural, cultural, peri-urban, and even urban landscapes, as defined by Hermann et al. (2011) as the visible features of an area of land, its landforms, and how they integrate with natural or man-made features. The idea that people are a part of the landscape and that it is altered for their benefit has always been fundamental to landscape development (Linehan & Gross 1998; Antrop 2011). According to de Groot (1992), landscape functions are the ability of landscapes to directly and indirectly meet human needs by offering goods and services. According to Vallés-Planells et al. (2014), landscape, cultural identity, and diversity—all influenced by the ways in which people have interacted with their surroundings throughout history—are crucial elements of human well-being and sustainable development.

Value and landscape can be connected through the idea of landscape services. According to Müller et al. (2008), landscape sciences provide valuable insights into the spatial distribution of human activities and their impact on significant landscape processes and structures that underpin the provision of services. This is because their primary focus is on spatial pattern and scale.

Defining functions and services at the landscape scale is an additional strategy to incorporate the idea into land management decisions. Thus, landscape ecology may serve as the foundational science for development of sustainable landscapes. Local stakeholders must be involved in decision-making regarding necessary landscape modifications to better suit their views of value in state systems where spatial planning policy is decentralised (Termorshuizen & Opdam 2009).

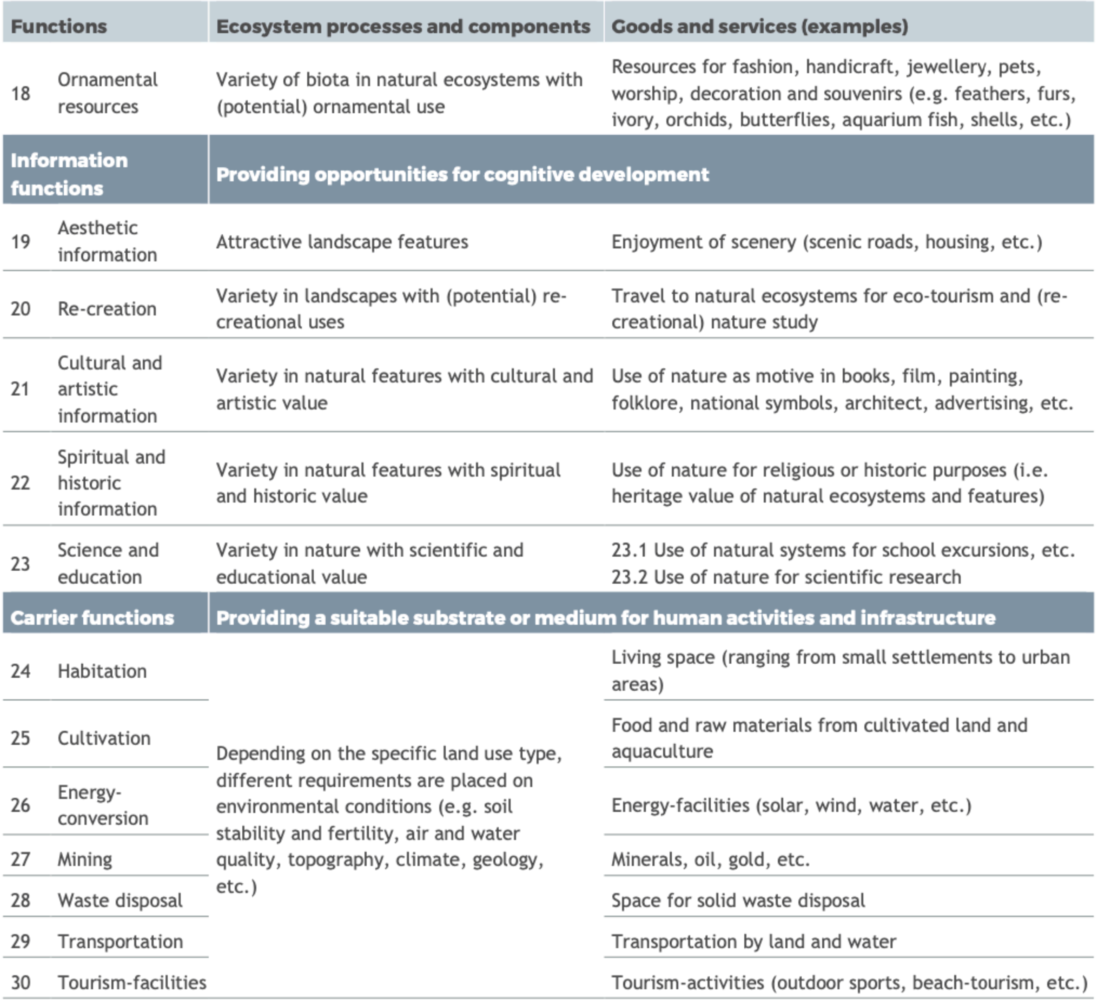
In contrast to a "ecosystem," "landscapes" might be more appealing to scientific fields outside of ecology because they are connected to people's local surroundings. The term "landscape services" is preferred as a specification of "ecosystem services" because locals define their environment more as a "landscape" than as an "ecosystem" (Termorshuizen & Opdam 2009). Together with this method of using participatory approaches in planning, the terms "landscape function" and "landscape service" have recently gained prominence in literature (Bastian & Schreiber 1999; de Groot et al. 2010; Willemen et al. 2010). According to Termorshuizen & Opdam (2009), "Landscape Services" is a better concept than "Ecosystem Services" since it has a stronger correlation with pattern–process relationships. Additionally, they claimed that landscape services are more relevant and legitimate to local practitioners and better integrate scientific disciplines.

All products and services that landscapes offer to support life are referred to as landscape services. Nature's potentials, materials, and processes (raw materials, biomass, biodiversity, etc.) as well as the services provided by cultural elements and human-made structures (buildings, settlements, infrastructure, etc.) are all included. (Konkoly-Gyuró, 2014, correspondence for personal use).

Landscape functions are classified into five main categories according to de Groot (2006) (based on de Groot 1992 and de Groot et al. 2002):

- Regulation functions
- Habitat functions
- Production functions
- Information functions
- Carrier functions

Functions		Ecosystem processes and components	Goods and services (examples)
Regulation functions		**Maintenance of essential ecological processes and life support systems**	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVB-protection by O_3 (preventing disease) 1.2 Maintenance of (good) air quality 1.3 Influence on climate (see also function 2)
2	Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favourable climate (temp., precipitation, etc.) for, for example, human habitation, health, cultivation
3	Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	3.1 Storm protection (e.g. by coral reefs) 3.2 Flood prevention (e.g. by wetlands and forests)
4	Water regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation
5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land 6.2 Prevention of damage from erosion/siltation
7	Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land 7.2 Maintenance of natural productive soils
8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients (e.g. N, P and S)	Maintenance of healthy soils and productive ecosystems
9	Waste treatment	Role of vegetation and biota in removal or breakdown of xeric nutrients and compounds	9.1 Pollution control/detoxification 9.2 Filtering of dust particles (air quality) 9.3 Abatement of noise pollution
10	Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species 10.2 Pollination of crops
11	Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases 11.2 Reduction of herbivory (crop damage)
Habitat functions		**Providing habitat (suitable living space) for wild plant and animal species**	
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of biological and genetic diversity (and, thus, the basis for most other functions)
13	Nursery function	Suitable reproduction-habitat	Maintenance of commercially harvested species
Production functions		**Provision of natural resources**	
14	Food	Conversion of solar energy into edible plants and animals	14.1 Hunting, gathering of fish, game, fruits, etc. 14.2 Small-scale subsistence farming and aquaculture
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Building and Manufacturing (e.g. lumber) 15.2 Fuel and energy (e.g. fuel wood) 15.3 Fodder and fertilizer (e.g. krill)
16	Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Improve crop resistance to pathogens and pests 16.2 Other applications (e.g. health care)
17	Medicinal resources	Variety in (bio)chemical sub-stances in, and other medicinal uses of, natural biota	17.1 Drugs and pharmaceuticals 17.2 Chemical models and tools 17.3 Test and essay organisms



Functions		Ecosystem processes and components	Goods and services (examples)
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewellery, pets, worship, decoration and souvenirs (e.g. feathers, furs, ivory, orchids, butterflies, aquarium fish, shells, etc.)
Information functions		**Providing opportunities for cognitive development**	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20	Re-creation	Variety in landscapes with (potential) re-creational uses	Travel to natural ecosystems for eco-tourism and (re-creational) nature study
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect, advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	23.1 Use of natural systems for school excursions, etc. 23.2 Use of nature for scientific research
Carrier functions		**Providing a suitable substrate or medium for human activities and infrastructure**	
24	Habitation	Depending on the specific land use type, different requirements are placed on environmental conditions (e.g. soil stability and fertility, air and water quality, topography, climate, geology, etc.)	Living space (ranging from small settlements to urban areas)
25	Cultivation		Food and raw materials from cultivated land and aquaculture
26	Energy-conversion		Energy-facilities (solar, wind, water, etc.)
27	Mining		Minerals, oil, gold, etc.
28	Waste disposal		Space for solid waste disposal
29	Transportation		Transportation by land and water
30	Tourism-facilities		Tourism-activities (outdoor sports, beach-tourism, etc.)

Table 2: Functions, processes and goods and service of natural and semi-natural ecosystems. Reproduced and slightly adapted from de Groot (2006; adapted from Constanza et al. 1997, de Groot 1992, de Groot et al. 2002).

3.4 Green Infrastructure and Multi-functionality

The science of landscape services is supportive of green infrastructure (GI). An overview of the functions and services provided by the landscape above shows that different ecosystem types can provide a variety of services that are beneficial to society. If society is to make strategic plans, we must consider where the greatest need is for those services or where the creation of new habitats, ecosystems, and green spaces is required to meet those needs.

Because of its multi-functionality, GI can provide a variety of services to suit a range of requirements. The kinds of GI required are determined by the local environmental and human needs. For example, inner cities need space for recreation and climate services like controlling runoff from rainfall and lowering the heat island effect. More rural areas might need "wilder" habitats to increase connectivity between core wildlife value areas, like Natura 2000 sites, or buffer agricultural land to prevent fertiliser and pesticide runoff into water bodies, help with pollination, and help control pests.

Planning for multi-functionality is essential when designing landscapes and green spaces. Local needs should also be considered, as well as how best to incorporate GI elements into the design of the space or landscape.

In addition to helping to address local issues like access to green space, mitigating the effects of climate change, and the remediation of contaminated, derelict, or abandoned land, well-planned, multifunctional green space and landscape elements can also help to meet the goals of various sectors and providers. The financial burden on a single sector or provider can be decreased by utilising multiple funding sources through the collaboration of different sectors.

- **Benefits of Green Infrastructure for the society**

A wide range of stakeholders must support green infrastructure (GI) projects for them to be implemented successfully. Planners, investors, communities, policymakers, and decision-makers are among them. Many of them might not be familiar with the idea of landscape or ecosystem services, and they might find the scientific approach a little strange and, understandably, a little too academic. Therefore, it is frequently helpful to describe those services in terms of advantages that stakeholders outside of the scientific community can more easily identify. It can be easier and more successful to communicate the idea of green infrastructure if there is a clear set of identifiable benefits. Determining the requirements and sites for green infrastructure investment also requires an understanding of the advantages that GI can offer.

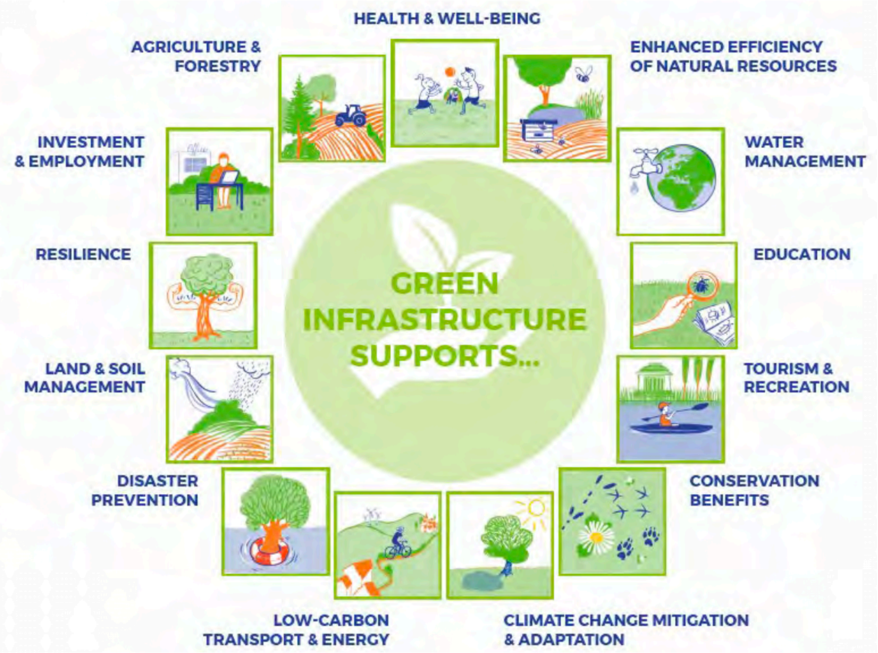


Figure 3: Groups of Benefits of Green Infrastructure (based on European Commission 2013b)

3.5 Climate Change Mitigation and Adaptation

It is commonly known that green spaces can help towns and cities cool down by providing shade and evapotranspiration from surrounding vegetation. Urban areas must be ready for rising temperatures as a result of climate change and an increase in the frequency and severity of extreme weather events. Increased temperatures have an impact on human health, either directly through heat-related exposure or indirectly through heat-related effects on airborne pollutants, such as raising ozone levels, which have been shown to exacerbate asthma symptoms (Goodman et al. 2018). Certain demographic groups—such as children and the elderly—are more susceptible than others. Approximately 60% of the 14,800 fatalities in France from the 2003 heatwave were elderly (Confalonieri et al. 2007). Investment in green infrastructure should therefore be considered a population's sensitivity to rising temperatures. The benefits of GI in lowering heat-related mortality should receive more attention because the population is getting older.

A variety of strategies, including the storage and sequestration of carbon from the atmosphere, should be considered when developing green infrastructure. More vegetation indicates a greater amount of carbon being stored in soil, plants, and animals.

Since the oceans evaporate more water as they warm and the air's capacity to hold moisture rises with temperature, an increase in the intensity of rainfall events is also likely a result of climate change for some countries (Mullan et al. 2012). Both in urban and rural settings, GI elements can aid in controlling and storing excess precipitation, thereby lowering the frequency and duration of flood events.

Climate change is expected to intensify storms, which means that natural systems will be disrupted more frequently by wildfires and stronger winds. Better forage and movement opportunities for impacted species are made possible by a well-connected network of natural spaces, which also allows for the repopulation of affected areas after disturbance events.

Landscape services providing this benefit include Local Climate Regulation, Water Regulation, Soil Retention, Water Supply, Refugium, Nursery, and Gas Regulation.

3.6 Introduction about Green Infrastructure in international Conventions and EU Regulations/Programmes

Several laws and policies, particularly at the EU level, specifically mention green infrastructure and encourage its development, preservation, and improvement.

Furthermore, specific components of green infrastructure, like forests or water bodies, are the subject of numerous international conventions as well as EU regulations and programs. However, several international conventions and EU regulations and programs promote the usefulness of green infrastructure, including its ability to lessen flooding, enhance air quality, and lessen the adverse effects of climate change.

- Green Infrastructure and EU Regulations

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Green Infrastructure

(GI) — Enhancing Europe’s Natural Capital – COM (2013) 249 final (Green Infrastructure Strategy).

The European Commission released this strategy in 2013, which defines the term "green infrastructure" (GI) for the purpose of defining its strategic application within the EU and explains how GI can help accomplish several important policy goals. As "a successfully tested tool for providing ecological, economic, and social benefits through natural solutions," it describes GI as having the potential to supplement or even replace conventional grey solutions on occasion. The Strategy specifically encourages spending on green infrastructure to maintain and improve the advantages that come from being in nature.

The following EU policies directly refer to Green Infrastructure:

- **Urban Agenda for the EU, launched with the Pact of Amsterdam (2016):** Agreed at the Informal Meeting of EU Ministers Responsible for Urban Matters on 30th May 2016 in Amsterdam, The Netherlands, the Pact of Amsterdam sets out an initial list of Priority Themes for the Urban Agenda for the EU. One of these twelve themes is “Climate Adaptation (including Green Infrastructure Solutions)”.

- **COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A Blueprint to Safeguard Europe's Water Resources - COM (2012) 673 final (EU Water Blueprint)**:

The EU Water Blueprint directly refers to Green Infrastructure (GI) and quotes GI more than once as an appropriate solution for problems concerning EU waters, their ecological status and vulnerability.

It promotes the use of “green infrastructure such as the restoration of riparian areas, wetlands and floodplains to retain water, support biodiversity and soil fertility, and prevent floods and droughts. This is a valuable alternative to classical grey infrastructure.

- **WHITE PAPER Adapting to climate change: Towards a European framework for action - COM (2009) 147 final:**

This White Paper directly refers to Green Infrastructure. It quotes Green Infrastructure “a crucial role in adaptation in providing essential resources for social and economic purposes under extreme climatic conditions. Examples include improving the soil’s carbon and water storage capacity, and conserving water in natural systems to alleviate the effect of droughts and to prevent floods, soil erosion and desertification”.

3.7 European structure for climate change

The climate system has been rapidly changing since the 1950s, according to scientific evidence. Many of the observed changes, such as warming atmospheres and oceans, melting glaciers, rising sea levels, and extreme weather events, are "unprecedented in magnitude and rate over decades to millennia," according to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which was published in 2014.

According to the 2014 IPCC report, Earth's temperature has increased during each of the last three decades more than it has any previous decade since 1850. The world has recently seen its highest atmospheric temperature since 1850, when records of the average global temperature first started to be kept. This occurred between 2015 and 2019 (JRC, 2020a)

As of late, 2019 was the second warmest year on average, trailing only 2016 in the record (C3S, 2020). Based on scientific estimates, the average temperature of the Earth's surface has risen by approximately 1°C since 1850–1900 (JRC, 2020a).

Over 90% of the excess heat in the climate system has been absorbed by the oceans since 1970, according to the IPCC's 2019 Special Report on the Ocean and Cryosphere in a Changing Climate (IPCC, 2019a). The cryosphere, or the portion of the Earth system that is made up of frozen water, is widely shrinking as a result of rising temperatures. Mass loss from ice sheets and glaciers, decreases in snow cover, thinning and expanding Arctic Sea ice, and rising permafrost temperatures are all contributing factors. Scientists have found that ice thickness 6 has decreased by more than 20 meters since 1960.

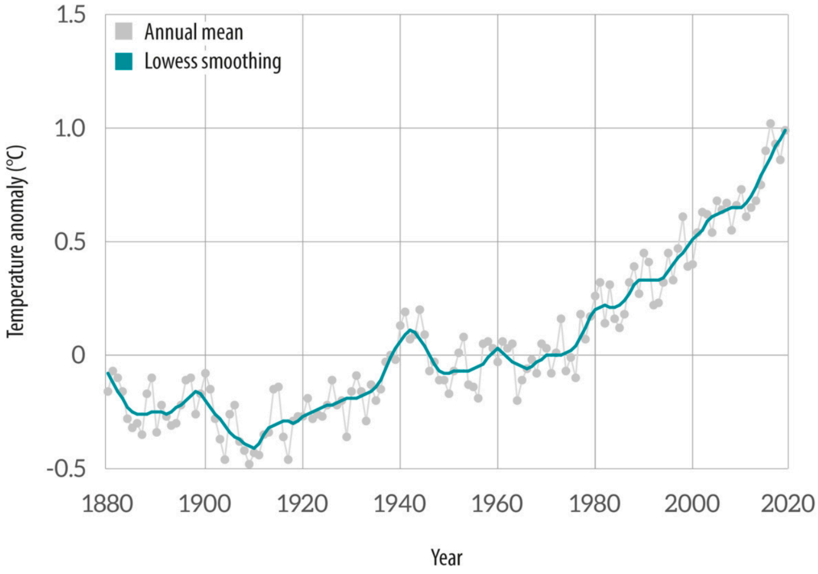


Figure 4: Global land-ocean temperature index

Data source: NASA

Extreme weather events like heatwaves (including marine ones), droughts, storms, heavy precipitation, floods, and powerful waves are occurring more frequently as a result of the observed changes in the climate system. (IPCC, 2014).

- **Risks of climate related impacts**

Over the past few decades, there have been noticeable changes in the climate that have affected every single continent and each ocean. The effects are considered in the context of natural and human systems by powerful evidence that is currently available, such as the reports published by the European Environment Agency (EEA). There is broad agreement across all sources that the likelihood of natural and human systems experiencing negative (and less so positive) effects from climate change increases with the amount and rate of future warming and related changes in the climate system. Additional variables that affect the likelihood of climate-sensitive events include geographic location, exposure, susceptibility, and the ability of human and natural systems to adjust to the effects of climate change (IPCC,2014). The rate at which population, consumption, production, technology, and land management practices change will also determine how risky climate change is (IPCC, 2019a).

Continued human-caused greenhouse gas emissions 'will increase the risk of severe, widespread and in some cases irreversible detrimental impacts' on human and natural systems, according to scientists (IPCC, 2014).Consequently, they issue a warning that limiting climate change and reducing its negative effects necessitates significant and ongoing reductions of anthropogenic greenhouse gas emissions within the bounds of what is known as the "carbon budget," or the maximum amount of greenhouse gases that human activity can produce without surpassing a predetermined degree of warming (EEA, 2020). Furthermore, increasing GHG absorption capacities is necessary for climate mitigation. Specifically, an increase in temperature of 2°C above preindustrial levels is thought to represent a threshold, above which there is a significantly increased chance of hazardous and potentially catastrophic effects on human and natural systems (IPCC, 2014). Based on current data, it is recommended that global warming be limited to 1.5°C (above preindustrial levels) in order to minimise the adverse effects of climate change (IPCC, 2018).

Yet, lowering or even eliminating greenhouse gas emissions in the future does not guarantee that global warming and its associated changes will come to an end. Therefore, adaptation measures are required in order to reduce the adverse effects of climate change that is unavoidable and to take advantage of any opportunities that may present themselves (EEA, 2020).

3.9 What does climate change mean for Europe?

While the average global temperature has increased by approximately 1°C since the pre-industrial period, satellite observations from Copernicus, the European Union's Earth Observation Programme, (C3S, 2019) show that temperatures in Europe have increased by nearly 2°C during the same period, with notable regional and seasonal variations. In addition, the average temperature in Europe rose gradually for the majority of the industrial era before abruptly increasing in the 1980s and reaching its highest point in 2019, the warmest year on record for the continent since temperature records were kept (C3S, 2020).

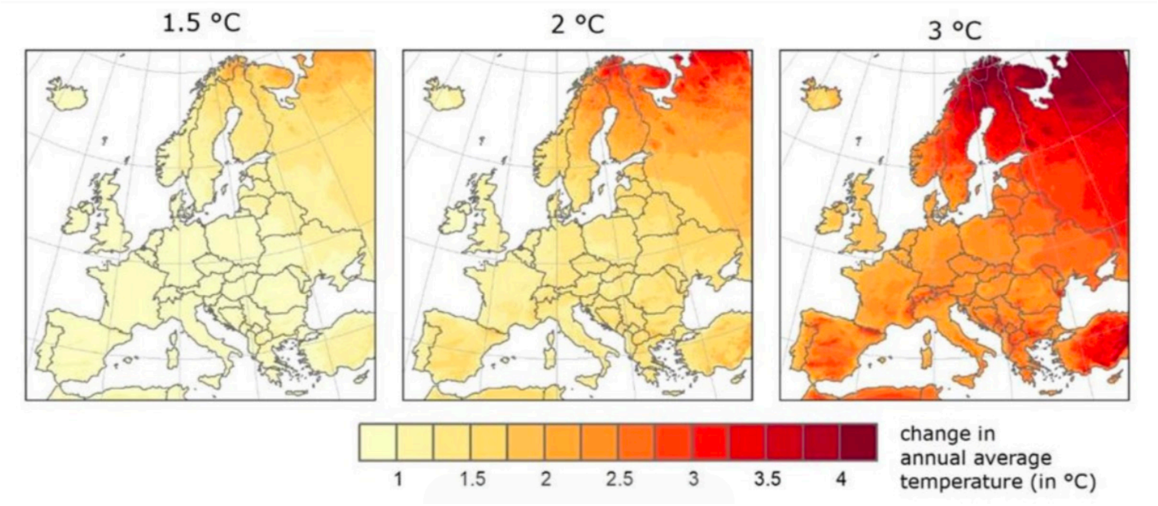


Figure 5: Climate change impacts and adaptation in Europe, PESETA IV Final Report, Joint Research Centre, 2020.

Scientific data indicates that a given rise in the average global temperature is correlated with a significantly greater rise in heat extremes in Europe. As per the latest 'European environment – State and outlook 2020' report, which is released every five years by the European Environment Agency (EEA), there has been a significant increase in the frequency of heat waves and extreme temperatures in Europe since the 1950s, especially after the year 2000. Some European countries experienced record-breaking temperatures in June and July 2019 due to two intense heatwaves.43 Such heat waves are far more common in Europe now due to human-caused climate change than they would have been in a climate system unaffected by human activity (EEA, 2020). It is predicted that these heat waves will occur more frequently and last longer throughout Europe. In the second half of this century, very extreme heatwaves are predicted to occur every two years under a high-emissions scenario, or unmitigated climate change (EEA, 2020). Furthermore, southern and southeast Europe will experience more intense heatwaves.

In most of northern Europe, the intensity of heavy precipitation events—which can result in flooding—has increased during the summer and winter and is expected to continue to rise, according to the EEA SOER-2020 report. The same source claims that although there is significant regional variation, Europe has seen a rise in the frequency of extremely severe flooding events in recent years. Additionally, it is predicted that river flooding will increase in frequency in the northwest and central-west of Europe, as well as pluvial and flash floods—both of which are the consequence of intense local precipitation events—will likely increase in frequency throughout the continent.

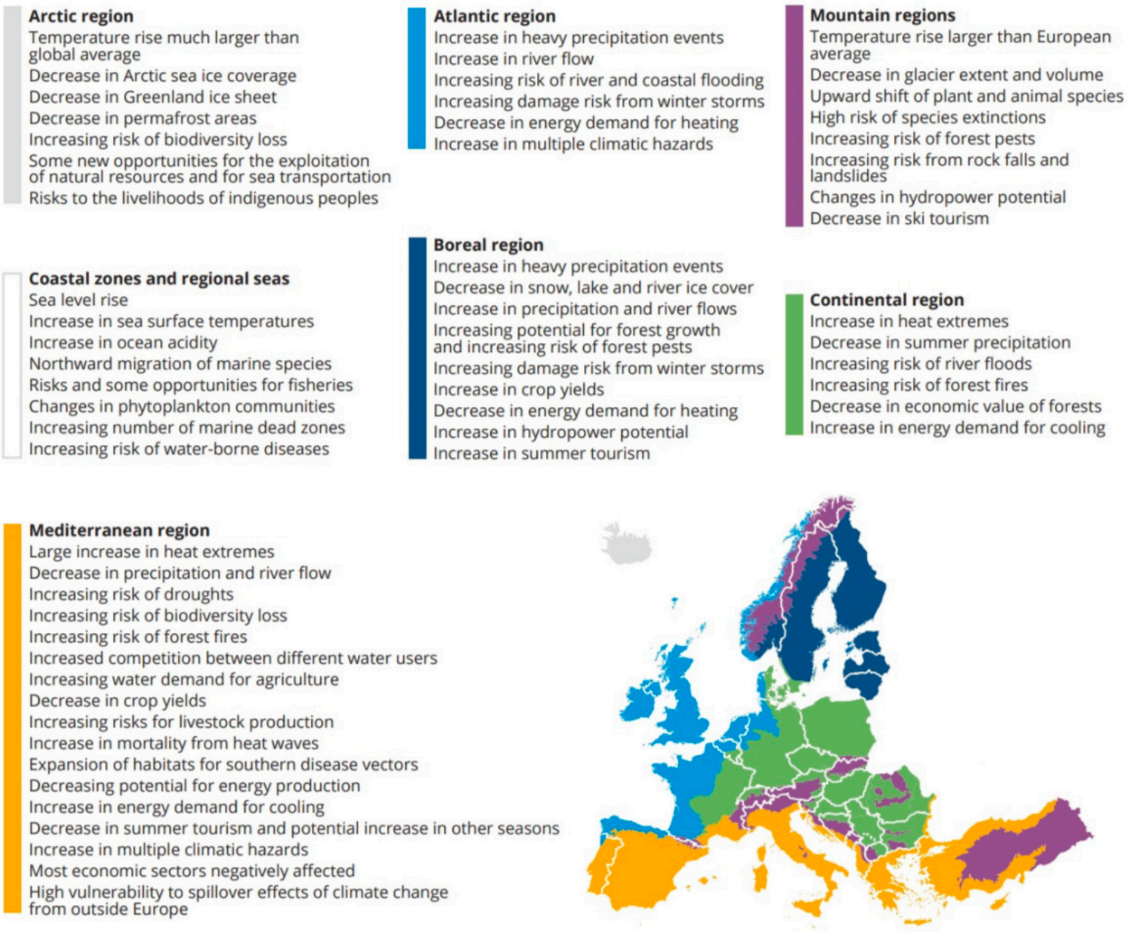


Figure 6: Source: Climate change impacts and vulnerability in Europe 2016, European Environment Agency, 2017.

- **Policy responses to climate change**

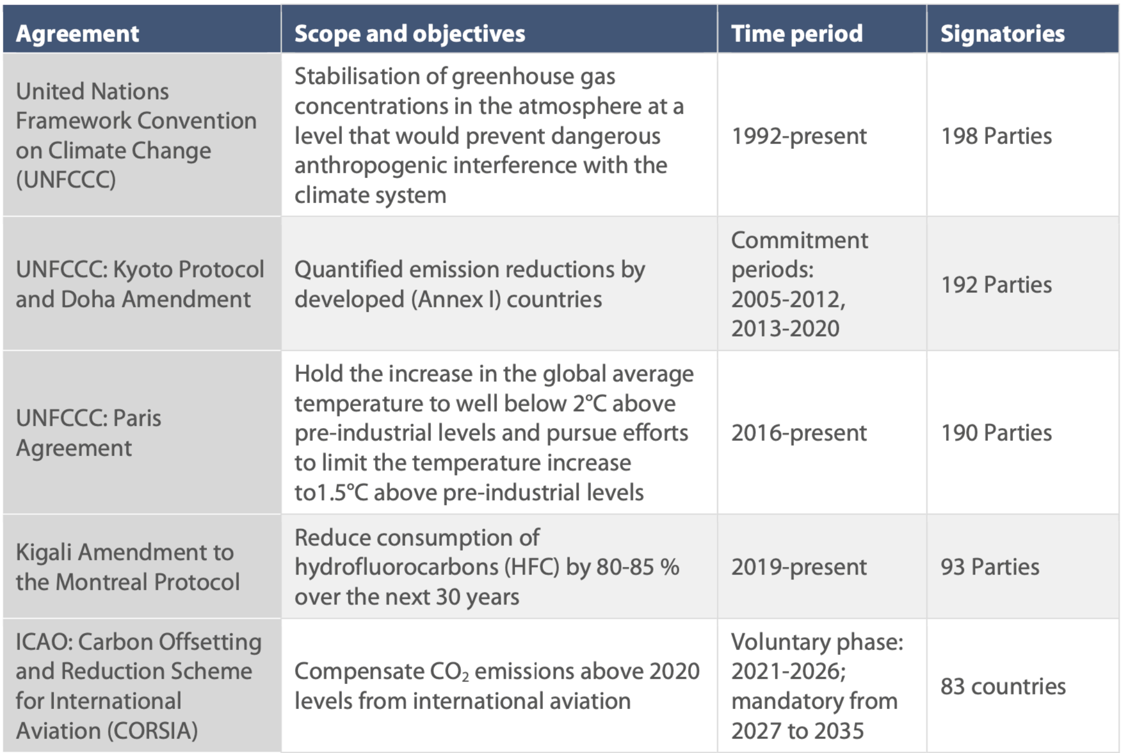
Mitigation and adaptation are two complementary strategies that can be used to prevent or lessen the various effects of climate change. Reducing greenhouse gas emissions and eliminating greenhouse gases from the atmosphere are two aspects of mitigation. Adaptation refers to actions taken to mitigate or stop the effects of climate change, such as erecting barriers to stop rising sea levels. Since effective mitigation lowers the need for and costs associated with adaptation, mitigation and adaptation are complementary strategies.

Most of the adaptation occurs on a local level, and those who adopt successful adaptation strategies should anticipate benefits. However, mitigation is a problem that requires global cooperation because cutting emissions in one area of the world will help all other areas. Therefore, when other parties are not following accordingly, there is no compelling reason for any party to bear the expense of emission reductions.

Creating and implementing successful policies to combat climate change is extremely difficult. This is demonstrated by the fact that, despite widespread recognition of the need to address climate change and increased attention in recent years compared to other environmental issues, global greenhouse gas emissions and their atmospheric concentrations continue to rise.

- **Climate action policies at international level**

Since the Intergovernmental Panel on Climate Change (IPCC) was founded in 1988, governments from all over the world have worked together to address the issue of climate change (UN general Ass, 1988).119 Based on the voluntary participation of thousands of scientists, the IPCC reviews and evaluates the scientific evidence on climate change and releases regular assessment reports that provide an overview of the state of science regarding climate change and its effects. 2014 saw the publication of the fifth assessment report (IPCC, 2014), and 2021–2022 will see the release of the sixth. In addition to its regular assessment reports, the IPCC has produced special reports. In 2018, for example, it published a report on global warming of 1.5°C (IPCC, 2018).



Agreement	Scope and objectives	Time period	Signatories
United Nations Framework Convention on Climate Change (UNFCCC)	Stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system	1992-present	198 Parties
UNFCCC: Kyoto Protocol and Doha Amendment	Quantified emission reductions by developed (Annex I) countries	Commitment periods: 2005-2012, 2013-2020	192 Parties
UNFCCC: Paris Agreement	Hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to1.5°C above pre-industrial levels	2016-present	190 Parties
Kigali Amendment to the Montreal Protocol	Reduce consumption of hydrofluorocarbons (HFC) by 80-85 % over the next 30 years	2019-present	93 Parties
ICAO: Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)	Compensate CO_2 emissions above 2020 levels from international aviation	Voluntary phase: 2021-2026; mandatory from 2027 to 2035	83 countries

Table 3: international climate agreement

- **United Nations Framework Convention on Climate Change**

Adopted at the Rio Earth Summit in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) came into effect in 1994. Stabilizing atmospheric concentrations of greenhouse gases at a level that would inhibit hazardous human interference with the climate system is its stated goal. The UNFCCC recognized that nations have responsibilities that are both common and unique. As a result, it was expected that developed countries (The developed countries (Annex I to the UNFCCC) are most European countries (including all EU Member States and the European Economic Community itself), Russia, Turkey, Japan, the USA, Canada, Australia, and New Zealand), who account for the majority of greenhouse gas emissions in the atmosphere and have greater political clout, would lead the charge in combating climate change by lowering their own emissions and supporting developing nations financially.

The Kyoto Protocol was adopted at the third Conference of the Parties under the UNFCCC (COP3, 1997) and went into effect in 2005. By 2012, developed nations are expected to have quantified reductions in their overall carbon emissions of 5.2% when compared to the base year of 1990. In order to fulfil their obligations, developed nations can now implement emissions-reduction initiatives in developing nations thanks to the establishment of an international emissions-trading system and a clean development mechanism.

Many developing nations saw significant economic growth, industrial development, and the emergence as significant greenhouse gas emitters in the years following the UNFCCC and Kyoto Protocol's adoption. As it became evident that developed nations acting alone would not be adequate, the parties to the UNFCCC negotiated a post-Kyoto agreement that incorporates all nations in combating climate change. The 2015 COP21 Paris Agreement seeks to keep global temperature increases well below 2°C over pre-industrial levels while pursuing efforts to keep increases to 1.5°C. In the second half of this century, the agreement seeks to balance greenhouse gas emissions and removals and guarantee that global greenhouse gas emissions peak as soon as feasible. The agreement also covers loss and damage, technology transfer and capacity building, financial support for developing nations, and adaptation to climate change.

The Paris Agreement obliges that all nations prepare nationally determined contributions (NDCs), take action to meet their goals, and report on progress. This contrasts with the Kyoto Protocol, which only binds developed nations to specific reduction targets. Parties are required to submit updated NDCs every five years, with the requirement that each Party's new NDC be more ambitious than its previous NDC to increase the level of ambition over time. Major emitters like the USA and China were able to support the agreement politically because of its architecture, which is based on voluntary national commitments.

As part of the 2030 Agenda for Sustainable Development, a 15-year plan to achieve the goals, all UN Member States adopted climate change as one of the 17 Sustainable Development Goals in 2015 (United Nation General Assembly, 2015)

- **Climate action policies at EU level**

According to the goals of the Paris Agreement, the EU is determined to act to attain climate neutrality by the year 2050. Climate action is one of the goals of EU environment policy, according to Article 191 of the Treaty on the Functioning of the European Union (TFEU). The definition and execution of Union policies and activities must incorporate environmental protection requirements as mandated by Article 11 TFEU. By 2020, the EU aims to reduce its greenhouse gas emissions by 20% from 1990 levels, and it is currently on course to surpass this goal. The EU-27's GHG emissions in 2019 were 24% lower than in 1990. The EU is on track to meet its 2020 target of 20% renewable energy, with an 18.9% share in renewable energy in 2018. Nevertheless, the EU was not on track to meet its energy efficiency target of reducing energy consumption to 20% below baseline projections by 2020, as the EU's final energy consumption increased for four years in a row up until 2018. Nonetheless, the EU may very well meet and surpass its energy efficiency target for that specific target year (2020) since steps taken in response to the Covid-19 pandemic have decreased GHG emissions and energy use, even though energy use and emissions may rebound later.

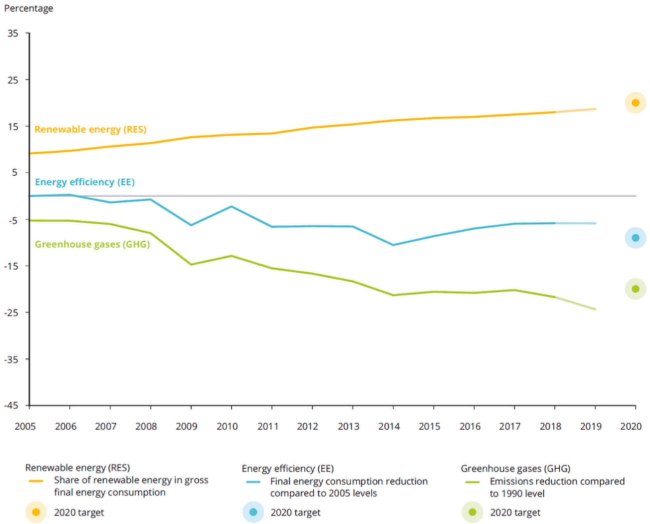
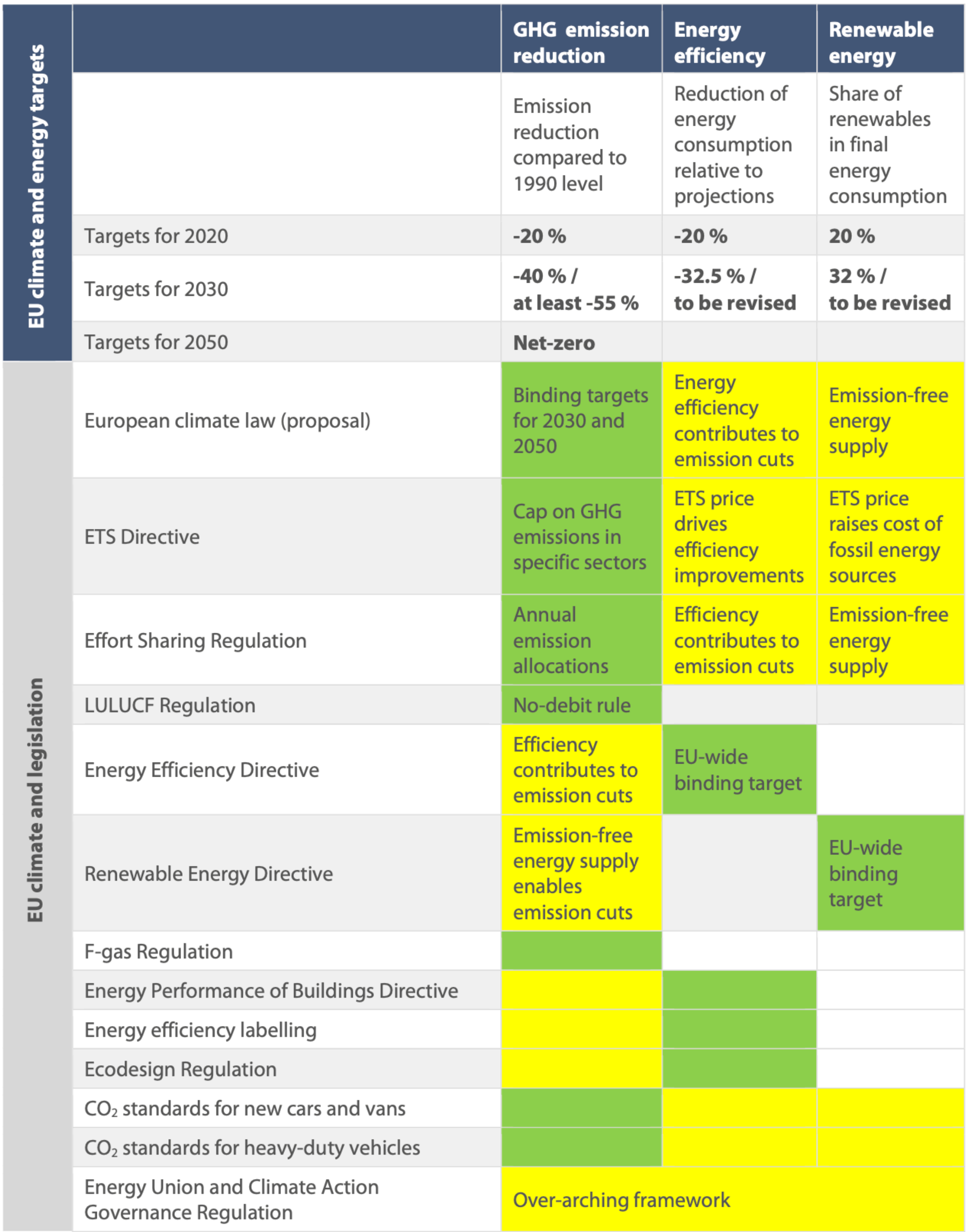


Figure 7: Progress towards 2020 targets for EU GHG emissions, renewable energy share, and energy consumption. Source: Trends and projections in Europe 2020



		GHG emission reduction	Energy efficiency	Renewable energy
EU climate and energy targets		Emission reduction compared to 1990 level	Reduction of energy consumption relative to projections	Share of renewables in final energy consumption
	Targets for 2020	**-20 %**	**-20 %**	**20 %**
	Targets for 2030	**-40 % / at least -55 %**	**-32.5 % / to be revised**	**32 % / to be revised**
	Targets for 2050	**Net-zero**		
EU climate and legislation	European climate law (proposal)	Binding targets for 2030 and 2050	Energy efficiency contributes to emission cuts	Emission-free energy supply
	ETS Directive	Cap on GHG emissions in specific sectors	ETS price drives efficiency improvements	ETS price raises cost of fossil energy sources
	Effort Sharing Regulation	Annual emission allocations	Efficiency contributes to emission cuts	Emission-free energy supply
	LULUCF Regulation	No-debit rule		
	Energy Efficiency Directive	Efficiency contributes to emission cuts	EU-wide binding target	
	Renewable Energy Directive	Emission-free energy supply enables emission cuts		EU-wide binding target
	F-gas Regulation	🟩		
	Energy Performance of Buildings Directive	🟨	🟩	
	Energy efficiency labelling	🟨	🟩	
	Ecodesign Regulation	🟨	🟩	
	CO_2 standards for new cars and vans	🟩	🟨	🟨
	CO_2 standards for heavy-duty vehicles	🟩	🟨	🟨
	Energy Union and Climate Action Governance Regulation	Over-arching framework		

Table 4: EU energy and climate targets and related legislation

Source: EPRS (green: direct contribution to targets; yellow: indirect contribution).

- **EU initiatives**

To promote climate-friendly practices and technologies, the EU has started and is supporting several initiatives and activities. Introduced by the European Commission in 2008, the Covenant of Mayors for Climate and Energy is a grassroots endeavour involving over 10,000 democratically elected local governments from 60 different nations. The signatories voluntarily pledge to carry out the energy and climate goals of the EU. Constructed on three pillars, the Global Covenant of Mayors was formed in 2016 by the merger of the Covenant with the Compact of Mayors, another city initiative, and mitigation, adaptation, and secure, affordable, and sustainable energy.

- **EU adaptation strategy**

The first EU adaptation strategy, adopted in 2013 (COM, 2013), was centred on Member State adaptation strategies and measures, improved decision-making information, and climate-proofing EU-level action by encouraging adaptation in important vulnerable sectors like cohesion policy, agriculture, and fisheries. In order to create a unified body of knowledge on adaptation in Europe, the European Commission and the EEA partnered to create the Climate-ADAPT platform.

The Commission adopted a new EU strategy on climate change adaptation in February 2021 (COM,2021), with the goal of improving both the EU's and the world's ability to adapt to and minimize the effects of climate change while also advancing and accelerating actions throughout the economy and society. The Commission intends to step up and expand support to partner nations and local governments to further the strategy's global reach.

The plan takes care of the need to advance current understanding and manage the uncertainties related to climate change. It also envisions the creation of policies across all spheres and levels. To improve EU readiness for the effects of climate change, the strategy primarily focuses on how it interacts with other strategies. Moreover, future legislative proposals will address adaptation.185 Member states will continue to be the primary implementation partners, just as they were in the previous strategy. The Commission indicates interest in expanding the EU and Global Covenant of Mayors to support local and regional authorities in transitioning from planning to implementation.

The creation of natural solutions, taking steps to fill knowledge gaps, and funding climate adaptation are important components of the plan. The European Insurance and Occupational Pensions Authority may be developed further, and the Commission emphasizes the value of the insurance industry in knowledge-gathering as well as in expanding insurance coverage to mitigate the costs associated with climate change.

- **Impacts of climate change on cities**

Cities in Europe will be affected differently based on their physical attributes, layout, and geographic position. Heat, flooding, water scarcity, and drought are the main climate threats that are particularly relevant to cities; however, other climate hazards, like wildfires, can also be significant for some. Cities are more vulnerable to weather extremes than other places because of their sealed surfaces, dense populations, and high levels of property, commerce, and other activities. Cities that have a high degree of soil sealing are more vulnerable to the effects of heatwaves because artificial surfaces absorb more solar heat than green areas. Furthermore, it hinders water infiltration, raising the risk of flooding (European Environment Agency, 2011).

Numerous city functions, infrastructure systems (such as the supply of energy and water, sanitation and drainage, transportation, and telecommunication), services (such as emergency medical care), the built environment, and quality of life will all be significantly impacted by climate change (A.Revi et al, 2014). These effects may have repercussions for individuals, groups, and places both inside and outside of the city (European Environment Agency, 2016). Extreme weather conditions, such as heat waves or flooding, can harm the transportation system and impede the flow of people and goods, which can have a knock-on effect on other sectors of the economy, like industry. Cities are also more susceptible to the effects of climate change outside of their borders since they rely so heavily on their hinterlands and larger regions for resources like food, water, energy, and other necessities.

- **Potential for reducing emissions and climate proofing**

Approximately 75% of EU citizens reside in urban areas, with that percentage expected to nearly double by 2050 (European Commission Website). This implies that a significant portion of the production-consumption dynamic within European society is also concentrated in these areas. Most of the EU's energy use and associated greenhouse gas emissions are attributed to cities. Cities have a high population density and high environmental pressure, but they also present chances for resource conservation and economies of scale. Compactness and density of urban areas facilitate the use of more energy-efficient housing, transportation, and service providers. Cities also offer favourable environments for experimentation and innovation (Vandecasteele et al, 2019). Local governments can test different options in different districts or try solutions on a smaller scale before implementing them more widely (SOER, 2020).

Cities have important capacities for addressing climate change (OECD,2010). Municipalities should focus on the following key areas of mitigation: waste and water management, land-use planning, transportation and mobility, local renewable energy generation, and lighting of buildings and infrastructure (Join Research Centre, 2018). In order to keep global warming to 1.5°C, there are currently a number of urban mitigation options that show high multidimensional feasibility. These include energy-efficient appliances, electric vehicles, bioenergy, low-energy buildings, improved public transportation and local shared mobility, less food waste, ecosystem restoration, and more sustainable urban planning.

Adaptation is contingent upon local and regional conditions, including the threats posed by climate change. These actions can be broadly categorized into three categories:

- “soft" adaptation measures (like early warning systems and insurance against damage from natural disasters);
- "grey" (technical) adaptation measures (like building dykes and using green infrastructure for water runoff management or microclimate moderation);
- green, ecosystem-based adaptation measures

The best outcomes are frequently obtained by combining those different types of measures (EEA, 2016). There are various ways that adaptation can be implemented: adapting to the aftermath of disasters and change (addressing the harm caused by a disaster and recovering from it); gradually boosting the effectiveness of current conventional measures, like strengthening flood defences or sewage capacity; or changing how we address the effects of climate change by using alternative approaches (e.g. changing city design, building design, behaviours).

- **Challenges and opportunities**

The importance of nature-based solutions for mitigating and adapting to climate change is becoming increasingly apparent (Seddon et al, 2020). An important part of removing carbon from the atmosphere is done by forests. While younger (secondary) forests have a higher potential for removing CO2, old-growth (primary) forests store the most carbon.

Nature- Based solutions have advantages for the microclimate, water retention, planetary health, and natural areas for leisure and recreation in addition to storing carbon. Restoring damaged ecosystems can be very important for increasing resilience and carbon storage capacity. Green infrastructure can also help with climate adaptation. City trees and parks can provide shade and noise abatement, as well as enhance the microclimate. Extreme precipitation events can be lessened, and their effects can be retained by natural areas.

- **Causes of Urban Heat Island and Its Effects**

The following are listed as the causes of UHI by Santamouris et al. (2007), Akbari et al. (2001), and Oke (1987):

- Reduced evapotranspiration due to a decrease in vegetation
- Solar radiation absorption as a result of low albedo
- Obstruction to airflow due to increased rugosity
- High levels of heat release caused by humans

Nonetheless, a multitude of factors play a role in the development of the urban heat island. The following figure shows the major contributing factors to the emergence of UHI.

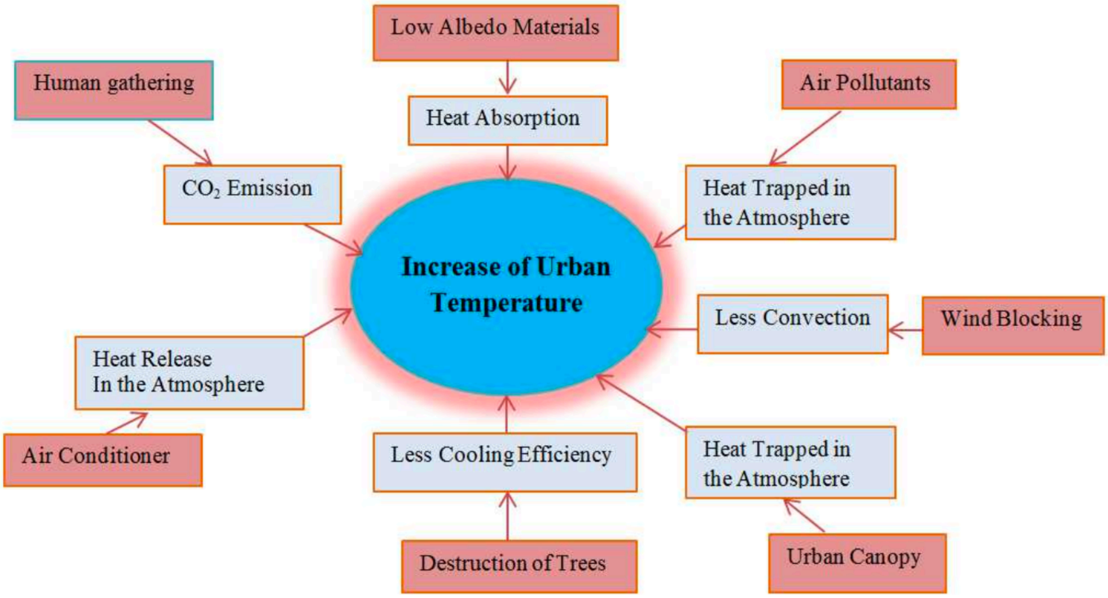


Figure 8: Process of Urban Heat Island (UHI) Formation.

- **Effects**

In the summer, the effects are particularly severe in the arid and tropical regions. Those who live in the middle of the city find it uncomfortable. People with limited endurance experience heat stress due to the extreme heat, which can lead to both illness and death (Voogt 2004). In addition, more energy will be needed to cool the buildings so that people can feel comfortable due to the rising temperatures. Both public and government spending will increase because of this. In the summer, there may be a 2-4% increase in energy demand for every 10C increase in temperature (Akbari, 2001). Nevertheless, the worst affected by the microclimate effect are those who work outside of buildings, on the roads, or in public areas.

To meet the rising demand for electricity, more fossil fuels are burned, which results in higher emissions of greenhouse gases and a worsening of the climate (Adinna 2009). Meanwhile, greater use of air conditioners exacerbates the effects even further. Nonetheless, because of the higher temperatures in the winter, the UHI effect tends to make people feel more comfortable (Shahmohamadi 2010; Voogt 2004; Mobaraki). The impact of UHI on human life is shown in the following figure.

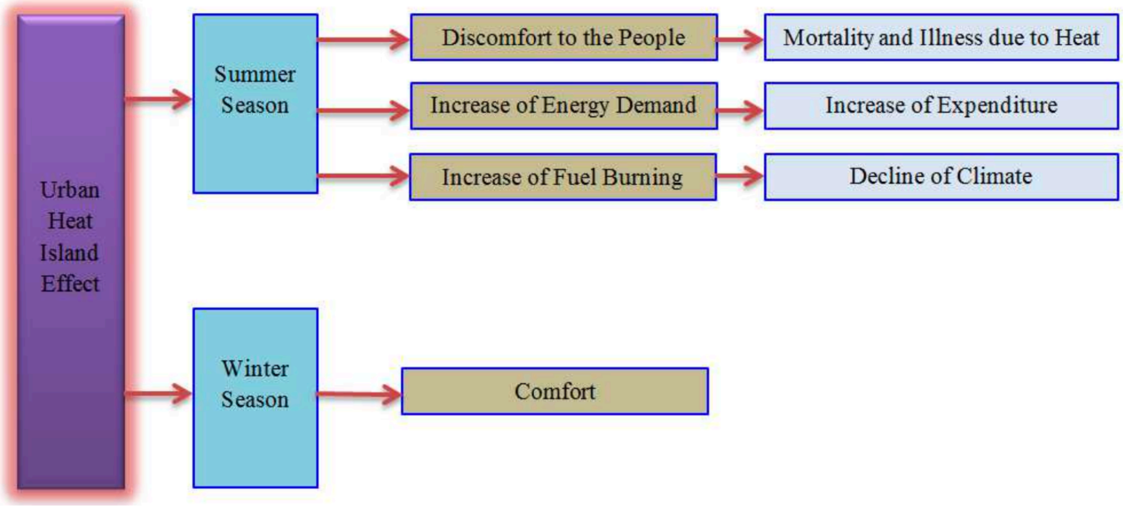


Figure 9: Impact of UHI on human life

Theeuwes (2012) quantified the influence of urban water surfaces and green vegetation on the urban heat island effect. They discovered that a 10% increase in vegetative cover can lower the temperature by 0.6K, and they noted that trees can significantly lessen the impact. They did, however, concluded that the presence of water bodies increases the effect rather than lowers the temperature.

LI et al. conducted a case study by examining Tsinghua University's hot environment in order to develop an urban planning strategy. They proposed that planting trees and leaving adequate space between buildings would effectively lessen the intensity of heat islands. Adinna et al. (2009) evaluated the urban heat island effect's effects in Nigeria's Enugu city and recommended countermeasures to keep the effect under control. According to their research, Enugu's urban effect can be lessened by using high densities of green vegetation, low-absorbent roofing materials, and lighter pavement materials. The effect of cool surfaces and shade trees on the urban heat island effect was investigated by Akbari et al. (2001). They discovered that urban trees and surfaces with high albedo materials significantly aid in reversing the heat island effect. The cost savings resulting from the UHI effect mitigating measures is also computed in their paper. According to Akbari et al. (2001), the demand for electricity may increase by 2-4% for every 10C increase in temperature. Conversely, by taking mitigation measures to lessen the UHI effect, 20% of the energy used for air conditioning can be saved. Yamamoto (2006) provided an overview of various UHI effect mitigation strategies as well as projects in Japan and other nations, such as Freiburg, Germany's wind paths. He suggested several important mitigating actions, including improving urban airflow, restoring green spaces in urban areas, and constructing energy-efficient structures and transportation systems.

- **Strategies to Reduce Urban Heat Island**

There are two methods for mitigating the urban heat island effect, according to Sailor (2006). One way is by making the urban surface more albedo; the other is by making more evapotranspiration. Nonetheless, the following is a description of the main tactics used to lessen the UHI effect:

1. **High Albedo roofing material**

Heat from the sun is absorbed by dark roofs, which keeps homes warm. On the other hand, light-coloured roofs with comparable insulation qualities do not warm up a lot when they reflect sunlight (Akbari et al. 2001). Thus, choosing a color for your roof can help lower the temperature. Low-albedo roofing materials absorb solar heat and warm the house, which increases energy consumption for air conditioning. Thus, using high albedo roofing materials is one of the mitigation strategies. According to Bretz et al. (1998) and Rosenfeld et al. (1992), there is no additional cost to the roof if cool surfaces are achieved through colour changes. The EPDM materials, which resemble rubber, don't affect the price of colour change (Sailor 2006). According to Sailor (2006), roofing materials should be made of white materials with an albedo greater than 0.60 rather than black materials with an albedo of 0.05 to 0.10. Using roofing materials with varying albedos, from 0.20 to 0.60, Bretz et al. (1998), Akbari et al. (1998), and Konopacki et al. (1997) investigated the efficacy of albedo and discovered that the roof temperature decreased by 250C for 0.60 albedo compared to 0.20 albedo. According to Sailor, D. J. (2006), the efficacy of UHI effect mitigation strategies is influenced by the convection of roofing materials.

2. High albedo pavement

If the materials used to pave roads and highways had a high albedo, more solar radiation could be reflected (Akbari et al. 2001). Therefore, choosing pavement materials wisely can also help to lessen the impact of UHI. According to Levinson and Akbari (2002), after curing different concrete mixes with albedo ranging from 0.41 to 0.77, some reflective concrete surfaces were suggested. According to Sailor (2006), it is possible to create white cement mixtures with an albedo that is higher than that of the most reflective grey cement mixtures. However, because of the sky view factor, using high albedo materials for roads and highway pavement may not be as effective. Even if it is used, the surrounding buildings will block part of the reflection. Furthermore, a significant section of it is obscured by cars during the majority of the day. The high albedo pavements also contribute to the glaring issue that is related to cooling roofs. High albedo pavements, according to Sailor (2006), may improve nighttime visibility and lessen the need for light. He goes on to say that glaring during the day will impair visibility.

3. Green vegetation

One of the best ways to lessen the effects of the urban microclimate is to increase the amount of vegetation. (Wilmers, 1988; Takebayashi and Moriyama, 2009). Tree planting programs, both residential and municipal, can help achieve this (Sailor 2006). Because of their evapotranspiration, trees help to mitigate the heat island effect (Akbari et al. 2001). Once more, because trees absorb CO2, they directly contribute to a decrease in the UHI effect (Akbari et al. 2001). Empirical derivations, according to Robitu et al. (2006) and Pearlmutter et al. (2009), also showed that applying green vegetation reduces temperature. Heusinkveld et al. (2012) and Steenveld et al. (2011) support the statement as well. Due to the dense population in the centre of cities, enormous amounts of CO2 are emitted, which raises the temperature. Growing more trees will aid in improving the situation by absorbing CO2.

4. Shade trees

Large shade trees can shield surrounding homes and pedestrian areas from the sun's rays, keeping them relatively cool. Through the process of evapotranspiration, shade trees also aid in lowering the temperature (Sailor 2006).

Between 1992 and 1996, the United States planted close to 200,000 shade trees annually in an effort to reduce heat islands, safeguard the climate, and enhance urban air quality (Scott et al. 1999). The main function of shade trees is to block sunlight, which helps to keep buildings relatively cool (Akbari et al. 2001). It lowers air temperature, cuts down on building air conditioning, and enhances air quality. There are costs and maintenance associated with planting shade trees. However, it takes a few years for shade trees to mature and begin shielding a building from intense heat. Extreme storms can also threaten human life because shade trees are susceptible to them (Sailor 2006). The foundation of the nearby streets and buildings may be impacted by these trees' paths.

5. Pervious pavements

Since impermeable pavements prevent water infiltration, evapotranspiration's cooling effect is negligible in this instance (Sailor 2006). It can be anticipated that the temperature will be able to drop somewhat if the impermeable pavements are replaced with pervious pavements that will permit water to seep in. Water that has seeped into the pavement will keep it cool, which will raise the temperature.

6. Water bodies

According to Robitu et al. (2006), an increase in water bodies may result in a decrease in temperature because of their evaporative action and increased wind speed. Once more, water's high capacity to absorb heat will aid in lowering the temperature in cities.

7. Urban planning

Proper urban planning can also play a vital role in the mitigation of the UHI effect.

8. Green roofs

As per Wong's (2005) findings, between 21 and 26 percent of a city's total area is made up of roofs. Thus, if the roofs are vegetated, it will significantly lessen the impact of UHI. Low temperatures are maintained by green roofs' ability to absorb heat and filter air (Getter 2006). By using heat energy, plants continue to evapotranspiration, which cools the surrounding air. Furthermore, green roofs contribute to the delay of runoff duration, keeping cities cooler for an extended period (Getter 2006). It contributes to lowering the temperature by keeping itself colder as it absorbs water as well. Once more, by lowering energy demand, green roofing will balance the energy use in the corresponding building.

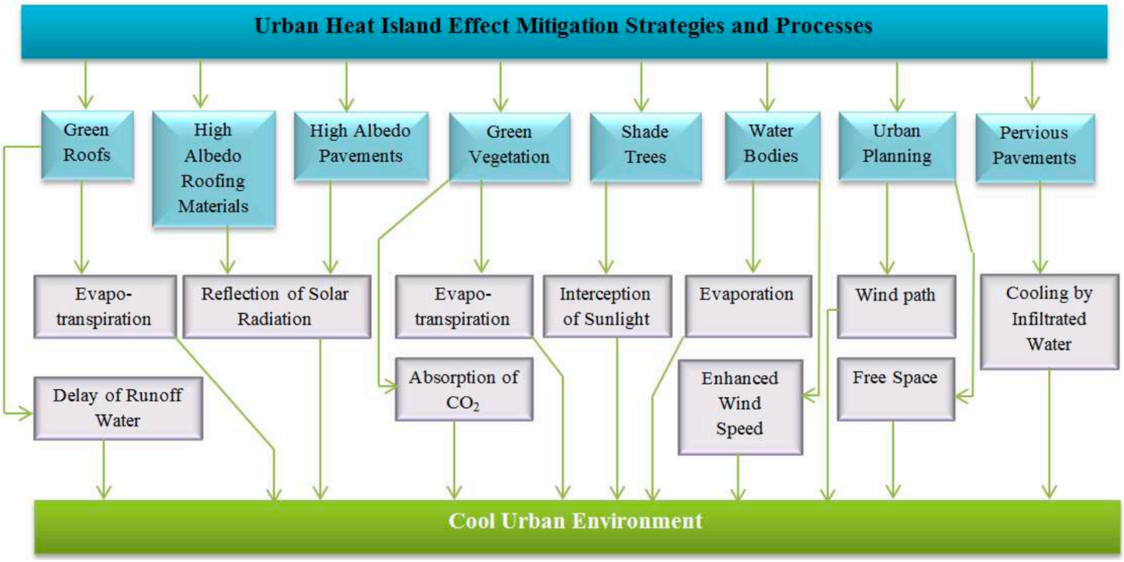


Figure 10: Urban Heat Island Effect Mitigation Strategies and Processes.

- **Flood risk and climate change**

The Intergovernmental Panel on Climate Change (IPCC) Special Report on "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation," also known as the SREX report (Field et al, 2012), evaluated the most recent research on climate change and the effects of extreme events critically. A wide range of academic and governmental experts involved in the multi-stage review process collaborated with Working Groups of the IPCC to produce the report, which was the result of a multi-national and multidisciplinary authorship. A vast array of data, viewpoints, and theories were evaluated, and a prioritisation of subjects was determined based on factors such as significance, probability, and degree of confidence.

Floods are described as "the overflowing of the normal confines of a stream or other body of water or the accumulation of water over areas that are not normally submerged" in the glossary of the IPCC SREX report.

River floods, flash floods, urban, pluvial, sewer, coastal, and glacial lake outburst floods are all examples of floods. Different mechanisms produce these different classes of floods.

According to Bates et al. (2008), several climatic system characteristics, including temperature patterns (which cause phenomena like soil freezing, snow and ice melt, and ice jam formation) and precipitation (intensity, duration, amount, timing, phase—rain or snow), have an impact on floods. Conditions in drainage basins, including pre-existing river water levels, snow and ice cover, soil characteristics and status (permeability, soil moisture content and its vertical distribution), urbanisation rate, and the existence of dikes, dams, and reservoirs, also have an impact on floods.

River flooding near sea level may occur simultaneously with storm surges or exceptionally high tides (Brakenridge et al. 2013).

Large river basins typically experience river floods because of intense and prolonged rain, but high-latitude areas can experience snowmelt floods, which are occasionally exacerbated by rain or ice jams. Highly heavy rainfall with a short duration can cause floods in small basins. In a region, the relationship between rainfall totals and flood response can be complicated. While the location of the rain's fall within the catchment often controls the flood response, antecedent conditions can influence how the land reacts to a rainfall input. Floods can also be caused by landslides, decreased channel conveyance, and the abrupt failure of structures that are meant to prevent them, like ice jams, landslide dams, or glaciers obstructing glacial lakes. Occasionally, severe downstream flooding can be directly caused by the catastrophic collapse of an artificial dam (Kundzewicz et al, 2012).

- **Reasons for a perceived increase in flood risk**

A perceived rise in flood risk could be caused by a few factors, including increased exposure of people and property, better and expanded disaster reporting, and higher frequency and/or intensity of the hazard (Kundzewicz et al. 2012). The media has an impact; today's news coverage is global and generally more positive than it was in the past (Kundzewicz 2011). It's known as a "CNN effect." Climate, hydrological/terrestrial, and socioeconomic systems are the primary drivers of anthropogenic changes in actual flood risk (Kundzewicz and Schellnhuber 2004).

The figure shows the drivers of changes in flood risk in a schematic format. Activities aimed at reducing risk lessen potential loss and hazard by modifying exposure and vulnerability.

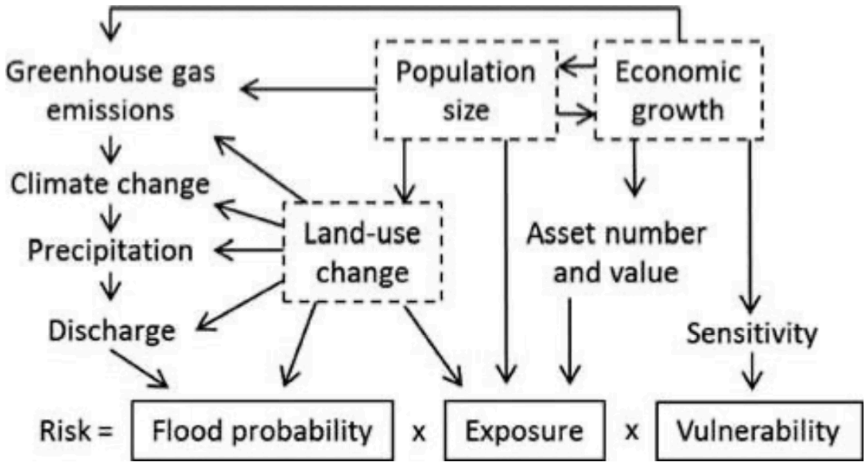


Figure 11: Factors related to the climate system

The water-containing capacity (and water vapour content) of the atmosphere (Koutsoyiannis 2012) and the features of intense precipitation, such as its volume and distribution in space and time as influenced by large-scale circulation patterns, are two of the main climate-system factors that determine flood risk.

Nevertheless, since they are oversimplified and the associated processes are extremely complex, these facts have occasionally caused confusion. Climate-related variables at the land surface include evapotranspiration and snow melting, precipitation phase, temperature sequence (critical for river or lake ice formation and thawing) and preconditioning of surface hydrological variables (soil moisture content, groundwater, and surface water levels).

Many of the variables that affect floods, such as precipitation (volume and timing, amounts falling as rain and snow), snow cover, antecedent soil moisture content, surface water levels, sea level, conditions in glacial lakes, and vegetation, could physically change in response to a change in climate, which could also affect the features of floods.

According to Seneviratne et al. (2012), there are significant regional and subregional variations in the patterns, but it "is likely that there have been statistically significant increases in the number of heavy precipitation events (e.g. 95th percentile of precipitation totals of all days with precipitation) in more regions than there have been statistically significant decreases." There is a trade-off between the percentile and the sample size because even if the 95th percentile does not indicate an extreme event, we would still need to deal with a much smaller sample size if we took a higher, say, 99th percentile.

- **Difficulty in identification of climate signals**

It can be challenging to discern between climatic and non-climatic factors in the instrumental record when assessing the causes of changes in flood hazard.

It is particularly challenging to distinguish ongoing changes in land-use change (including urbanisation) and altered river regulation from changes in flow data related to climate change in rivers that pose a threat to towns and cities because these rivers are typically not in their natural state. When these effects are combined, they are challenging to measure. For example, when land cover changes, it can be difficult to determine even whether imposed hydrological changes are changing or not (Teuling et al. 2010, Oliveira et al. 2011).

Only model-based analysis can provide a convincing demonstration of the effects of land use on flood risk; empirically based attribution is not feasible except at very local, plot, or experimental scales due to the abundance of confounding variables.

Lastly, discharge records—which are typically acquired by converting river stage (level) to discharge at gauging stations using a rating curve—are the subject of flood frequency analysis. However, the stage/discharge relation is unstable when channel aggradation (or degradation) is taking place, and flooding may increase (or decrease), resulting in higher (or lower) river levels at the same flood discharge. To account for channel changes, many sites around the world regularly update their rating curves. However, rating curve estimates present unique challenges for semi-arid wadi systems, where flood events can be high-magnitude and short-lived, and the channel cross-section varies with each flood. In the context of climate change and flooding, however, the main question is whether flood water volumes or peak discharges determined by meteorology are shifting.

- **Floods in Europe**

Even with significant investments in flood prevention, flooding is still a major issue across the continent.

Significant floods have devastated large portions of Europe in recent decades, resulting in numerous fatalities and yearly average material damage estimated to be in the billions of dollars or euros (Kundzewicz et al. 2012). According to Lugeri et al. (2010), the exposure of people and economic assets to flood hazards has increased significantly in Europe over the past few decades (Barredo 2009).

Because there are some inconsistent signals across studies and regions, particularly in the summer, the SREX report determined that there is a medium level of confidence in the trends for heavy precipitation in Europe that have been observed thus far. Moberg et al. (2006) reported increasing trends in the high percentiles of daily winter precipitation, which were subsequently supported by several more thorough country-based studies (Hattermann et al. 2013). With conflicting signals in the recorded records, there is little confidence in the trends in southern Europe and the Mediterranean region (Benito and Machado, 2012). According to a recent study (Zolina et al. 2010), during the past 60 years, the persistence of wet spells has increased by roughly 15-20% over most of Europe. This increase has not been correlated with an increase in the overall number of wet days.

Numerous national flood studies have been conducted throughout Europe; however, it is impossible to identify spatially ordered patterns of changes in flood magnitude and frequency caused by climate change. Yet, Kunzewicz et al. (2013) have shown that there was an increase in the frequency of significant floods in Europe between 1985 and 2010.

Boberg et al. (2009, 2010) projected a clear increase in the contribution to total precipitation from more intense events using daily statistics from various models for European sub-regions under the IPCC SRES A2 scenario. High-resolution studies projected European precipitation extremes for 2071–2100 show a tendency to rise in northern Europe, particularly during the winter.

However, the likelihood of floods, especially flash floods, which carry the highest risk of fatality, may rise due to the anticipated increase in the frequency and intensity of heavy precipitation over a significant portion of Europe (EEA 2004). Because of less snow accumulation, if climate projections are accurate, northeastern Europe should see a noticeable—and advantageous—decrease in the probability of floods in the late 21st century. This generally corresponds to lower flood peaks (Dankers and Feyen 2008, Hirabayashi et al. 2008).

To determine damages, the SREX report evaluated combinations of estimates of current and future flood frequency curves with estimates of current and future damage potential (as represented by a relationship between flood damage and flood magnitude).

The UK Foresight Future Flooding and Coastal Defence project (Hall et al. 2005) estimated average annual damage in 2080 of £1.5 billion, £5 billion, and £21 billion under similar climate scenarios but different socio-economic futures. The current average annual damage was estimated at £1 billion. This project found a wide range in projected average annual damage. By modifying the shape of the flood frequency curve using precipitation outputs from climate models and rainfall-runoff models for a sample of UK catchments, the Foresight project represented the impact of climate change on flood frequency.

In contrast to the UK Foresight project, the EU-funded Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis project (Ciscar 2009, Feyen et al. 2009) assumed no change in economic development and in population in flood-prone areas. Instead, it used a hydrological model to simulate river flows, flooded areas, and flood-frequency curves from climate scenarios derived from RCMs. There are significant regional differences in the effects, with Central and Eastern Europe expected to see especially large increases in both the number of people flooded and economic damages (over 200%), while parts of northeastern Europe will see a decrease in average annual flood damages. When population growth is considered, Maaskant et al. (2009) estimated that there could be a fourfold increase in potential flood victims in The Netherlands by the year 2040.

In addition to recently developed urban areas, linear infrastructure, including roads, railroads, and subterranean railroads with insufficient drainage, is likely to sustain greater damage from flooding (Defra, 2004, Arkell and Darch 2006).

Higher runoff volumes could raise the possibility of dam failure, which would cause significant socioeconomic and environmental harm (Rico et al. 2008). Even though they are rare, glacial lake outburst floods in glaciated regions of Europe have the potential to have a significant negative socioeconomic and environmental impact, even when they occur far downstream from the source of the hazard (Huggel et al. 2004).

3.9 Worldwide examples of Green Infrastructure

Barcelona

Due to the industrial revolution and the improvement of agricultural techniques in the XVIII century, cities in the global north have historically grown as a result of population migration from rural to urban areas (Farrell, 2017) which has led to the urbanisation. In order to deal with this population growth by changing the peri-urban interface's land uses from rural to urban, the trend of urbanisation, in which more people are concentrated in urban regions than in rural areas, has led to the extension of urban hinterlands (Planella, 2019). This alteration of natural areas, which hinders many natural processes like wildlife migrations, natural water flows, infiltration, or pollination, along with the alteration of the landscape, modifies the land uses for agricultural, residential, commercial, and industrial purposes, is thought to be a result of the population growth and the needs of the city. Ecosystem services are undervalued and lost because of ecosystem fragmentation and degradation (MEA, 2005). According to Calaza-Martnez (2016), "The rapid and disproportionate urban population growth combined with the massive population migration generates overpopulated cities, with low liability, and essentially without open and green spaces." This results in a lack of housing or dwellings of poor quality, no social cohesiveness, and health issues made worse by dense car traffic in cities. Additionally, the lack of soil permeability intensifies the heat island effect and raises the risk of flooding.

Barcelona is currently the second most populous city in Spain with an official estimated population of 1,620,809 people (Departament d'Estadstica i Difusió de Dades, 2018) and 3,665,687 people (Eurostat, 2018) when considering its metropolitan area. The city of Barcelona has been unable to expand due to the morphological features of its territory, so it has been densifying. As a result, it has become a compact city with semi-tall buildings of 5–6 stories and primarily narrow streets, with a net density of 6.6 people per km2 (Department d'Estadstica i Difusió de Dades, 2018). Because of its compactness, Moreno-Garcia (1994, p. 710) has demonstrated that Barcelona experiences a heat island effect, wherein downtown temperatures can be up to 8 °C higher than those in less compact places.

Due to its high population and traffic density, high proportion of diesel vehicles, low precipitation, and urban design with grey and narrow streets combined with a lack of green spaces, Barcelona has some of the highest levels of air pollution and noise in Europe (Nieuwenhuijsen, et al., 2014). According to the Department of Statistics and Dissemination of Dades (2018), there was only 7.1 m2 of green space available per inhabitant in 2017, and according to Mueller et al. (2016), one-third of the population did not live within the advised 300 m of a green area that was 0.5 hectares.

Barcelona boasts 3,611 hectares of green infrastructure, encompassing 35.3% of the city's land area, based on data from 2009. Within this expanse, 1,076 hectares constitute purely urban green spaces, 1,795 hectares fall within the municipal district within Collserola Nature Park, and 740 hectares are privately-owned green areas, primarily situated in the elevated sections of the city. This translates to approximately 17.71 square meters of green space per inhabitant (6.64 square meters within the urban environment, excluding Collserola). Consequently, the overall presence of green zones is notably substantial. However, only 30% of this total is dedicated to strictly public, urban greenery. Another 20% is allocated to private greenery, which contributes to the city's greenery and provides environmental benefits, although it isn't accessible to the public. The remaining

50% consists of wooded greenery within the Barcelona municipal district in Collserola.
The 1,076 hectares of publicly accessible city green spaces are predominantly concentrated in three districts: Sants-Montjuïc (comprising 27.8%), Sant Martí (15.4%), and Horta-Guinardó (11.3%). Conversely, districts with historic cores, such as Gràcia (3.6%), Sant Andreu (5.1%), and Ciutat Vella (5.9%), have fewer green areas due to their dense urban layouts and limited available space. When including Collserola, Sarrià-Sant Gervasi emerges as the district with the largest expanse of greenery, exceeding 1,266 hectares.

Despite the presence of two sizable, wooded parks, Collserola and Montjuïc, green infrastructure within the city predominantly occupies smaller areas, typically ranging from 1 to 5 hectares. Moreover, these green spaces are well-distributed throughout the urban landscape, making them easily accessible to the city's residents. Approximately 57% of these green zones cover less than 1,500 square meters, and there is generally limited connectivity between them.

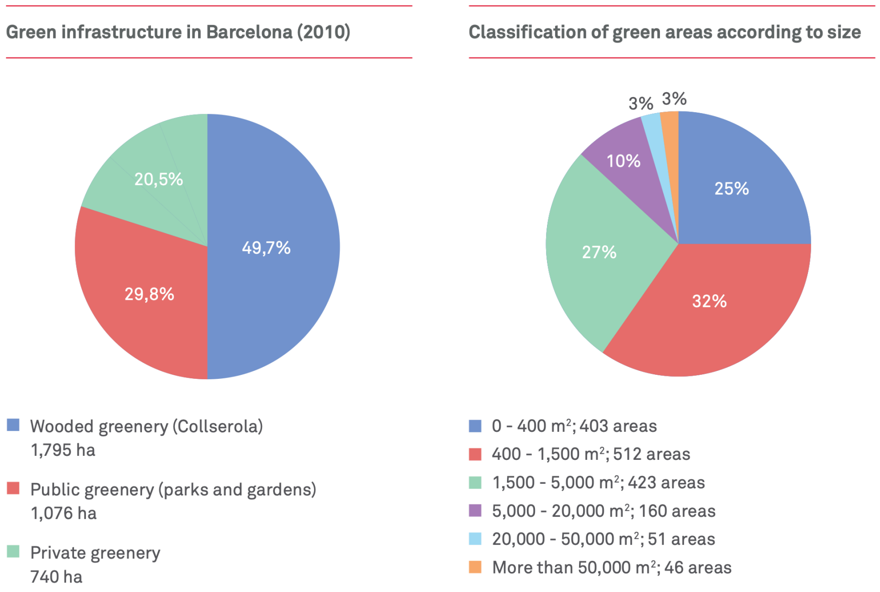


Figure 12: GI in Barcelona and its classification

Urban green was described by Barcelona's City Council (Ajuntament de Barcelona, 2013, p. 9) as green areas (mainly parks and gardens) that are a part of the urban fabric and have been included to change the urban environment. This greenery becomes green infrastructure when it is connected to natural areas or farmland, acting as a single ecological complex system that provides ecological, environmental, social, and economic benefits. The providing, regulating, cultural, and supporting services that people receive from the ecosystem are collectively referred to as ecosystem services by (MEA, 2005).

The term "green infrastructure" (GI) originated for the first time in 1994 (Firehock, 2010), and a wide range of academics and organizations have defined it. However, the European Environmental Agency (EEA), 2011, claims that there is no definition that is universally accepted for the term. However, most definitions believe that green infrastructure is a multipurpose tool for landscape conservation because of its connectivity, where green areas became a network of functional spaces whose management offers a wide range of ecosystem services, rather than isolated spaces preserved just for aesthetics.

Additionally, the concept of green infrastructure may change depending on the scale at which it is used, offering various benefits (European Environmental Agency (EEA), 2011). In contrast, green infrastructure at the landscape level (regional, national, and transnational) is implemented to preserve and connect natural areas to benefit biodiversity and combat habitat fragmentation. Green infrastructure at the urban scale is implemented to connect parks and other green spaces primarily for the benefit of people.

Of course, green infrastructure at the landscape size would also be beneficial for people, while green infrastructure at the urban scale would be beneficial for biodiversity, habitat preservation, and minimising landscape fragmentation. It is meant to clarify that green infrastructure is already a widely accepted idea that might be deployed at various scales and for multiple goals, each of which could result in a different set of advantages. Additionally, the type and qualities of the green infrastructure assets—which may be man-made or more natural/semi-natural—are also predetermined by the scale of green infrastructure deployment (European Environmental Agency (EEA), 2011).

The "Pla del Verd i de la Biodiversitat de Barcelona 2020" marked a series of basic lines for the improvement and the increase of urban green, not only at the level of parks and gardens but also at the level of trees and other types of green. In recent years, the city of Barcelona has been approving several strategies under its umbrella. It was an innovative policy that addressed how to develop and create new green spaces, how historical parks and gardens should be preserved, how to manage all urban green spaces, and how to propagate and convey all these practices. From the perspective of both biodiversity and vegetation combined, all in all" (City Council, Management of Barcelona's Urban Green) (Planella, A., 2019).

Green infrastructure within the urban fabric

Green infrastructure is integrated throughout the urban landscape, but it is frequently fragmented and lacks cohesion. The objective of GI is to improve its ecological, environmental, social, and economic benefits by linking different green spaces with vegetation to create a robust and efficient ecological network.

Figure 13: GI in the urban fabric in Barcelona

DIAGNOSIS OF GREEN INFRASTRUCTURE AND BIODIVERSITY

This section describes the status of green infrastructure and biodiversity in Barcelona. The assessments conducted have been formulated through concurrent procedures employing a consistent methodology, encompassing the following steps:

- Gathering information.
- Identifying deficiencies in understanding and procedures.
- Producing additional internal documents and research.
- Examining the practices of other urban areas.
- Extracting the most noteworthy data (Commission of Urban Habitat and Environment, 2020)

Figure 14: The green network of Barcelona

Urban green corridors

Green corridors connect outlying natural areas with the urban fabric and provide a backbone for the city's ecological infra- structure to thrive by incorporating green spaces and fostering biodiversity.

One of the most significant green infrastructure projects in Barcelona is the Superblock project. A superblock is a large area of the city that is restricted to vehicle traffic, creating a pedestrian-friendly environment that promotes walking and cycling. Each superblock consists of several blocks, and within each block, there are green spaces, plazas, and playgrounds. This initiative has transformed some of the busiest and most polluted areas of Barcelona into vibrant, green, and healthy spaces.

The Programme entitled *Let's fill streets with life, the establishment of Superblocks in Barcelona*, came about from the need to rise to the two-fold challenge of improving people's quality of life, by making the city healthier and more habitable, while reducing the impact of human activities and ensuring the environment's short- and long-term integrity (Ajuntament de Barcelona, 2016).

There aren't many green areas in Barcelona's urban environment. Without counting the Collserola Natural Park, there is nearly 7m2 of green space per resident so increasing the amount of green space must be one of the top priorities (Ajuntament de Barcelona, 2016).

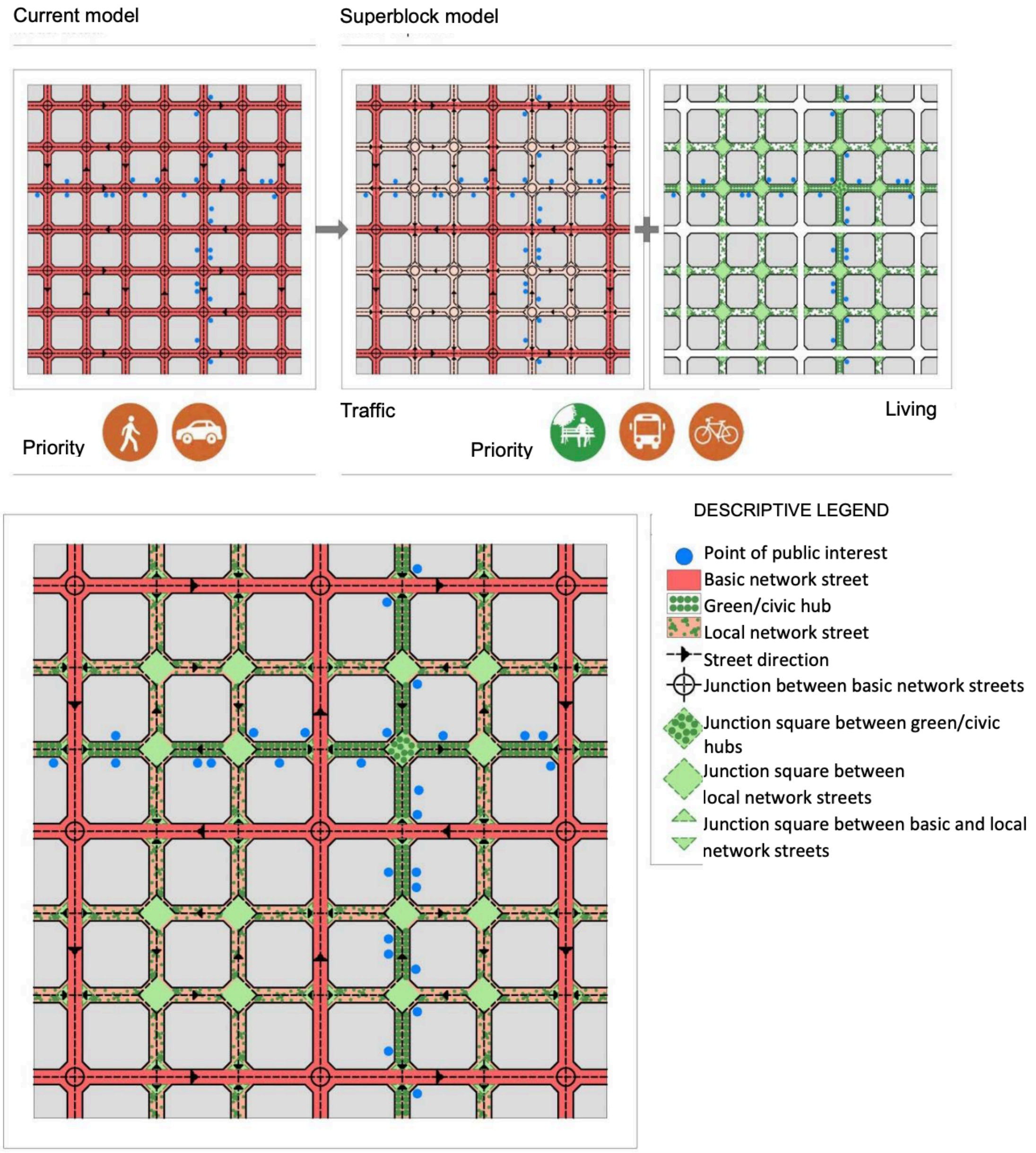


Figure 15: Superblock model

All these clusters need to consider making their public spaces more liveable, add more greenery, and plan with pedestrians and sustainable mobility at the forefront.

The purpose of the model is to help people regain their citizenship, which is currently restricted to pedestrians, and to inspire locals to public spaces by making them more liveable and adding more greenery to the streets (Ajuntament de Barcelona, 2016).

The Superblock Model must be implemented alongside a 21% decrease in private vehicle traffic in the city to balance these two fundamental functions of living and transportation. This change in mode will encourage the use of more environmentally friendly forms of transportation. In this regard, expanding the networks will support in achieving a high level of accessibility throughout the city, including the public transportation system, cycle lanes, and pedestrian paths.

Another target is to have 81.54% of all journeys on foot, bicycle, and public transport journeys by 2024. The council listed 300 specific measures for the coming years, including but not limited to adding 32km pedestrian-only streets, expanding bike network by 40%, adding 30km/hr lane on roads with three or more lanes, etc.

Figure 16: Green space before and after Superblock implementation.
Image source: Ajuntament de Barcelona

The Superblock project is also likely to increase the number substantially as Barcelona revitalises its streets and public spaces.

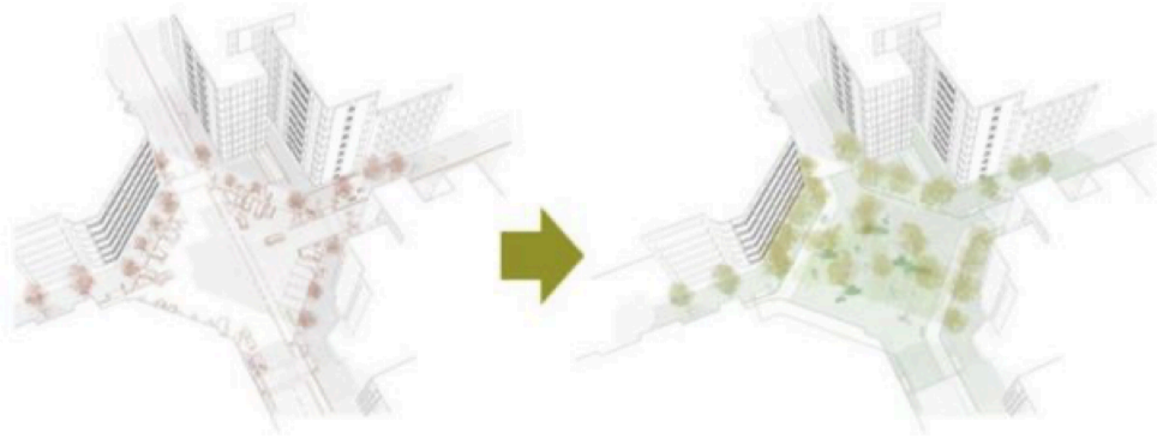


Figure 17: Planned redesigning of intersection in L'Eixample District to create green plazas. Rendering: Ajuntament de Barcelona

London

London is known for being a green city all over the world. London's diverse and special landscapes and green spaces are assets that can strengthen a sense of place and identity, enhance health and well-being, increase environmental resilience, and make the nation's capital a more appealing and prosperous city (London green grid; 2012;). These iconic areas include the former royal hunting grounds of the historical royal Parks; the relic countryside, such as the grasslands, forests, and common lands of Hampstead Heath, Epping Forest, and Wimbledon Common, which have been protected as London has grown; and the small green squares, such as Berkeley Square and Russell Square. These assets, which frequently have cultural and heritage value, can function as key infrastructure capable of guiding and supporting sustainable growth, responding to the challenges of climate change, and delivering an improved quality of life for all who live, work, and visit London through enhancement, extension, better connection, and good design (London green grid; 2012).

The ALGG's framework is composed of four essential components. Existing and proposed green connections and corridors, like the proposed London riverside Link, as well as designated and protected landscapes that are typically found at the edge of London and flow across administrative boundaries to neighbouring areas, and which frequently include the Thames, established open spaces, and opportunities for creating new parks, like the Wandle Valley regional Park (London green grid; 2012).

To secure environmental, social, and economic benefits, all London Green Grid (ALGG) will promote a transition from grey to green infrastructure. The ALGG alters how we perceive London to be a green city. From thinking of London as a city with parks, green spaces, and a countryside landscape to appreciating this network as a crucial component of the city's infrastructure (London green grid; 2012).

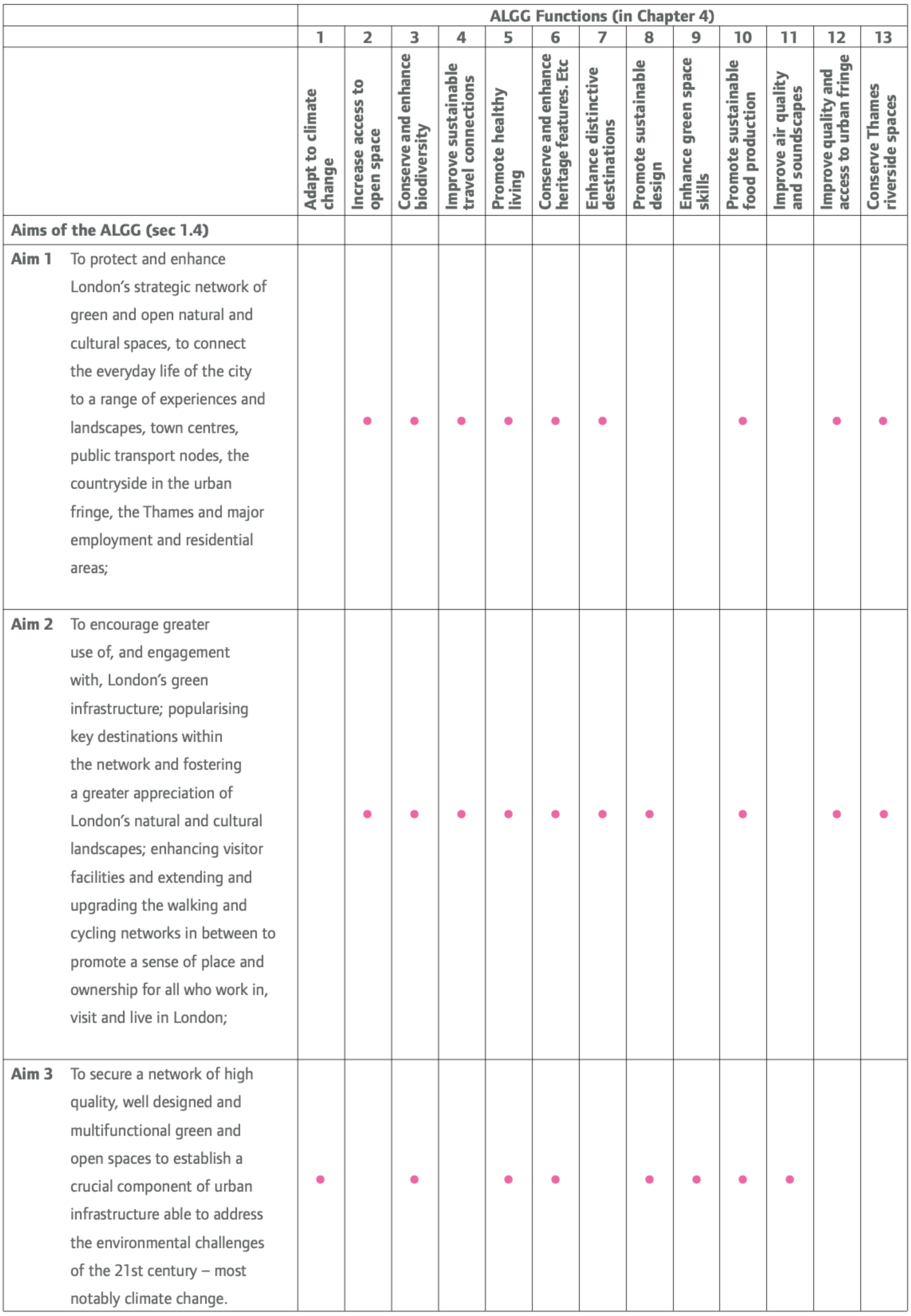
Current green infrastructure will perform better and function more effectively thanks to this interconnected network. The ALGG offers a network of wonderful green spaces and routes that connect London, much like London's street pattern. By being connected, the ALGG's value and utility are greatly increased, allowing for a variety of uses such as pedestrian traffic, water management, cooling of dreary urban areas, and ecological corridors (London green grid; 2012).

Aim 1

Aim 2

Aim 3

Figure 18: The goals of ALGG



	ALGG Functions (in Chapter 4)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	Adapt to climate change	Increase access to open space	Conserve and enhance biodiversity	Improve sustainable travel connections	Promote healthy living	Conserve and enhance heritage features. Etc	Enhance distinctive destinations	Promote sustainable design	Enhance green space skills	Promote sustainable food production	Improve air quality and soundscapes	Improve quality and access to urban fringe	Conserve Thames riverside spaces
Aims of the ALGG (sec 1.4)													
Aim 1 To protect and enhance London's strategic network of green and open natural and cultural spaces, to connect the everyday life of the city to a range of experiences and landscapes, town centres, public transport nodes, the countryside in the urban fringe, the Thames and major employment and residential areas;		●	●	●	●	●	●			●		●	●
Aim 2 To encourage greater use of, and engagement with, London's green infrastructure; popularising key destinations within the network and fostering a greater appreciation of London's natural and cultural landscapes; enhancing visitor facilities and extending and upgrading the walking and cycling networks in between to promote a sense of place and ownership for all who work in, visit and live in London;		●	●	●	●	●	●	●		●		●	●
Aim 3 To secure a network of high quality, well designed and multifunctional green and open spaces to establish a crucial component of urban infrastructure able to address the environmental challenges of the 21st century – most notably climate change.	●		●		●	●		●	●	●	●		

Table 5: ALGG functions

The goal of the ALGG is to build an interconnected, multipurpose network of open spaces with good connections to places where people live, work, and travel, as well as to the Green Belt, the Blue-Ribbon Network, and particularly the Thames. This will create a landscape with a rich variety of uses that will appeal to and be accessible to everyone, benefiting both people and wildlife.

Figure 19: In line with the wider ALGG vision, a long-term landscape strategy has emerged for the Arcadian Thames area – west London.

This proposes a landscape framework which integrates parkland, public access networks, habitats for nature conservation, areas for food production, management of flood waters, key visitor destinations and a recognition of the area's historical past.

Figure 20: Prepared by Gross Max Landscape Architects.

Adapt to climate change and promote urban greening:

London is already susceptible to the effects of climate change, particularly floods, droughts, and heatwaves, according to the mayor's climate change adaptation strategy. In addition to hotter, drier summers and warmer, wetter winters, further climate change is predicted to increase the frequency and intensity of extreme weather events like heatwaves and very heavy rainstorms (London green grid; 2012).

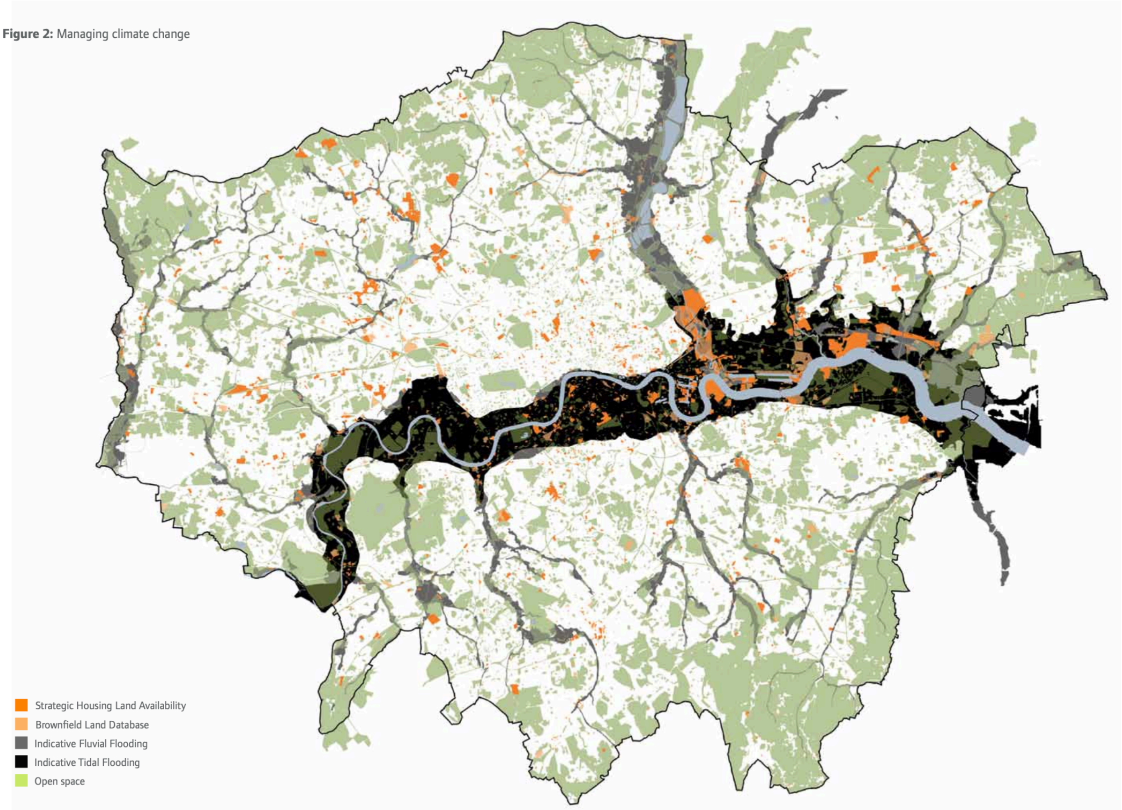


Figure 21: Mapping Climate change

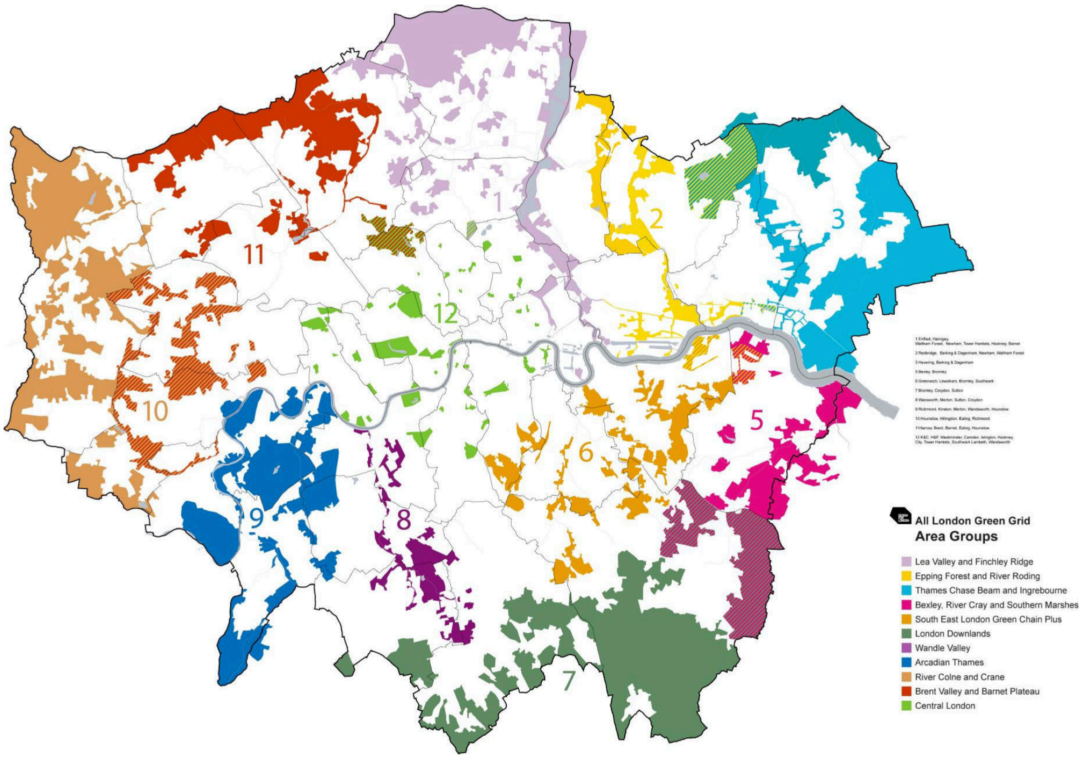


Figure 22: All London Green Grid

Each Green Grid area is briefly described in this section, which also highlights the strategic elements of the open space network. It draws attention to and makes recommendations for improvements to the existing east-west links, open space network of landscape corridors, and the urban areas it serves. Additionally, it identifies the important open space opportunities that should be taken into consideration when developing and delivering the network and putting the Green Grid into practice.

The Thames Tideway Tunnel

In recent years, combined sewer overflows (CSOs) have caused an average of 39 million tonnes of untreated wastewater containing raw sewage to overflow into the River Thames in London 50 to 60 times a year. Recently, Thames Water upgraded London's primary sewage treatment facility (Department for Environment food and Rural affairs, 2015).

The current system of major sewers, which consists of combined sewers that transport both sewage and surface runoff from rain to sewage treatment facilities for processing before discharge, was created for a city of 4 million people in the 19th century. These CSOs are made to release extra untreated wastewater into the River Thames when they are at capacity. This prevents the hydraulic capacity of sewage treatment facilities from being exceeded, resulting in sewage backing up and flooding buildings and roads (Department for Environment food and Rural affairs, 2015).

In dry weather, this network is currently operating at 80% or more of its design capacity, which means that even light rainfall can cause the CSOs to release untreated sewage into the river Thames. If nothing is done, sewage may eventually overflow into the river even on dry days (Department for Environment food and Rural affairs, 2015).

The UK must have adequate systems in place for the collection and treatment of wastewater in order to protect the environment, according to the Urban Wastewater Treatment Directive (UWWTD).

Because it is operating at around 80% capacity in some places at certain times of the day, even when it is dry, London's current sewerage system is under pressure and has little extra capacity to handle heavy showers. As London develops as a business hub, more people will work there daily, which will result in more housing construction. However, as cities become more urbanised, there will be less green space for runoff. As a result, when it rains, the system is quickly overwhelmed, resulting in frequent, sizeable discharges of combined, untreated sewage into the river Thames. The situation will only get worse if nothing is done.

Additionally, warmer water temperatures and decreased summer river flows are predicted results of climate change. These could have an impact on the river's dissolved oxygen levels. The less oxygen that can dissolve in water, the more quickly organic matter in sewage will decompose and use up oxygen. Aquatic life would consequently become more vulnerable to any pollution as a result.

Numerous studies have been conducted over a long period of time looking at a wide range of potential solutions to the untreated wastewater issues in the Thames. Both tunnel-based and non-tunnel-based options have been offered in these.

The Thames Tideway Strategic Study was established in 2000 to examine the environmental effects of combined sewer discharges to the tidal River Thames and to make suggestions for potential solutions to maintain adherence to the UWWTD. The Thames Tideway Tunnel, also known as "the Tunnel," is a significant project to build a sewer tunnel that will run 25 kilometres from Acton in West London to Abbey Mills in East London. This tunnel is used to divert storm sewage overflows that would otherwise enter the Thames (Department for Environment, Food & Rural Affairs ,2017).

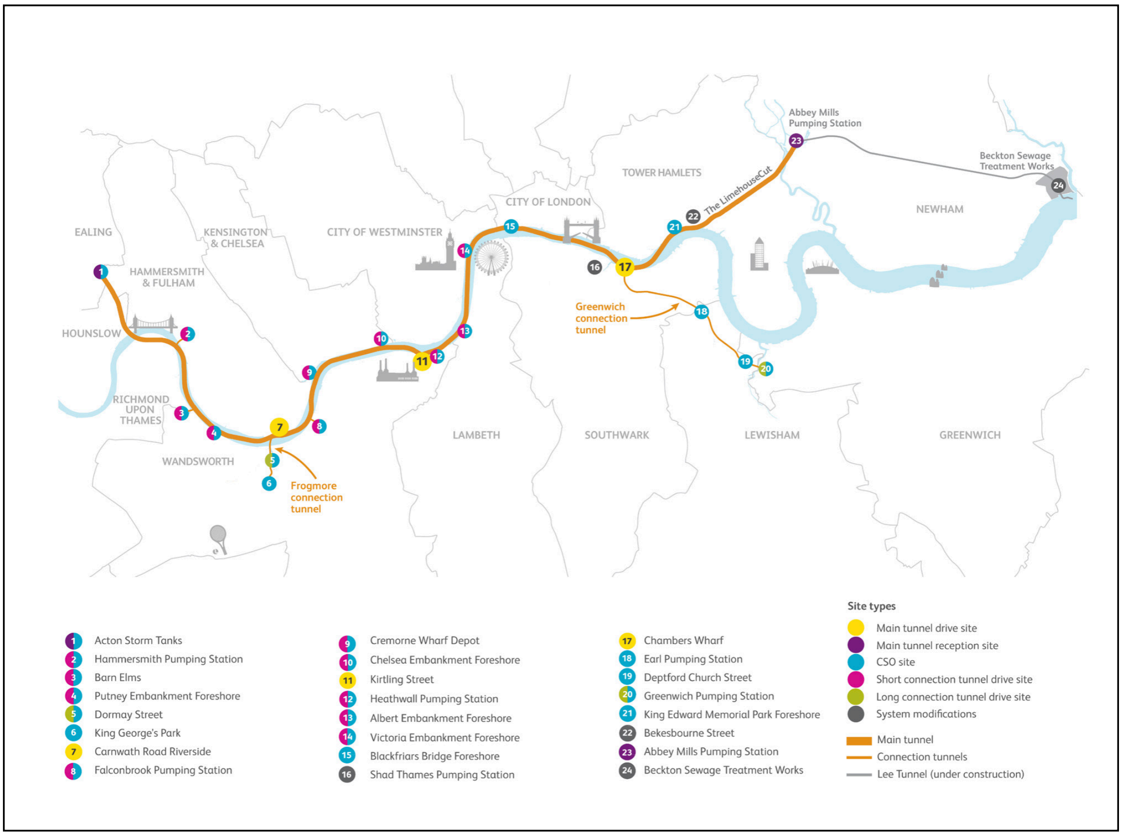


Figure 23: Schematic route of the Tunnel (Source: Thames Water)

Copenhagen

Copenhagen is a city known for its strong focus on sustainability and green initiatives. One such initiative is the development of green infrastructure, which refers to the network of natural and semi-natural areas, features, and green spaces within and between urban areas that provide a range of ecosystem services.

Some examples of green infrastructure in Copenhagen include:

Green roofs

Copenhagen has been at the forefront of promoting green roofs, which are roofs covered with vegetation that provide a range of benefits, such as reducing the urban heat island effect, improving air quality, and reducing stormwater runoff. The city has set a goal of having green roofs cover 5% of all roofs by 2025.

Back in 2008 the city of Copenhagen began focusing on alternative ways to handle rainwater and the Wastewater Plan 2008 became the first plan document that included approaches in that direction. In 2009 Denmark oversaw the UN Climate Change Conference COP15 which defined the framework for the strategies that could be implemented to meet the challenges of climate change. During that period, the focus on green roofs intensified setting a goal for urban design with green roofs in the Climate Plan of the City of Copenhagen (Green roofs Copenhagen).

Since then, Green Roofs have become integrated in different guidelines such as the guidelines for Sustainability in constructions and civil works, which mandates green roofs for all the municipalities buildings. Green roofs are also a part of the city's Strategy for Biodiversity. Since 2010 green roofs are mandated in most new local plans. A calculation based on approved new local plans mandating green roofs gives a total of 200.000 m2 of green roofs to be installed.

The City of Copenhagen has collected several cases and local plans from residential commercial and public green roofs projects; these projects include:

Residential buildings

- **8 – house**

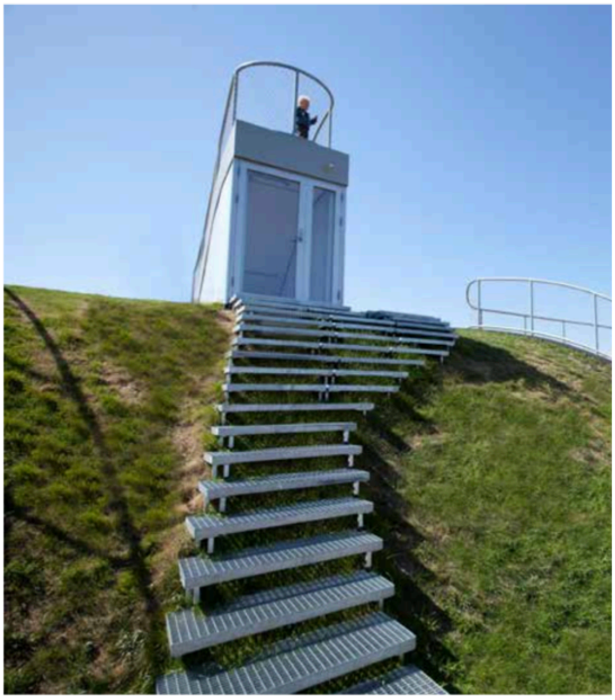
With spectacular views towards the Copenhagen Canal and over Kalvebod Fælled's protected, open spaces, 8 House will not only be offering residences to people in all of life's stages as well as office spaces to the city's business and trade - it will also serve as a house that allows people to bike all the way from the ground floor to the top, moving alongside townhouses with gardens winding through an urban perimeter block.

- **Birkegade Penthouses**

Elmegade district is probably one of the most densely populated areas of inner Nørrebro, CPH. Especially the triangular block between Birkegade / Egegade / Elmegade has a very high density, which is reflected in the very narrow courtyards.

And it is precisely around the cramped courtyard that the concept for BIR originates. The driving concept is to create the ‘missing garden’ at the top of the existing housing block in association with 3 new penthouses, so all residents gain access to a genuine outdoor garden.

To qualify ‘the missing garden’, JDSA took inspiration from the Copenhagen gardens, which characteristically has an associated functionality. Therefore, a rooftop garden is designed as a space of functions and an associated materiality.



- **Nørrebrogade 184**

The green roof is a pilot-project for Copenhagen’s Building Renewal which provides a platform for further research on how to incorporate a biodiverse green roof on an existing roof and how to incorporate it into historic heritage buildings.

Commercial buildings

- **Nordre Toldbod**

Langelinje is a place visited by many people, and it is important to show environmentally friendly solutions to some of the grave challenges we face in the form of adapting to the coming climate changes.

- **TCC – Hotel**

TCCs landscape is a new park in Copenhagen-a Park that is lifted to second floor. Where there is light, air, a view of Copenhagen's skyline, harbour, railway land and a good case study for the green development of Copenhagen.

- **HENKEL / Carl Jacobsensvej**

This is a prime example of how to incorporate a bio-diverse green roof on an existing roof and how to incorporate it into historic heritage buildings.

- **The City Dune**
- **The New National Archives**

Public buildings

- **Tagensbo skole**

The green multifunctional roof offers a meeting point for neighbours and users of the school. The creation of new green areas encourages future development of a greener and more sustainable cityscape to the benefit of the residents. In view of future climate changes, the green roof area acts as a retainer for surface water and subsequently reduces the strain on the city drainage system.

- **The Library / Bispebjerg kulturhus**

This green roof is visible from both the inside of the building and from the streetscape surrounding this public building, which is situated in a densely developed area. The green roof works well as a show case locally to promote the ways green roofs can transform otherwise disregarded spaces and provide an aesthetic variation.

- **Gyldenrisparken**

There is an imminent need for more Day Care Centres in Copenhagen, in this context this project shows how you can develop alternative ways of creating outside space, where Day Care Centres in the city might lack outside area.

- **Korsgadehallen**

The building provides a method of constructing new public buildings without dismantling and removing green recreational areas.

- **Environmental centre**

The zigzag shaped building incorporates solar panels and photovoltaic cells in its distinct architecture. Merging with its surrounding nature, through a grass meadow covered roof sloping to the ground. Approximately 35 members of staff and administration will have their daily workplace at the centre. The Environmental centre is placed in the Northern part of Copenhagen, a developing area which is to be built as an innovative sustainable green new area.

As part of the concept of sustainable development of North Harbour sustainable solutions are integrated in the actual design of the environmental centre.

The building produces energy through 10m2 of solar panels and 140 m2 of photovoltaic cells, combined with heat storage and thermal activity covering the energy needs meaning the building will be a zero-energy building.

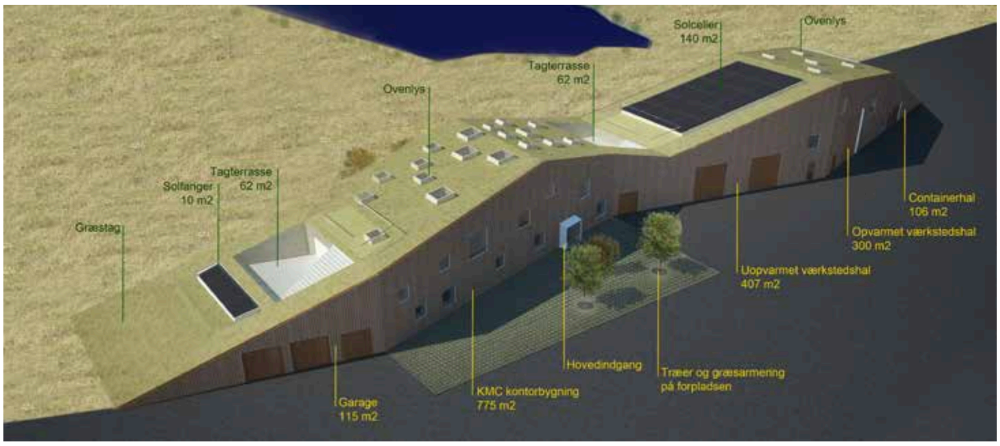


Figure 24: Function of zigzag shaped buildings

Climate change is one of the greatest challenges facing humanity today because the risks it poses to the planet and future generations are enormous and require that we take urgent action. Its impacts are already having far-reaching economic, social, and environmental consequences and, therefore, tackling it concretely is one of the most urgent global public policy commitments for governments today. International agreements, most recently the agreement of the Conference of the Parties (COP21) in Paris, have been developed to unify national governments in their efforts to reduce the anthropogenic causes of climate change by setting ambitious energy and climate targets.

The report of the European Environment Agency *"Climate change, impacts and vulnerability in Europe 2012 - An indicator-based report"* highlighted, already in 2012, that in the coming decades the European region and, in particular, the Mediterranean region will have to face particularly negative impacts of climate change, which, combined with the effects due to anthropogenic pressures on natural resources, make the Mediterranean region one of the most vulnerable areas in Europe (EEA, 2012). The negative impacts expected in the coming decades are mainly related to an exceptional rise in average and maximum temperatures (especially in summer), an increase in the frequency of extreme weather events (heat waves, droughts and episodes of heavy rainfall), and a reduction in average annual rainfall and river flows, resulting in a possible decrease in agricultural productivity and loss of natural ecosystems.

The extraordinary events that in recent years have anticipated what could be normal scenarios – such as the vast fires in Australia, Alaska, and the United States, devastating tropical cyclones, records of populations exposed to heat waves – and the data on 2019, which was the hottest at a global level since records began and closes a decade with numerous global temperature records, demonstrate the urgency of action to avoid, at the end of the century, a global temperature increase of 3°C, which could have irreversible effects.

Tackling climate change therefore requires a substantial change in approaches to city and regional planning, both in terms of reducing climate-altering emissions (mitigation) and making urban systems more resilient to progressive variability in the climate (adaptation). Indeed, even if greenhouse gas emissions are drastically reduced, the warming of the earth's atmosphere will continue for decades, and the consequences will be felt for centuries due to the delayed effect of past emissions. This explains why adaptation and mitigation are two complementary elements.

For European cities, the impacts of climate change are already evident and are expected to become increasingly intense in the future. Temperatures are rising, precipitation patterns are changing, ice and snow are melting, and the average sea level is rising. The results of a survey of European cities conducted as part of the EU project - Adaptation Strategies for European Cities - show that 81% (out of 196 responses) have already experienced periods of extreme heat and this is expected to be the main impact that cities will face over the next 30 years, while 71% hypothesise that urban areas will be increasingly affected by water scarcity.

The summary report “Climate Change 2014”, published in 2015 by the Intergovernmental Panel on Climate Change (IPCC), unequivocally demonstrates the existence of global warming and points out that, according to 95% of the international scientific community, human activity is the dominant cause.

These phenomena already have, and will increasingly have in the future, significant consequences for various socio- economic sectors such as agriculture, fisheries, energy, infrastructure, tourism, and health. Indirectly, global warming will also lead to major social impacts that will change the structure of urban areas and exacerbate situations of inequality and poverty. The environment in cities is also subject to deterioration, from air quality to urban greenery, if actions aren’t immediately taken.

The effects generated by climate change represent, therefore, a clear reality that can no longer be ignored, one which requires concrete actions not only to repair the damage caused by the phenomena that have already occurred, but, above all, to safeguard human settlements from probable future events, some of which are inevitable, even with the strictest policies to reduce greenhouse gas emissions.

4. Green Infrastructure and Climate change in Italy

4.1 Introduction about GI in the national/regional Law and Policy

There are, however, numerous acts at the national and regional level that comprehend regulations and references to the potential individual elements of GI, such as Natura 2000 sites, ecological networks, protected areas, forests, areas with environmental value, etc. Italy has a very rich and complex legal system, particularly in the fields of landscape, cultural, and environmental heritage.

The Italian Constitution gives the State only legislative control over "Protection of the environment and ecosystems," but it gives the Regions and other Local Bodies specific management authority over a number of different sectors. Therefore, it is clear that the primary tenets of the Convention on Biological Diversity (CBD), the European Strategy for Biodiversity, or the Geographical Indications (GI) cannot be effectively implemented in Italy without collaboration between the State and the Regions with regard to the specific authorities granted to them in different domains, as well as with regard to the organization and administration of key sectors affecting the conservation of nature.

4.2 Green Infrastructure in Italy

Although there has been much discussion about green infrastructure in Italy, no clear regulations or guidelines have been produced yet. A green economy is thought to require green infrastructure, which is why the 2013 Conference of Rome's "Nature of Italy" thematic session focused on the preservation and improvement of ecosystem services and natural capital through green infrastructure.

There were two significant occurrences on this subject in 2017. The Green Infrastructure Conference - Nature Based Solutions for resilient and sustainable cities: European experiences have been presented, with special attention to the role of urban forests - is being promoted in Orvieto by the National Research Council as part of the COST GreenInUrbs program.

The location of the second meeting was Milan. The instruments for evaluating the services provided by ecosystems and the role that these can play in urban areas were highlighted at the conference on "Green Infrastructures for More Liveable Cities," which was organized by Green City Italia and Bocconi University.

4.3 Regional and Local Planning

National Regulation Starting from the **Act 1150/1942 e seq, "Land Planning Act"**

The Italian urban planning legislation is **characterised by an overlapping of norms that are not always exclusively urban, which modified but did not replace the previous ones, creating a corpus that has never come to constitute a single text.**

"Urban Planning", now, after the 2001 Constitutional Reform, "Land Management", is a matter of "Concurrent Legislation" between State and Regions; that is, Regions must observe the fundamental principles derived from state legislation. But in this case a framework law on Land Planning or Land Management doesn't exist, so, every Region approved its legislation.

4.4 Territorial Plan of the Piedmont Region

Piano Territoriale della Regione Piemonte (PTR)

The Regional Territorial Plan, foreseen by Lr. 56/1977 et seq., defines the strategies and objectives at regional level, entrusting their implementation, through moments of verification and comparison, to the bodies operating on a provincial and local scale; establishes the actions to be undertaken by the various planning subjects, in compliance with the principles of subsidiarity and competence, to implement the purposes of the PTR itself.

With DCR no. 122-29783 of 21st July 2011 the Region has approved the new Regional Territorial Plan (PTR). This instrument, necessary for the government of sustainable spatial development, requires the safeguarding of strategic assets that as such should not be altered by transformation and growth processes, and at the same time locates areas destined for activities which are impacting but indispensable for today's society. Regarding the management and protection of environmental heritage, assets identified are not to be considered constraints, but the stimuli for implementing a comprehensive design of transformation, always having the awareness of having to deal with rapidly changing processes.

4.5 Regional Landscape Plan

Piano Paesaggistico Regionale (PPR)

The Regional Landscape Plan (PPR), adopted by the Regional Council with D.G.R. 53-11975 on 4th August 2009, is the primary tool for the sustainable development of the entire regional territory based on quality of the landscape and the environment. It is conceptually coherent with the European Landscape Convention and is drawn up in accordance with the Cultural Property Code of the Landscape (Legislative Decree 42/2004 and subsequent amendments). The PPR, which recognises the landscape value of the entire

regional territory, assumes a strategic and integration role between landscape and sectoral policies and contains prevailing provisions on those contained in other sector planning tools. The Regional Landscape Plan has been approved with D.C.R. no. 233-35836/2017 on 3rd October 2017.

The PPR, which combines and coordinates various approaches (perceptive, historical-cultural, morphological-settling and naturalistic-environmental), identifies the **Regional Ecological Network** - RER, which, with the elements of the historical-cultural and fruitful networks, constitutes the **Landscape Connection Network** (Art. 42 of the implementing rules). RER consists of: Core Areas or Nodes, Ecological Connections, Project Areas (Buffer Areas, Nodes Areas, River Areas, and Environmental Passages) and Environmental Reclamation Areas.

- **Urban Planning National Regulations Act 14th January 2013, no. 10 Standards for the development of urban green spaces (OJ no. 27 of 1st February 2013).** The Act stipulates that all municipalities with more than 15,000 inhabitants carry out a census of trees in their urban areas. The purpose of the census is the editing of the *Catasto alberi* (Register of trees), which records and classifies all the trees: monumental ones, those on school grounds, in historical gardens, equipped with greenery and included in the roadbeds. In addition, in the above-mentioned municipalities, a new dedicated tree must be planted for each child born or adopted, whose data is communicated to the parents of the child. Administrators at the end of the mandate must produce a "green budget" demonstrating the impact of public administration on the public green (number of trees planted and felled, consistency and status of green areas, etc.).

- **National Strategy of Urban Green** Strategia nazionale del Verde Urbano In 2018, in Novara, Piedmont, an important event took place: the Conference of presentation of the National Strategy of Urban Green. Act 10/2013 assigns to the Committee for the Development of Public Green the responsibility of proposing a National Plan (than became a Strategy) that establishes criteria and guidelines for - the realization of permanent green areas around major conurbations and tree-lined rows along the roads. The greening of the walls and the paving stones, the creation of gardens and vegetable gardens and the improvement of the settlements (public and private) and of infrastructures.

4.6 Regional Regulation

Regional Act 56/1977 et seq “Soil Protection and Land Use” (Land Planning Act)

This Act identifies the bodies in charge of spatial planning (Region and Local Authorities), the planning tools and their contents. Municipalities must draw up a **Local Urban Plan** (Piano Regolatore Generale Comunale). This Plan constitues the planning tool for the entire municipal territory. Among the aims of the plan there are: the containment of land consumption, the protection of agricultural areas, natural and environmental resources and historical-artistic and landscape heritage. The Plan must ensure an allocation of 12.50 square meters per inhabitant of public green areas (urban parks or game and sport areas), to be increased if the population exceeds 20,000 inhabitants.

4.7 Green Infrastructure and nature-based solutions

Italy needs to act quickly now to both slow down climate change and prepare for its effects. Infrastructure assets will be impacted by climate change, which will disrupt the services they provide and jeopardise the stability of social and economic networks. The Italian peninsula experienced heat waves during the summer months of 2021, despite it not being as hot as previous years. The highest temperature recorded during one of these heat waves was 48.8 oC in Syracuse, Sicily. Additionally, there were significant downpours that resulted in mudslides, landslides, and flooding, particularly in the Liguria region. Extreme weather events brought on by climate change have a negative influence on power grids, train lines, and metro systems. The effects of climate change on transportation infrastructure, both nationally and locally, are examined in a recent report organized by the Ministry of Infrastructure and Transport (MIT)1 (see Box 1.1). The report projects that by 2050, the direct economic impact of climate change on Italy's infrastructure assets could reach up to EUR 5.17 billion annually, a twelve-fold increase over the current value of damages (Ministero delle infrastrutture e dei trasporti (MIT), 2022)

MIT has committed to the "transformative resilience" approach in order to implement effective adaptation strategies and make infrastructure resilient to climate change. The latter takes a more systemic and integrated approach to go beyond the conventional method of addressing the climate crisis with ad hoc measures. This strategy makes use of "green" measures, or methods that improve upon ecosystems' many advantages and the natural world to increase the adaptability and resilience of infrastructure assets (Ministero delle infrastrutture e dei trasporti (MIT), 2022).

4.8 Case study: Torino (Urban Heat Island, Flooding)

The history of Turin goes back to the Roman era to the formation of the Italian state and the present. Turin served as Italy's industrial hub for a large portion of the 20th century. It was home to a massive concentration of companies that manufactured automobiles, gearboxes, and other related products, which fueled the country's post-war "economic miracle."

Turin's modern reputation stems from its accomplishments in technology, engineering, higher education, design, and manufacturing; it also comes from a long history of social activism, a progressive political and intellectual heritage, and a rich artistic and cultural legacy that is fueling the city's expanding tourism sector. With a plethora of infrastructure, including an international airport, an intermodal cargo port, and high-speed rail connections to Milan and the rest of Italy, Turin is the economic hub of the region.

With more than 50 square meters of green space (both public and private) per resident, Turin is among the greenest cities in all of Italy. The city has a lot of parks and greenways left over from its baroque past, but it also has a very capillary network of green spaces, with over 93% of city dwellers being able to access a green recreational area within 300 meters of their home thanks to its focused efforts to turn brownfields into green fields, reclaim river corridors as ecological greenbelts, and create neighbourhood green spaces with every redevelopment project.

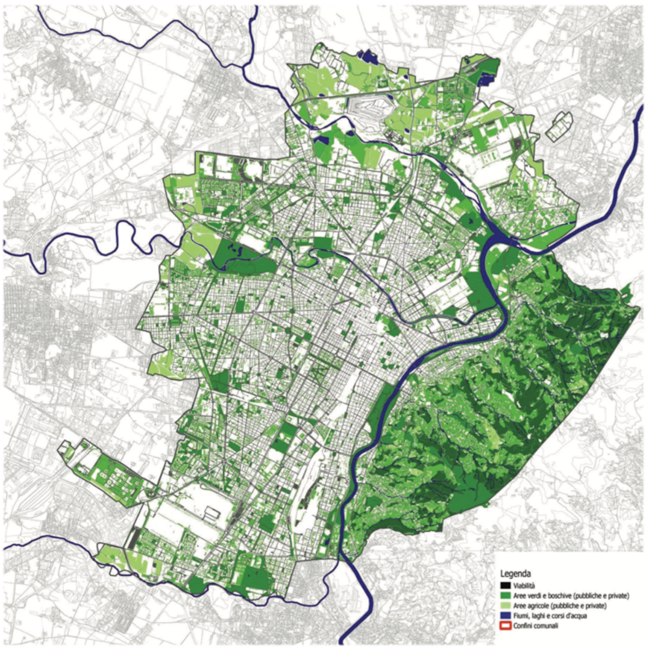


Figure 25: Turin’s green system; source: Turin, European green capital

Turin has made tremendous progress in the heating sector and is currently the most district-heated city in Italy, with over 50% of the city connected to district heating systems. This is in addition to significant improvements in the transportation sector, which have significantly reduced greenhouse gas emissions. Turin has reduced its CO2 emissions by 33% since 1991 as of 2018, thanks to improvements in efficiency in both new construction and retrofits, as well as other advancements in LED street lighting replacement.

- **Climate Change: Mitigation**

While the city's policies have had a significant impact on the residential and transportation sectors as well as public buildings, the economic restructuring process the city has undergone in recent decades has had a direct impact on emission levels, particularly industrial emissions.

Based on data from 1991, Turin produced its first energy audit in 1992. 2010 saw the City of Turin ratify the Turin Action Plan for Energy (TAPE) and sign the Covenant of Mayors. The documents comprise the following:

- Baseline CO2 Emissions Inventory for 1991.
- Baseline CO2 Emissions Inventory for 2005.
- Action Plan to fulfil the pledges made by the Mayors Covenant to cut CO2 emissions by thirty percent over 1991 levels by 2020.

Emissions were determined directly for the Baseline CO2 Emission Inventories for 1991 and 2005, and indirectly when needed, using the estimation methodologies outlined in the Covenant of Mayors for the calculation of energy consumption by sector.

The data on CO2 emissions is categorized by the type of energy source (fossil fuels, electricity, district heating) and the type of emission source (transportation, industry, services, public lighting, municipal buildings, and residential buildings).

Turin's CO2 emissions decreased from 6.27 million tons in 1991 to 3.48 million tons in 2017, a 44.52% decrease. The reduction values also account for the industry sector in comparison to the TAPE results.

In terms of CO2 emissions in 2017, the residential sector contributed the most (386.26%), followed by services (24.24%), transportation (19.68%), and industry (14.79%).

Reductions in per capita CO2 emissions were largely made possible by persistent public investment and energy-saving measures. The construction of Italy's largest district heating system has significantly increased heating efficiencies; Green Public Procurement policies have ensured that all energy used by the City in buildings and services is from renewable sources; the adoption of an energy efficiency code for private construction; and energy efficiency in public buildings and street lighting have all reduced the use of private automobiles.

Since 1991, technological advancements have resulted in a 34% increase in electricity generation efficiency, largely due to the notable expansion of renewable energy production. The accomplishment of citizen-driven initiatives is closely linked to the City of Turin's ambitious CO2 emission reduction targets, which are in line with the EU strategy. Municipal Resolution N. 29, which declared a climate and environmental emergency and committed to further CO2 emission reduction of 40% by 2030 (excluding industry) and net carbon neutrality by 2050, was approved by the City of Turin on July 1, 2019.]

In an effort to lower emissions and pollutants associated with the transportation industry, the City of Turin has been increasing the availability of transportation options over the last 20 years. The objective has been to reduce the use of public vehicles by encouraging walking and bicycling and improving the competitiveness, comfort, and sustainability of the public transportation network.

The goals and modal share targets for 2025, as well as the strategic actions to achieve those targets, are outlined in the Sustainable Urban Mobility Plan, which was adopted in 2011 (9). The main tactics include building out public transportation infrastructure—such as the railway link (10) and Turin's first metro line (11);

creating a network of bikeways and pedestrian streets and areas; enhancing pedestrian safety in the streetscape; and replacing the fleet of private automobiles with cleaner, greener models.

The Bike Mobility Plan (13), whose strategic objective is to raise the cycling modal share from 3% to 15% in ten years, was approved by Turin in 2013. A 735-car free-floating car sharing program was launched in 2015, along with an electric vehicle sharing program that uses only 100% certified renewable electricity and 120 charging stations spread across the city.

By 2030, Turin seeks to have cut its CO2 emissions by 60%. To achieve net carbon neutrality by 2050, additional emission reductions are the long-term goal.

The City of Turin will incorporate strategic actions into the pertinent planning documents and tools at its disposal to accomplish these goals, and it will work to implement them with the assistance of local stakeholders and citizens. In order to achieve this, the City is collaborating with the Polytechnic University of Turin to establish an Energy Centre that will maintain direct communication with the public and professionals employed in the environmental and energy sectors.

- **Climate Change: Adaptation**

Turin is creating a climate adaptation plan in order to guarantee a high standard of living, advance sustainable development, and foster innovation. Climate change is one of the Administration's top priorities. Ten city offices sent representatives to an interdepartmental working group that the city formed to develop the strategy. Along with other regional stakeholders including utilities, small and medium-sized businesses, trade associations, environmental organisations, universities, and the Piedmont Region, this working group has collaborated closely with the Regional Environmental Agency. Through the EU Life Derris project, special efforts were made to work with SMEs to create plans for adaptation.

Arpa Piemonte created a climate vulnerability analysis in 2017 at the City's request, outlining the current circumstances and projecting medium- and long-term trends.

The IPCC data and the two emission scenarios, RCP 4.5 and RCP 8.5, are used in the simulations of future scenarios, which extrapolate to the year 2100.

According to the vulnerability analysis, heat waves and heavy precipitation events are the main threats associated with climate change.

After the analysis, the risks were examined for potential effects on housing, green infrastructure, public transportation, industrial processes, public health, social services, quality of life, and stormwater management.

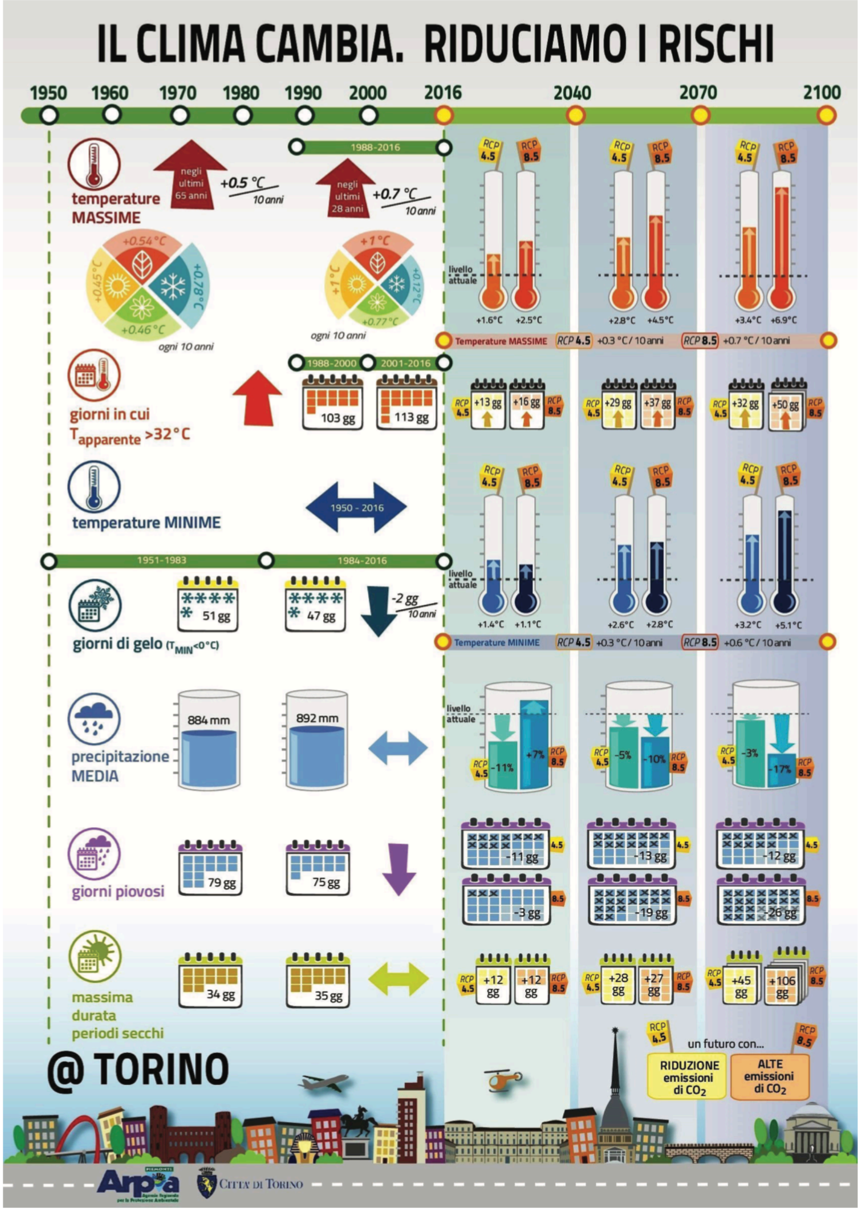


Figure 26: Infographics summarising the vulnerability analysis by showing the trend of climate parameters in the past and their future projections.

The climate task force also performed an in-depth examination of the risks posed by heat waves and floods, thus making it possible to identify particularly high-risk areas.

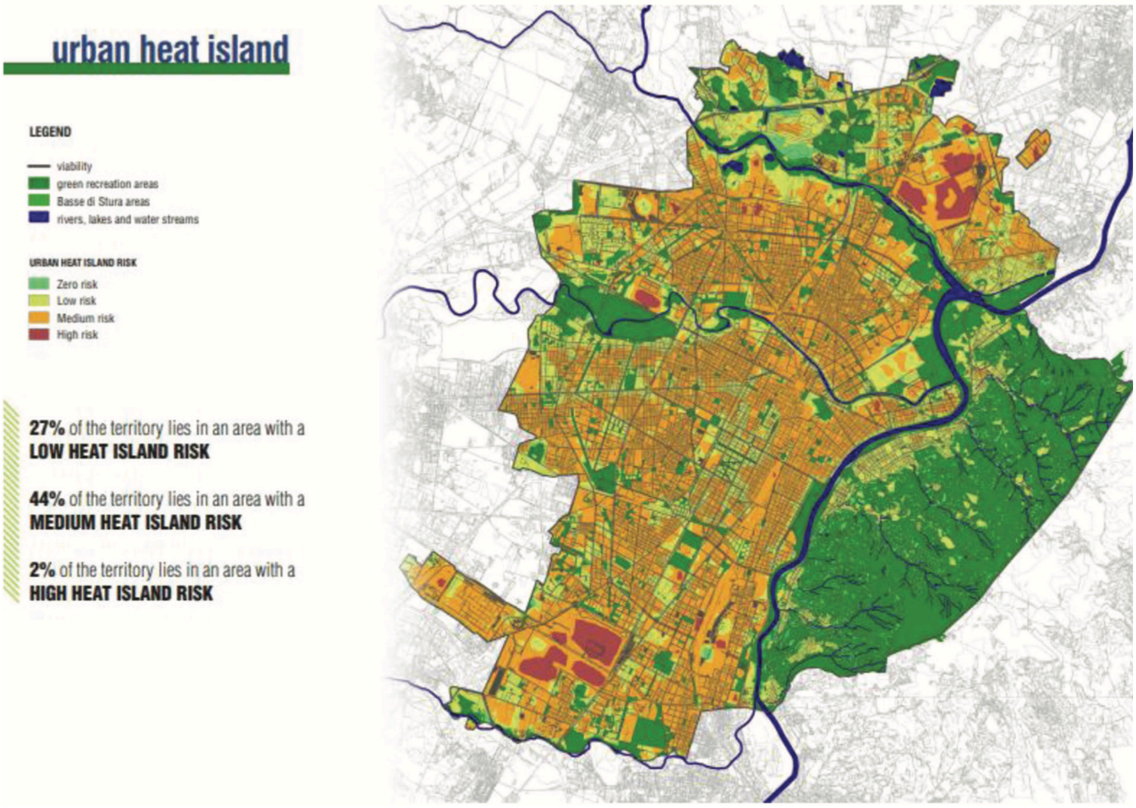


Figure 27: Distribution of heat wave risk classes (high, medium and low)

Urban heat island effects during heat waves and localized flooding from intense precipitation events are Turin's main climate challenges.

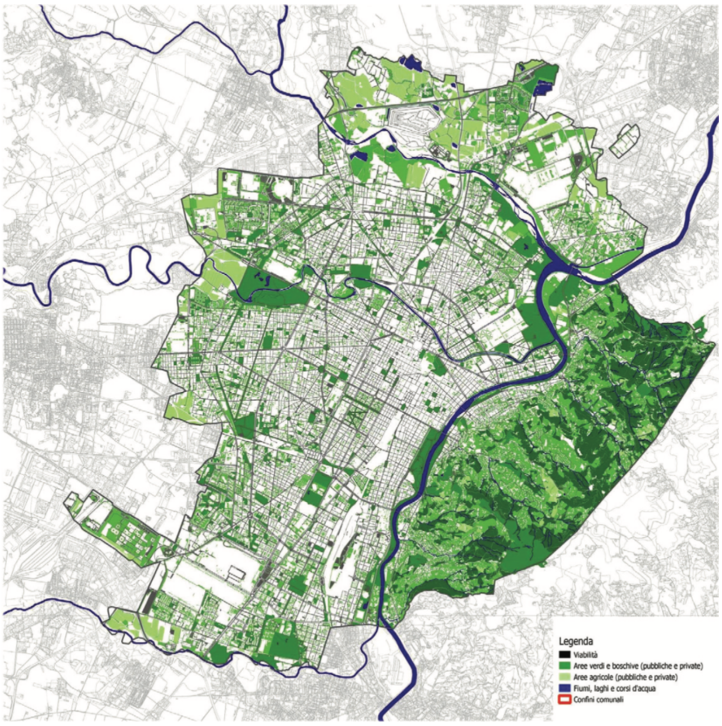
Turin looked up based data, created risk maps, and identified a set of actions for each risk to start and finish the vulnerability analysis phase. Turin is currently working on developing monitoring systems. Reducing impact vulnerability is the aim of incorporating climate change adaptation into current administration policies.

- **Participatory urban forestry**

The City of Turin has launched several programs targeted at raising the urban tree cover to optimise ecosystem services for adaptation goals, in addition to significantly expanding green and open space. In order to raise public awareness of the importance of trees in urban environments, these initiatives are also firmly rooted in citizen engagement processes:

- “Provide a tree to your city” is a program that enables citizens to donate money to the city for the purpose of planting and caring for new tree plantings.
- “Trees for the future” is an initiative wherein volunteers from the community work with city technical staff to plant hundreds of trees twice a year in areas that have been identified as critical in terms of potential mitigation of climate change.

- **Turin’s Green infrastructure system**



With over 50 m2 of green space per resident, public and private green spaces make up 35% of the city's total land area (about 47 km2). Twenty-three percent of the 47 km2 are designated as green space for recreational, social, and sporting purposes (sports fields excluded).

Currently, 93% of people reside 300 meters or less from a recreational green space. The target is to attain 100% by 2030. The City of Turin has been working with the Piedmont Region, local health authorities, Civil Defence, senior-care facilities, social cooperatives, and volunteer associations to implement a plan since 2004 to lower the health risks associated with heat waves.

Public and private green spaces comprise 35% of the city's total land area (about 47 km2), with over 50 m2 of green space per resident. Sports fields excluded, twenty-three percent of the 47 km2 are set aside as green space for social, recreational, and athletic uses.

Now, 93% of people live 300 meters or less away from a green space for recreation. By 2030, the goal is to reach 100%. Since 2004, the City of Turin has been implementing a plan to reduce the health risks associated with heat waves in collaboration with the Piedmont Region, local health authorities, Civil Defence, senior-care facilities, social cooperatives, and volunteer associations.

In order to achieve the following objectives, the City's Climate Adaptation Plan attempts to reduce the effects of climate change on human health and comfort, as well as on the environment and urban infrastructure:

- Reduce the likelihood of a critical event (such as heat islands or frequent floods);
- Modify the urban environment and services to manage emergencies and reduce exposure.
- Modify existing buildings to enhance life quality and control energy consumption.
- Manage the evolution of urban ecosystems.
- Cultivate an awareness of climate risk when planning public works projects.
- Get people ready for new circumstances.

The following are the development goals through 2030:

- Creating 2,297,824 m2 of new green space on publicly owned land, which is a 21% increase in the total amount of recreational green space.
- Creating an additional 276,490 m2 of recreational green space from private land development rights, which is 20% of all private areas to be redeveloped in accordance with the plan for general urbanisation.

- **Green urban areas/ Green Infrastructure**

The General Masterplan is the main tool used to identify the existence and size of green areas and green infrastructure.

The Provincial Territorial Plan, in addition to the General Masterplan, outlines the ecological corridors that run through the city.

Lastly, the city is currently working on approving its first Strategic Plan for Green Infrastructure, which sets forth the strategic goals for how the city's green infrastructure will develop over the next several decades.

The investment priorities for the creation of public green spaces are specified by these instruments.

In addition to providing ecosystem services like shade during heat waves, rainwater management for extreme precipitation events, and river expansion areas to lessen flooding from rivers, green spaces and infrastructures also benefit locals and tourists.

Socially green spaces become hubs of cultural integration by offering leisure activities, gathering spots, social hubs, celebration spaces, and venues for cultural events.

Economically speaking, green spaces can increase property values, create opportunities for tourism and cultural events, and supply much-needed infrastructure to communities.

93% of the city's population lives within 300 meters of a recreational green public space thanks to the city's exceptionally capillary green infrastructure system (green schoolyards, agricultural areas, and green street infrastructure are not included in this statistic).

The presence of public art, a variety of activity types for all ages, good visibility and lighting, and more than 90% of the system being maintained and usable are the main markers of the system's quality.

Bigger green spaces also have better cycling connectivity with other cycle paths and a higher biodiversity quotient. The four main blue corridors in the city provide opportunities for walking, jogging, and cycling. They also frequently feature larger open green spaces with breathtaking views of the surrounding hill and mountain landscapes and rivers. Along its entire length, the Po' river is home to many historically significant buildings and offers multiple access points to the water for activities like canoeing.

- In 2018, the yearly allocation for the advancement and upkeep of green spaces surpassed 10.4 million euros. All public green spaces, including playgrounds, must be accessible by foot, and any architectural barriers preventing access to green spaces have been removed. While playgrounds are gradually being retrofitted with universally accessible equipment, over 60% of the 286 playground areas in the city already have at least one inclusive play item. All 286 playground areas in the city are universally accessible.

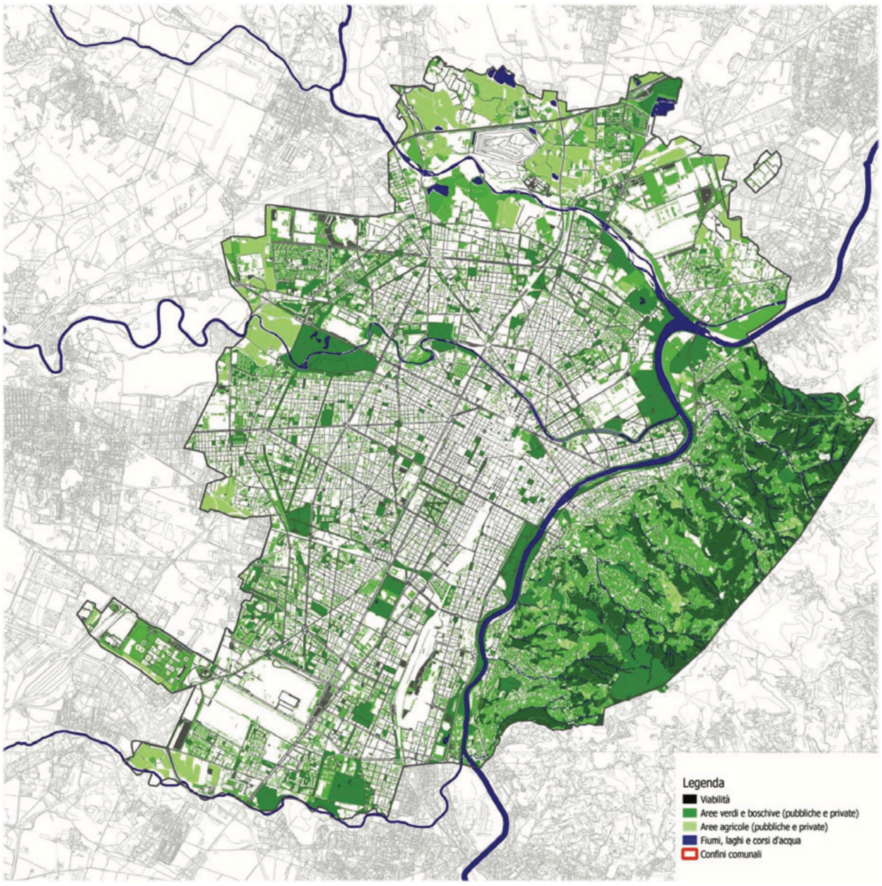


Figure 28: Turin's Green Infrastructure (public and private): approximately 47 square km or 35% of total land area.

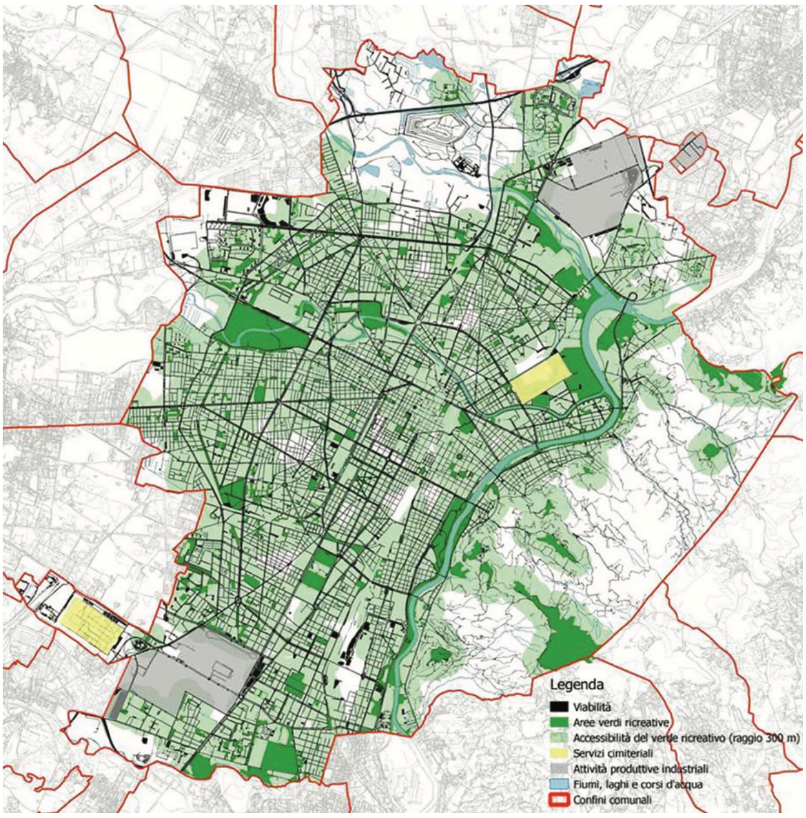


Figure 29: Accessibility to Public Green Recreational Areas: 93% of the population lives within 300m of a recreational public green area.

- **Sustainable Land Use**

Plenty of formerly industrial land were rezoned as new green areas and mixed-use development as part of the 1995 General Masterplan, which was the most important policy to limit sprawl and protect the environment over the previous 30 years. The Masterplan gave the city permission to move forward with the daylighting of a central portion of the Dora River and the reclamation of large areas of the city for the creation of over 400 hectares of new green spaces. In addition, it severely restricted greenfield development in Turin's hillsides by directing housing development to brownfield areas and designating sizable portions of the city as future park space. Sensitive environmental corridors and areas were also protected under the original Provincial Territorial Coordination Plan (1999) and the 2011 revision.

Every tree that is felled is required to be replaced with a new planting, according to the City's Green Code, which also governs tree maintenance and planting. In addition to reducing the effects of urban heat islands, this helps to preserve infiltration areas. Furthermore, all newly constructed commercial buildings must have porous parking areas that permit the infiltration of rain gardens, tree trenches, and other NBS.

The use of NBS is additionally encouraged by the City's Energy Efficiency and Sustainability Code for buildings.

- **Future Plans**

The importance of green infrastructure in the city will only increase due to its recreational value and its growing capacity to generate ecosystem services, which will only increase in value because of climate change and an increase in the frequency of extreme weather events.

Turin aims to be the greenest major city in Europe as well as the greenest city in Italy.

The primary objectives outlined in the almost finished Strategic Green Infrastructure Plan (SGIP) will guide the creation and advancement of the City's green infrastructure system:

1. Fulfil the requirements of a shifting population
2. Reduce the risk of climate change by using ecosystem services
3. Improve biodiversity and ecological health
4. Increase the interconnectivity of green spaces ever further.
5. Make use of green infrastructure to increase social participation and inclusion
6. Make use of green infrastructure to advance outdoor and cultural tourism

The Administration's vision for 2030, "Turin 2030 - Sustainable and Resilient," is outlined in an Action Plan that is firmly centred around a sustainability agenda.

This agenda's environmental pillars include circular economy, food and other waste reduction, upcycling and recycling; climate resiliency, intended as both mitigation and adaptation; green infrastructure and nature-based solutions; a revamped public transportation system, electric and shared mobility, safe streets, and mobility as a service.

Not only do the environmental goals align with the social and economic facets of the overarching vision, but the actions also reinforce and support each other.

As a result, the action plan offers a comprehensive vision for the city's future that is based on resilience and sustainability.

The participatory city, dynamic city, liveable city, and just city are the four macro-objectives that make up the plan. Since these overarching goals are not sector-specific, each is guided by the principles of sustainability and resilience.

The action plan, which is the direct result of the political mandate of the Administration, was reviewed by stakeholders in order to discuss structural actions and strategic goals as well as to request projects and initiatives from the public and private sectors. The Strategic Green Infrastructure Plan, the Emergency Management Plan, and the General Masterplan revision—all of which are well underway—are just a few of the strategies and plans that the Turin 2030 action plan carefully integrates the environmental goals, including those of the Climate Resilience Adaptation Plan and the Strategic Green Infrastructure Plan.

Turin is particularly interested in how green infrastructure can improve living standards, lessen climate vulnerability, and help cities prepare for medium- and long-term climate change scenarios. The city has launched an innovative public tender for the quantitative and qualitative valuation of ecosystem services within the city, with three goals in mind, to further the city's ability to strategically maximize the quality and role of green infrastructure in producing ecosystem services.

- Create a tool to assess the impact of new urban developments on ecosystem services produced and to calculate any eventual environmental compensation required to mitigate any loss in services.

- Develop strategies to maximize ecosystem services produced by the existing public green infrastructure with the aim of improving quality of life and environmental quality.

- Develop strategies to strategically develop additional green infrastructure to contrast climate vulnerabilities.

The analysis will primarily concentrate on the following ecosystem services: flood protection, stormwater runoff management, biodiversity, carbon storage, particulate matter capture, mitigation of the effects of urban heat islands, and socio-cultural benefits.

Lastly, the analysis will put a number on the strategies the City will need to invest in, accounting for potential future climate scenarios, as well as the financial outlays necessary to put those strategies into action.

5. Research methodology

5.1 Introduction

This chapter outlines the various methodologies used for data collection pertinent to the research. It covers aspects such as the locations of the case study, research design, sample size, data collection techniques, and data management. The research is conducted in Novara, Italy. The research employs two primary tools: document and policy analysis, data collection to produce UHI and flood risk maps. These methods will be discussed in more detail in the subsequent sections.

5.2 Document and policy analysis:

Document analysis (also known as document review) is a systematic approach to reviewing and evaluating both printed and digital documents. This process involves evaluating and interpreting the data to extract meaning, gain understanding, and develop empirical knowledge (Corbin & Strauss, 2008; Rapley, 2007).

To include the information in the research, an evaluation of the earlier literatures has been conducted. Considering this, the European and Italian plans for climate change and green infrastructure have been thoroughly analyzed in order to produce a comprehensive concept.

5.2.1 Green infrastructure as a planning concept

Many examples of green infrastructure (GI) being used as a planning concept and/or tool for sustainable development can be found throughout Europe and the rest of the world. These examples include development control, biodiversity protection policies, and green and open space planning.

The factors that influence the creation of GI strategies and plans vary from region to region and from territory to territory in terms of economic, sociocultural, and environmental factors. Important economic factors include recreation, lowering flood risks, mitigating the effects of climate change, preserving and enhancing biodiversity, and cutting back on health care expenses.

Since GI is based on the science of ecosystem services and acknowledges and encourages the multifunctional nature of green and blue spaces, it naturally aligns with the three widely acknowledged pillars of sustainable development: the environment, society, and economy (Purvis et al. 2018, figure 1)

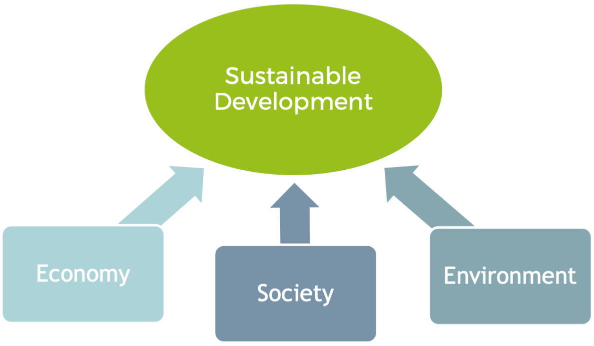


Figure 30: The three Pillars of Sustainable Development

Though they go by different names, GI is recognised by many plans and strategies as a component of a regional network that also applies at other geographical scales. They also acknowledge that GI serves a purpose beyond traditional nature conservation, with socioeconomic concerns being seen as change agents.

For instance, the National Planning Policy Framework in the UK mandates that local planning should "plan positively for the creation, protection, enhancement and management of networks of biodiversity and green infrastructure" (Ministry of Housing, Communities and Local Government 2018). This approach is seen as a crucial tool for promoting sustainable development in the country. In other places, the term is strongly linked to the urban environment and, more especially, water management (US EPA 2018). It is also becoming more and more associated with urban water management in cities worldwide (Liu & Jensen 2018).

The notion of GI is not as well-established in national and regional planning in Central Europe, although professionals in planning and conservation are familiar with the term; however, their interpretations of GI vary depending on their respective backgrounds.

Numerous initiatives and plans throughout Central Europe demonstrate the application of the GI concept and the understanding that it can yield several advantages. Three examples from Central Europe where the concept is applied, if not explicitly named, are the Blue/Green Network in the Polish city of Lodz, the German publication "Bundeskonzept Grüne Infrastruktur" (BfN 2017), and the Corona Verde project in Turin, Italy (Città metropolitana di Torino 2015).

5.3 Desk research

It is essential to gather substantial data from the chosen area to gain a deeper understanding of the planning process, best practices, and obstacles that impede the implementation of the Green Iinfrastructure in Novar, Italy.

Gathering information was categorized into two parts: desk research and producing maps according to the data of the city.

Desk research is generally equated with a literature review and is succinctly defined by Jackson (1994, p. 21) as “the process of accessing published secondary data.” This definition highlights two key characteristics of desk research. Firstly, it relies solely on published secondary data, which broadly includes books, journals, articles from various databases, and business and research reports (Jackson, 1994, pp. 21-22). The term “secondary data” refers to data that already exists, having been collected previously for purposes unrelated to the current project (Jackson, 1994, p. 20). Secondly, all desk research activities are conducted “in-house” (Jackson, 1994, p. 11). In this regard the articles, books and data related to the chosen area has been carefully mentioned in the literature review.

5.4 Case study: Novara, Italy

Architect Gianfranco Pagliettini won the March 2000 international competition to design Novara's urban plan, which was subsequently accepted by the City Council in March 2001. With more than 100,000 residents, Novara is Piemonte's second-biggest city, after Torino, the region's capital. Located on the Torino-Milano axis, Novara is located 35 km closer to Milano than it is to Torino, which is 90 km away. Until the middle of the 19th century, Novara belonged to the historical "Lombardo-Veneto" state, which had Milano as its capital. Throughout the 20th century, Novara's population continued to grow toward Milano. Even though Novara is currently a part of Piemonte, it still operates as a satellite city inside the Milan metropolitan region.

Some argue that this ambiguous status is good for urban development because it helps important local industries like publishing (De Agostini), food production (Pavesi - Barilla), and chemicals (Donegani, Alcoa). Its advantageous location at the meeting point of the east-west (Lyon-Eastern Europe) and north-south (Genova-Germany) axes further strengthens its status as a hub for trade. On the other hand, there are drawbacks to the town's closeness to one of Italy's last remaining productive agricultural areas, the northwest rice-cultivation plain. These activities support the urban economy as a whole, even in the face of market challenges and production-related contamination that increasingly contradicts urban quality-of-life standards. As such, Novara is among the few towns in northwest Italy that has not seen a decline in population over the previous thirty years.

Novara's size is perhaps the only thing in common with other medium-sized Italian towns. Novara has always served as Milan's auxiliary town, in contrast to other towns that have frequently grown from their medieval status as "Liberi Comuni" into true urban states. Novara's capacity to establish a central hub for its region and to forge its own unique and autonomous urban identity has been hampered by this relationship.

The development pattern of the modern town, which shows a lack of attention to the appearance and usability of new neighborhoods as well as the urban and rural landscape, is indicative of this secondary role. The historic center has undergone a fundamental renewal, there is a high density of largely homogeneous building types, and expansion generally follows road lines. Furthermore, public areas are frequently insufficient and of low quality.

Novara has recently come to the realization that the conventional intermetropolitan relationships on which it has depended are changing as a result of the effects of globalization and significant infrastructural advancements that have a direct bearing on the town. The city understands that it lacks the necessary organizational structures and facilities to manage these changes.

• There is a lack of access to highways and motorways from logistical and industrial areas;

• There are inadequate services;

• The facilities are of low quality; and the town has little appeal overall.

The 2000 urban plan for Novara attempts to tackle two issues: rectifying the city's lack of territorial centrality and urban identity and scheduling its regeneration to interact with significant European intermodal platforms. Leveraging these modifications to improve continuity and add fresh aspects and qualities is part of the plan. A framework for sustainable development is suggested by the urban plan by:

• Rearranging the traffic pattern to enhance access to major roads and drastically cut down on through traffic in the central urban area.

• Moving businesses to more accessible areas and repurposing vacant space to make room for public amenities like parks for entire cities.

• To make hotels more accessible.

• To establish connections between university centers and urban and industrial areas with the proposed new technological and scientific growth pole centered on pharmacy and novel chemicals.

• To revitalize the townscape, which is presently unloved and lacks character, by:

- Redefining the currently unfinished or ignored urban periphery.'
- Gateways to the town' being rebuilt.
- Renovating historic sites and monuments in the historic center and surrounding area.
- Introducing new, lower-density building types.establishing a new green belt around the town's edges, along rivers, with a network of bike paths and footpaths leading to the countryside, in order to establish a clear framework of parks and green areas, which has been lacking. In this case, the plan is

in favor of reviving native vegetation and converting intensive farming into ecologically sound traditional methods.

5.4.1 Urban Heat Island in Novara

Early 19th-century English chemist and meteorologist Luke Howard (1772–1864) was the first to document the effect of urban areas on local climates, citing higher air temperatures in comparison to nearby rural areas (Howard, 1833; Oke, 1982). In his analysis, he focused on two related but distinct topics (the impact of urbanization on the quality of meteorological data and the factors contributing to the urban effect) in relation to the London urban extension.

According to Howard's analysis, the city's temperature "is not to be considered as that of the climate"; rather, he indicates of an "artificial warmth" resulting from the city's design, dense population, and heavy fuel use.

Four primary causes of these variations in air temperature were identified by Howard (1833):

- Human heat-generating activities, particularly in the winter, add to the atmosphere's warming.
- The unevenness of urban surfaces can impede the movement of the "gentle" summer winds.
- The geometry of urban surfaces, which "traps" radiation and obstructs "free radiation to the sky.”
- The availability of moisture for evaporation in the nation.

There are many different factors that contribute to UHI, including changes in land use, air pollution, and urbanisation. The environment and public health are significantly impacted by UHI, as demonstrated by a plethora of studies, making this a crucial area of study. But as cities continue to grow, the surface temperature has increased. This has a big impact on how resources and energy are distributed in cities, which puts more pressure on power supplies. In addition, the urban heat island effect exacerbates the air quality and increases the concentration of pollutants in cities. Overall, the UHI effect has a detrimental effect on the different facets of social-ecological systems in local communities. This alteration also has an impact on how urban ecological systems function, which could ultimately seriously harm the health of the citizens (Howard, 1833; Yang et al., 2016).

This issue is being made worse by climate change, which is causing heat waves to occur more frequently, be more severe, and last longer. According to research, there is evidence that air pollution and higher temperatures can increase the risk of long-term diseases like obesity, diabetes, hypertension, asthma, respiratory, and cardiovascular disorders, as well as infectious diseases like malaria (Wang et al., 2023).

We have chosen to examine the phenomenon of urban heat islands in this research using Novara, which is the capital city of the province of Novara in the Piedmont region in northwest Italy, to the west of Milan with 101,916 inhabitants (on 1 January 2021), it is the second most populous city in Piedmont after Turin. Due to its significant industrial role the city requires a major urban transformation. Because of its dense urban fabric and high concentration of anthropogenic heat sources, the city remains vulnerable to the formation of urban heat islands despite these efforts.

5.4.2 Flood risks in Novara

Water-related crises are among the most significant environmental risks of our time, posing the biggest barriers to human security and development among both natural and man-made hazards (Adikari and Yoshitani 2009). Approximately 70 million people are affected by floods annually on average (UNDP 2004; United Nations 2011), and future floods will be more severe (Swiss Re 2012). Researchers and public officials are paying more attention to figuring out what factors lead to these kinds of risks as a result of these data (IPCC 2012). Broadly speaking, risk is the result of a community's combination of hazards, vulnerabilities, and exposure to elements that could have negative consequences (Cardona et al. 2012).

According to Smit and Wandel (2006), the human-environment system is fragile and susceptible to harm and disturbances resulting from the social, economic, and environmental circumstances of the community (UNISDR 2004; Kasperson et al. 2005). According to Brooks (2003), social vulnerability is the vulnerability of the human environment. It can be linked to a variety of individual characteristics, including gender, age, education, economic status, and race, as well as intricate community dynamics and support networks that may have an impact on an individual's capacity to respond to specific threats (Cutter et al. 2003; Mechanic and Tanner 2007). The Sendai Framework for Disaster Risk Reduction has been extensively discussed and supports the spatial identification and inclusion of vulnerable individuals in the risk management planning process (Aitsi-Selmi et al. 2016). As a communication tool for all the actors in the disaster management framework, from academic communities to political, governmental, and humanitarian agencies, it became apparent that it could improve effective mitigation plans meant to increase social capacities (Dunning and Durden 2011; Eakin and Luers 2006). Monitoring, forecasting, and assistance phases may benefit from an earlier understanding of a community's needs (Morrow 1999; Fernandez et al. 2016) and a mapped representation of the individuals who need additional care before, during, and after a flood (Flanagan et al. 2011). According to Morrow (1999), maps are regarded as "low-tech" technologies that can convey the same information to various stakeholders, be enhanced with helpful information (like shelter locations) and be easily accessible to the general public. The advantage of using the geographic information system (GIS) to show flood vulnerability is that it allows one to track outcomes over time and space (Hebb and Mortsch 2007; Fedeski and Gwilliam 2007; Van Westen 2013). Updating the susceptible human indicators and adding new information on hazards, economic losses, and urban infrastructures, among other things, could enable this advanced monitoring. Politicians and other public authorities could then give priority to the areas that call for management measures.

Since the 1980s, there has been a rise in the number of floods across the European continent, primarily as a result of the ongoing increase in meteorological events (Munich Re 2012). Between 2003 and 2009, there were 26 significant flood disasters that were reported; these primarily affected Romania, the UK, and Italy

(CRED EM-DAT 2015). Since the late seventh century, floods have affected Italy multiple times.

Between 2009 and 2014, 99 recorded deaths and over 37,000 cases of displacement were reported (IRPI-CNR 2014). Specifically, the floodplain in northern Italy is an area where increased human activity, continuous asset concentration and sensitivity, and an increase in unequally exposed individuals have amplified flood damage (Alfieri et al. 2016). The northern Italian floodplain has been the most productive agricultural region since the early 1860s. The first notable immigration fluxes in the floodplain have resulted from this, necessitating a sizable labor force (Bonifazi and Heins 2011). Since then, its surroundings and landscape have undergone a great deal of change, making it the most populous region in Italy in recent times (Menichini 2005). This floodplain presents many areas susceptible to flooding due to its geomorphic and topographic settings as well as the intricate drainage system articulation (Sofia et al. 2014; Sofia and Tarolli 2017; Sofia et al. 2017). One of the most recent significant floods was the one that happened in Piemonte from October 13–16, 2000, leaving over 40,000 people homeless, five people missing, and three people dead.

5.5 Producing maps

5.5.1 Producing UHI and Flood risk maps

The Paris Agreement of 2015 sets out a global framework to limit global warming to well below 2°C, preferably to 1.5°C (degrees Celsius), compared to pre-industrial levels. To achieve this global temperature goal, countries aim to reduce growth of greenhouse gas emissions as soon as possible and rapid reductions, thereafter, based on the best available science, economic and social feasibility.

The effects of climate change are already well visible by increasing air temperatures, melting glaciers and decreasing polar ice caps, rising sea levels, increasing desertification, as well as by more frequent extreme weather events such as heat waves, droughts, floods and storms. Climate change is not globally uniform and affects some regions more than others. On the following diagrams, it is clear how climate change has already affected the region of Novara, the capital city of the province of Novara in the Piedmont region in northwest Italy, to the west of Milan, during the past 40 years. The data source used is ERA5, the fifth generation ECMWF atmospheric reanalysis of the global climate, covering the time range from 1979 to 2021, with a spatial resolution of 30 km.

The data will not show conditions at an exact location. Micro-climates and local differences will not appear. Therefore, temperatures will be often higher than those displayed especially in cities and precipitation may vary locally, depending on topography.

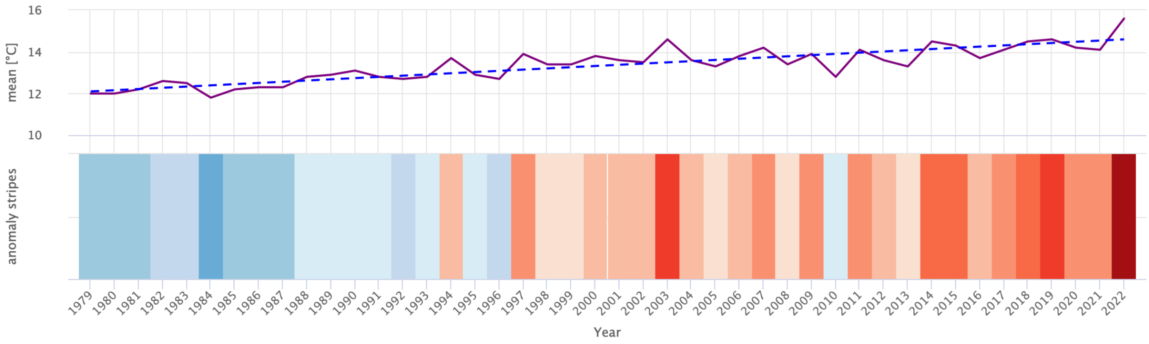


Figure 31: Mean yearly temperature, trend and anomaly, 1979-2022

The top graph shows an estimate of the mean annual temperature for the larger region of Novara. The dashed blue line is the linear climate change trend. If the trend line is going up from left to right, the temperature trend is positive, and it is getting warmer in Novara due to climate change. If it is horizontal, no clear trend is seen, and if it is going down, conditions in Novara are becoming colder over time.

In the lower part the graph shows the so-called warming stripes. Each coloured stripe represents the average temperature for a year - blue for colder and red for warmer years.

Also, the graph below shows an estimate of mean total precipitation for the larger region of Novara. The dashed blue line is the linear climate change trend. If the trend line is going up from left to right, the precipitation trend is positive, and it is getting wetter in Novara due to climate change. If it is horizontal, no clear trend is seen and if it is going down conditions are becoming drier in Novara over time.

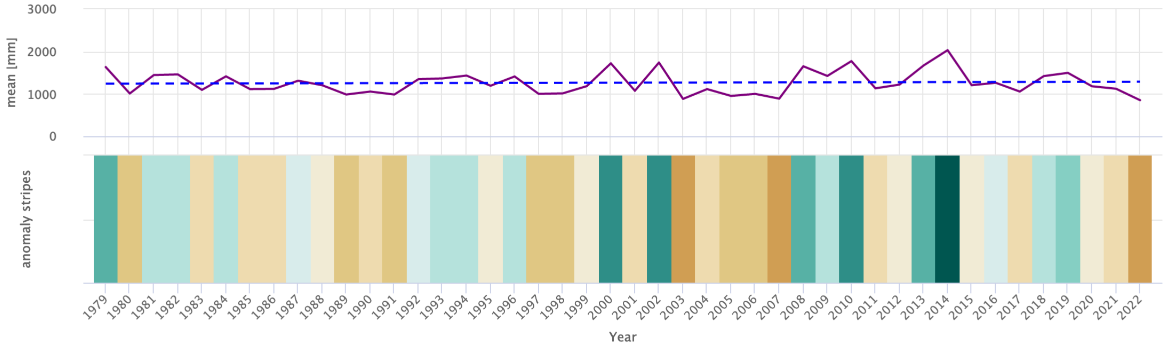


Figure 32: Mean yearly precipitation, trend and anomaly, 1979-2022

In the lower part the graph shows the so-called precipitation stripes. Each coloured stripe represents the total precipitation of a year - green for wetter and brown for drier years.

According to the data we have, we have produced the UHI and Flood risk maps.

To create UHI and flood risk maps, individual indices for flood and heat potential must first be developed and then applied to the city of interest. We generated UHI maps using Landsat 8 satellite images, which are the most unbiased, landscape-based metrics for assessing heat. For flood risk maps, we used DEM 10 data and the HEC-RAC software. These two indices were selected because they can be produced using readily available geospatial data and in situ measurements, and they have been recognized in the literature as reliable methods.

- **Producing maps using Landsat 8**

The image utilized for the study area was a cloud-free Landsat 8 OLL captured on December 30, 2023. It is a Level 2 product obtained from the USGS website. Geometric and atmospheric corrections, as well as calculations for brightness temperature and radiant power, were performed in the ENVI software environment for the specified limited cut area.

Landsat 8 OLI	Wavelength (um)	Spatial resolution (m)
Band 1 - Coastal aerosol	0.43 – 0.45	30
Band 2 - Blue	0.45 – 0.51	30
Band 3 - Green	0.53 – 0.59	30
Band 4 - Red	0.64 – 0.67	30
Band 5 - Near infrared	0.85 – 0.88	30
Band 6 - Shortwave infrared 1	1.57 – 1.65	30
Band 7 - Shortwave infrared 2	2.11 – 2.29	30
Band 8 - Panchromatic	0.50 – 0.68	15
Band 9 - Cirrus	1.36 – 1.38	30
Band 10 - Thermal infrared 1	10.60 – 11.19	100
Band 11 - Thermal infrared 2	11.50 – 12.51	100

Table 6: Multispectral bands Landsat 8 OLI and TIRS Bands (μm)

• Calculation of Heat Islands

Heat islands and land surface temperature (LST) reflect changes in the Earth's surface and are essential for studying and understanding global climate change. LST is a crucial indicator of the energy balance on the land surface and is one of the most significant physical parameters for land surface processes at both regional and global scales (Khandelwal et al., 2018). It also governs the coupling of water and energy between the land and atmosphere (Thakur and Gosavi, 2018). Estimating Earth's surface temperature is vital in climate, ecological, and hydrological cycle studies (Wang et al., 2019), as well as in analyzing land use/cover changes, soil moisture, plant water stress (Thakur and Gosavi, 2018), the effects of urbanization, drought monitoring and assessment, and irrigation projects (Nikam et al., 2016). The Planck's function method was employed to create the Earth surface temperature map, calculated using the following formula.

$$LST = \frac{BT}{(1 + W\left(\frac{BT}{\rho}\right)Lne}$$

In this regard, LST is the temperature of the earth's surface, BT is the brightness temperature, W is the wavelength of the thermal band and is equal to 11.5 micrometers and ρ is equal to $1/438\times^{-}10^{2}$ millikelvin and e is the emissivity value (Rongali et al., 2018).

- **Brightness Temperature in Landsat**

Brightness temperature is a measure used in remote sensing to quantify the thermal radiation emitted by the Earth's surface, as observed by satellite sensors, particularly in the thermal infrared spectrum. In the context of the Landsat satellites, brightness temperature is derived from the thermal infrared bands, specifically bands 10 and 11 on Landsat 8.

- **Radiance Conversion**

The digital numbers (DN) recorded by the Landsat sensor are first converted to spectral radiance (Lλ). This conversion uses the radiometric calibration coefficients provided in the Landsat metadata (Quinn et al., 2001).

$$L_{\lambda} = M_L Q_{cal} + A_L$$

In this regard L_{λ} *is the spectral radiation of the upper atmosphere,* Q_{cal} *is the digital value of the pixel, and* M_L *is the multiplicative conversion factor and* A_L *is the aggregating conversion factor and is equal to E3420-04.3 and 0.1, respectively (Wang et al., 2019).*

- **Brightness Temperature Calculation**:

The spectral radiance is then converted to brightness temperature (TB) using the inverse of Planck’s law. This formula relates the radiance emitted by a black body to its temperature.

$$TB = K2 / Ln(k1/L_{\lambda} + 1)$$

In this regard, TB is the brightness temperature in Kelvin, k_1 and k_2 are constant calibration coefficients for band 10 equal to 774.89 and 1321.08 respectively and band 11 equal to 480.89 and 1201.14 respectively, which is extracted from the metadata of the image.

K2	K1	Calibration factor
1321/0789	774/8853	Band 10
1201/1442	480/8883	Band 11

Table 7: Illumination temperature calibration coefficients for Landsat 9, source: Landsat 8 metadata

- **NDVI vegetation index and emissivity calculation**

Objects with a temperature higher than absolute zero emit electromagnetic radiation, which is called radiant flux. In a black body, all the heat is absorbed and diffused, and the ratio between the emission from an object and the emission from a black body at a constant temperature is called emissivity. The emissivity value is needed to convert the brightness temperature to the surface kinetic temperature (Ahmadi et al., 2015).

Relationship below, NDVImin and NDVImax are the lowest and highest NDVI respectively. In this method, NDVI thresholding is used, the pixel corresponds to dry soil with a thermal emissivity of 0.97 for Landsat. If NDVI is greater than 0.5, the pixels with NDVI value greater than 0.5 show the highest density of vegetation and their emissivity constant value is estimated at 0.99. If NDVI is between 0.2 and 0.5, the pixel is a combination of different phenomena and can be calculated from the following relationship (Rongali et al., 2018).

$$P_V = (NDVI-NDVI_{min})/(NDVI_{max}- NDVI_{min})^2$$

Emissivity is calculated based on the vegetation index and the following relationship

$$e = 0.004p_v + 0.986$$

After obtaining the required parameters, the ground surface temperature was calculated and then the following equation was used to convert the ground surface temperature map unit from degrees Kelvin to degrees Celsius.

$$\mathrm{LST(C)} = (\mathrm{LST(k)} - 273 \cdot 15)$$

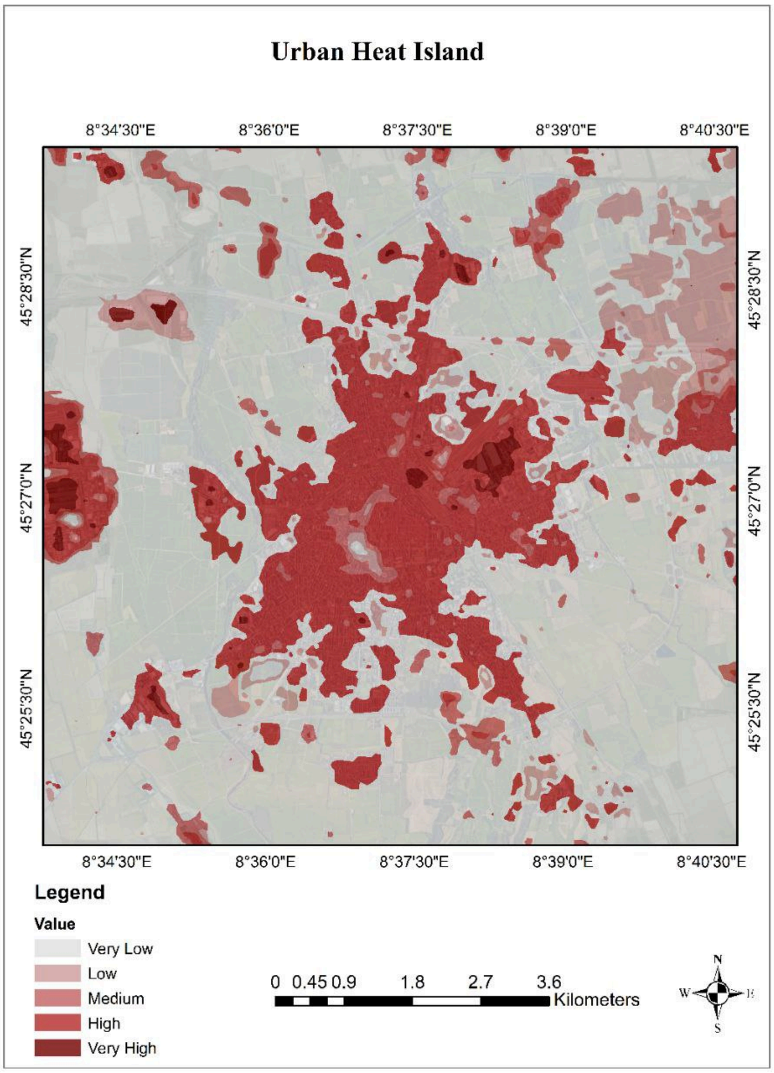


Figure 33: Urban Heat Island of Novara, made by author

- **HEC-RAS Model**

The HEC-RAS software, developed by the American Army Engineering Society, is a suite of tools designed for conducting river hydraulic calculations in both steady and unsteady flow conditions. The HEC-RAS system comprises three one-dimensional hydraulic analysis components: water level profile calculations in steady flow, unsteady flow simulations, and sediment transport calculations with moving boundaries. These components share a common geometric data display and use the same geometric and hydraulic calculation processes (Yamani, 2012).

- **HEC-GEO-RAS extension**

The HEC-GEO-RAS extension is a set of tools designed for use within the GIS software. It establishes a connection between ArcGIS and HEC-RAS software, facilitating the processing of spatial data for RAS modelling and the analysis of RAS results within a GIS framework. By processing terrain and other GIS data in ArcGIS with GEO-RAS, users can create and export geometry files for RAS analysis. To perform hydraulic calculations with the HEC-RAS model, cross-sections must be defined. This involves extracting the desired TIN map layer in the ArcMap software environment. Once the TIN layer is formed, various layers such as the flow centreline, river sidelines, flow limits, and cross-sections are drawn. After processing these layers in ArcMap, they are ready for extraction and use in the HEC-RAS hydraulic model. The HEC-RAS model can then calculate water level profiles for gradually varied steady flow in rivers and artificial channels under subcritical, supercritical, and mixed flow regimes.

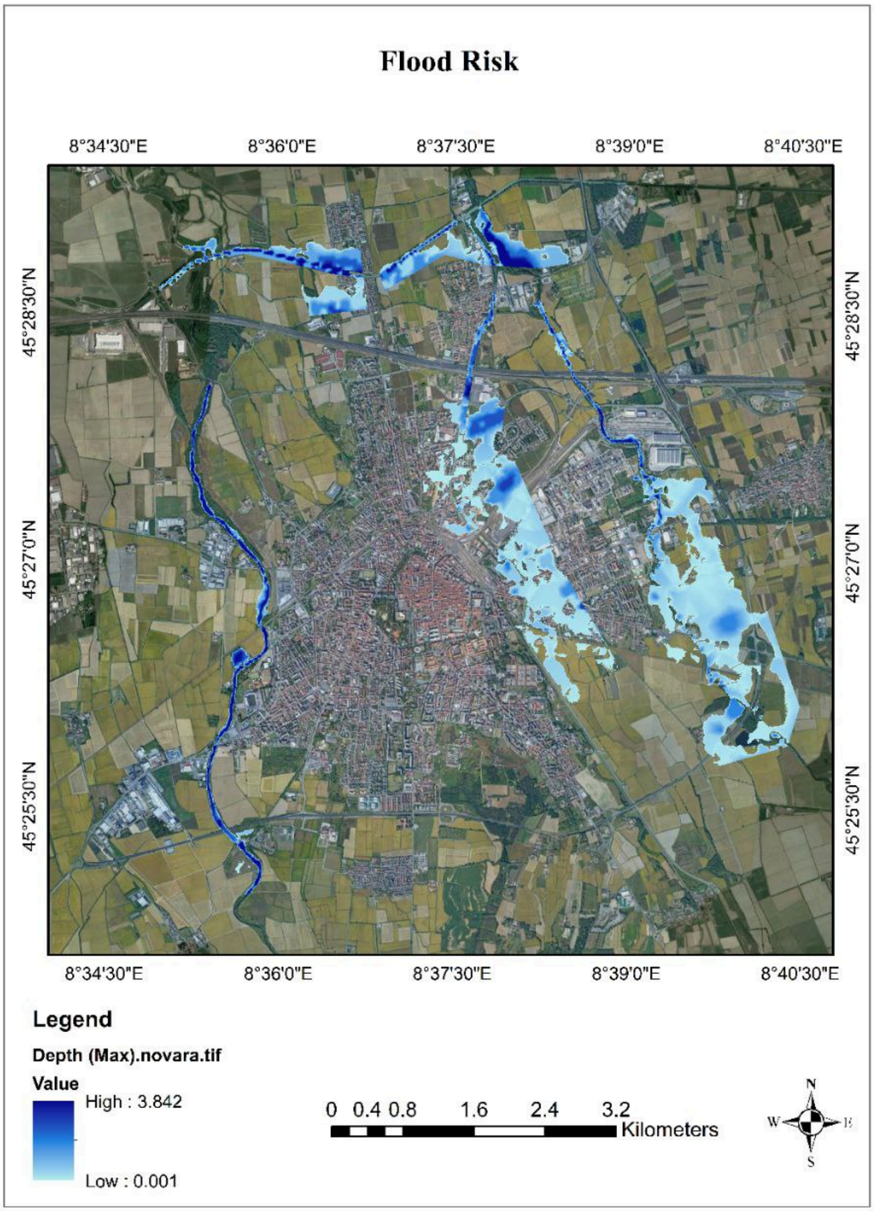


Figure 34: Flood Risk of Novara, made by author

5.6 Reliability and validity

In this research, Google Earth and GIS software were employed to create a digital elevation model with a 10-meter accuracy. The input data from the HEC-RAS model was then organized and formatted for flood zoning, simulating the river's hydraulic behaviour, and developing management scenarios.

This chapter details the methodologies used for data collection, including the case study locations, research design, sample size, data collection techniques, and data management, all conducted in Novara, Italy. The primary tools utilized were document and policy analysis, and data collection for producing Urban Heat Island (UHI) and flood risk maps.

Document and policy analysis were systematically carried out through an extensive review of printed and digital documents. This method, supported by established literature (Corbin & Strauss, 2008; Rapley, 2007), ensures a rigorous evaluation and interpretation of data to develop empirical knowledge. The analysis of European and Italian climate change plans provides a comprehensive framework, enhancing reliability.

Green Infrastructure (GI) strategies were explored through various examples across Europe, offering a diverse understanding of their implementation and impact. This chapter emphasizes the importance of integrating GI into policy and planning processes, in line with sustainable development principles (Purvis et al., 2018).

Desk research involved reviewing secondary data, a reliable method for accessing published information (Jackson, 1994). This approach was used to collect substantial data on best practices and challenges in implementing GI in Novara.

The production of UHI and flood risk maps involved developing indices for flood and heat potential using accessible geospatial data and recognized methods. The use of Landsat 8 satellite images and HEC-RAS software ensures the accuracy and reliability of the maps produced.

In summary, the methodologies described in this chapter are based on established scientific practices, ensuring the reliability and validity of the research findings.

6. Results and discussion

6.1 Introduction

Natural landscapes have been dramatically changed by urbanization, posing environmental problems like the Urban Heat Island (UHI) effect and higher flood risks. The integration of natural and semi-natural spaces into urban environments is known as Green Infrastructure (GI), and it presents a promising solution to these problems. This chapter examines the information obtained from Novara, Italy's UHI and flood risk maps in order to evaluate how well GI works to mitigate the effects of climate change. We may obtain a better understanding of the geographic distribution of heat islands, flood-prone areas, and the potential contribution of GI to the improvement of urban resilience by examining these maps.

6.2 Insights from Desk Research

This thesis's desk research provides deep insights into the complex role that green infrastructure (GI) plays in urban environments, especially in reducing the effects of climate change. This thorough analysis of previous research, guidelines, and case studies offered a solid framework for comprehending the theoretical and practical applications of GI. Through the analysis of Italian and European frameworks, the study brought attention to the noteworthy advancements in the incorporation of GI into urban planning and policy formulation. The strategic significance of GI in augmenting ecosystem services, biodiversity, and urban resilience was demonstrated by the examination of documents such as the EU Green Infrastructure Strategy and different regional ecological networks. The desk research demonstrated how GI promotes socioeconomic development in addition to being an instrument for environmental management, providing advantages like better public health, recreational areas, and air and water quality.

- **Integration into Urban Planning**

The successful integration of GI into urban planning frameworks across different European cities is one of the main takeaways from the desk research. For instance, the EU Green Infrastructure Strategy highlights how important it is to link natural and semi-natural areas in order to enhance biodiversity and ecosystem services. By using this strategic approach, GI is made to be a fundamental component of urban development rather than just an afterthought. According to the research, Italy's Lombardy and Piedmont regions have created detailed plans to integrate GI into urban and regional planning, realizing its potential to reduce the effects of climate change and improve urban resilience.

- **Ecosystem Services and Biodiversity**

The desk research made clear how important GI is to the provision of ecosystem services, which are vital to the sustainability of urban areas. Parks, urban forests, and green roofs are examples of green spaces that help with climate regulation, carbon sequestration, and the purification of the air and water. Another important factor is the increase of biodiversity through GI, which fosters ecological balance in urban environments by providing habitats for a variety of species. The study demonstrated how GI networks have allowed cities like Copenhagen and Berlin to successfully increase their biodiversity, leading to healthier urban ecosystems.

- **Socio-Economic Development**

The study emphasized that GI has socioeconomic advantages that go beyond its effects on the environment. For example, better air and water quality directly benefits public health by lowering the prevalence of respiratory and waterborne illnesses. GI-provided recreational areas improve both physical and mental health while promoting a feeling of community and overall wellbeing among city dwellers. The desk research also emphasized the economic opportunities brought about by GI, including the creation of jobs in the environmental management, landscaping, and maintenance sectors. These are opportunities that are essential to fostering urban areas' economic resilience.

- **Challenges and Opportunities**

The integration of earlier research and publications provides insight into the opportunities and problems related to the deployment of GI. For example, the analysis of successful case studies from cities like London and Barcelona showed the concrete advantages of green infrastructure (GI), like decreased urban heat island effects and efficient flood control. These benefits are especially important for cities like Novara that are under similar urbanization and climate pressures. Notwithstanding, certain obstacles were also noted, including financial limitations, conflicts arising from land use, and the requirement for multidisciplinary cooperation. The study underlined how critical it is to address these issues by involving stakeholders and implementing creative policy solutions.

- **Holistic Urban Planning**

The study made clear how important it is to use a comprehensive approach to urban planning that combines GI with conventional grey infrastructure to build resilient and multipurpose urban environments. This strategy is crucial for addressing the shortcomings of traditional infrastructure and optimizing the advantages of GI. The desk research demonstrated how integrated planning techniques, which combine grey infrastructure and GI to improve urban resilience and sustainability, have been adopted by cities like Singapore and New York.

- **Community Engagement and Stakeholder Collaboration**

The results underlined how crucial stakeholder cooperation and community involvement are to the effective implementation of GI projects. The study demonstrated that the sustainability of GI initiatives depends on societal acceptance. Urban residents' needs and preferences are met, and a sense of ownership is fostered when local communities are involved in the planning, execution, and upkeep of GI projects. Examples of community-led GI initiatives that have produced more widely accepted and sustainable outcomes in cities like Toronto and Melbourne were provided by the desk research.

- **Innovative Nature-Based Solutions**

The desk research also revealed the creative use of natural resources by cities in addressing climate-related issues. It has been demonstrated that these approaches, which imitate natural processes to control temperature, water, and pollution, are more affordable and environmentally friendly than traditional infrastructure. The analysis of strategies and policies at different levels of governance shed light on the financial and regulatory frameworks supporting global integration (GI), emphasizing the function of public-private partnerships and government incentives in promoting GI growth.

- **Urban Vegetation and Climate Mitigation**

The study also emphasized how important urban vegetation is for reducing the effects of climate change. In-depth examinations of vegetation indices and their relationship to city temperatures confirmed that green spaces have a cooling effect, which is essential for preventing the urban heat island effect. In addition, the review pointed out areas lacking in current GI practices and suggested directions for further investigation, including the need for long-term studies to evaluate the long-term efficacy of GI interventions and the investigation of novel technologies to improve GI performance.

- **Policy Implications**

The results of the desk research have important policy implications. The results support the inclusion of GI in municipal and national urban development strategies. This entails the establishment of legal frameworks requiring GI to be included in newly developed urban areas, financial incentives for private developers to do so, and public awareness campaigns highlighting the advantages of GI. In order to evaluate the effectiveness and long-term effects of GI projects, the research also recommends the creation of monitoring and evaluation systems.

To sum up, the desk research portion of this thesis provided thorough understandings of the principles, applications, and policy consequences of green infrastructure. It outlined the many advantages of GI in urban environments, offered a critical assessment of current methods, and offered suggestions for how to incorporate GI into plans for sustainable urban development. In addition to providing guidance for the empirical analyses carried out in the Novara case study, this foundational research added to the larger conversation about urban resilience and climate change adaptation. Policymakers, urban planners, and stakeholders can enhance the sustainability and resilience of cities globally by creating more effective strategies to integrate GI into urban environments by utilizing the insights obtained from desk research.

6.3 Insights on UHI and Flood Risks of Novara

This thesis's thorough examination of Novara's flood risks and Urban Heat Island (UHI) reveals important insights into the substantial effects of urbanization on the region's hydrology and climate. It also emphasizes the urgent need for strategic urban planning that incorporates Green Infrastructure (GI). The sharp temperature differences between heavily populated urban centers and greener, periphery areas are clearly depicted in the UHI maps. This spatial analysis demonstrates how green spaces are effective at reducing the urban heat island effect by demonstrating that areas with higher densities of vegetation have noticeably colder temperatures. In particular, the data shows that the cooling effects of urban greenery are exemplified by the fact that areas with parks and dense tree canopies have temperatures up to 8°C lower than highly urbanized zones. This realization highlights how crucial it is to increase the number of urban forests, green roofs, and other vegetative features in order to decrease heat retention in cities such as Novara. This will improve thermal comfort, lower the amount of energy needed for cooling, and enhance public health.

A major problem in many cities, including Novara, is the UHI effect, which is the phenomenon where urban areas experience higher temperatures than their rural counterparts. This thesis's analysis of temperature data and satellite imagery has shown that the city's industrial zones and central business district, which are dominated by concrete, asphalt, and other heat-absorbing materials, are where the most severe UHI effects are found. These places experience hotter daytime temperatures as well as longer nighttime heat retention, which exacerbates thermal discomfort and raises the need for air conditioning. On the other hand, temperatures are much lower in suburban areas and neighborhoods with lots of greenery and trees. The ability of targeted GI interventions to produce colder microclimates within urban areas is highlighted by this spatial differentiation.

Furthermore, GI has a cooling effect that goes beyond just lowering the temperature. By filtering pollutants from the air, green spaces can improve air quality and make urban environments more livable overall. By releasing oxygen into the atmosphere and absorbing carbon dioxide, trees and other vegetation serve as natural air purifiers, promoting healthier urban environments.

Furthermore, urban surfaces can be shielded from direct solar radiation by trees' shade, which helps to further reduce the heat island effect.

Concurrently, the flood risk maps offer an intricate representation of the city's susceptibility to flooding, specifically in areas with low elevation and those in close proximity to water features like rivers and canals. The risk of flooding during extreme weather events has increased due to urban expansion into floodplains, according to hydrological models, which are backed by data from the Digital Elevation Model (DEM) and HEC-RAS simulations. According to the analysis, by absorbing and slowing down stormwater runoff, areas with permeable surfaces—such as parks and wetlands—significantly reduce the risk of flooding. This result emphasizes how important GI is to improving urban flood resilience. By reducing peak runoff volumes and delaying peak flows, GI solutions like rain gardens, bioswales, and constructed wetlands effectively lessen the likelihood and severity of urban flooding.

Due to considerable urban sprawl into previously undeveloped floodplains, Novara's industrial and recently constructed residential areas are especially vulnerable to flooding. The HEC-RAS models utilized in this thesis highlight critical zones that are most vulnerable to flooding and offer a clear visualization of possible flood scenarios. The results suggest that the amount of stormwater generated during heavy rainfall events cannot be handled by conventional grey infrastructure, such as storm sewers and concrete channels. On the other hand, GI solutions like green roofs and permeable pavements can significantly improve the city's ability to manage stormwater sustainably. By enhancing evapotranspiration and natural water infiltration, these GI interventions lessen surface runoff and lower the risk of flooding.

Moreover, the thesis incorporates these regional perspectives from Novara with more general talks about the global effects of urbanization and climate change. It demonstrates how urban areas around the world are dealing with comparable problems and how GI provides a long-term solution. The amalgamation of case studies from cities that have effectively incorporated green infrastructure (GI) into their urban planning frameworks, such as Barcelona and London, offers useful illustrations of how Novara can improve its climate resilience. These cities have shown that the implementation of strategic green infrastructure (GI) can reduce urban heat island effect (UII) and flood hazards while also yielding a number of co-benefits, such as better air and water quality, increased biodiversity, and more social and economic opportunities.

The widespread application of green infrastructure (GI) in Barcelona, including the establishment of green roofs on public buildings and green corridors, has greatly enhanced stormwater management and decreased the urban heat island effect. In a similar vein, flood risks have been reduced and urban biodiversity and recreational areas have been improved by London's sustainable drainage systems (SuDS) and urban greening initiatives. These global examples are helpful role models for Novara, showing the real advantages of GI and offering a path forward for its efficient application.

Overall, the thesis makes a strong case for the need of using GI in urban planning as a comprehensive strategy to address flood risks and UHI in Novara and other places. It necessitates an all-encompassing, integrative planning approach that blends GI with conventional grey infrastructure, backed by strong regulatory frameworks, community involvement, and ongoing observation and adjustment. With climate change and rapid urbanization, the knowledge gained from this research offers stakeholders, policymakers, and urban planners a useful road map for building more resilient, sustainable, and livable cities.

The suggestions include encouraging public-private partnerships to fund GI projects, putting policies in place that incentivize the adoption of GI, and giving priority to the development of green spaces in high-risk areas. The thesis also supports the use of cutting-edge technologies and GIS tools to track the efficacy of GI interventions over time and modify plans of action as needed. Cities like Novara can improve the overall quality of urban life for their residents while simultaneously mitigating the negative effects of climate change by incorporating these insights into their urban planning practices.

6.4 Assessing Green Infrastructure and Climate Change

Evaluating Green Infrastructure's (GI) ability to lessen climate change's effects is essential to creating sustainable urban settings. This thesis offers a thorough assessment of the ways in which GI can help address the problems brought about by climate change, particularly in terms of reducing the impact of the Urban Heat Island (UHI) and managing the risks associated with flooding in cities such as Novara. Through the integration of a comprehensive literature review, policy analysis, and case study evaluations, the study underscores the diverse advantages of green infrastructure (GI), encompassing not only environmental benefits but also socio-economic and health enhancements. The thesis emphasizes how green infrastructure (GI)—such as permeable pavements, green roofs, and urban forests—is essential for controlling urban temperatures. According to Novara data, regions with a high concentration of vegetation have considerably cooler temperatures than their counterparts with a high concentration of concrete. This results in a decrease in the energy required for cooling and a subsequent reduction in greenhouse gas emissions. Furthermore, by filtering pollutants, the incorporation of green infrastructure (GI) into urban planning not only improves air quality but also lessens the urban heat island effect, thereby improving the quality of life for city dwellers.

Moreover, the evaluation of flood hazards using flood risk maps and hydrological models shows that GI is more capable of managing stormwater than conventional grey infrastructure. By facilitating natural water infiltration and lowering surface runoff, GI solutions like rain gardens, bioswales, and artificial wetlands lessen the severity of floods. This is especially important in light of the prediction that climate change will increase the frequency and severity of extreme weather events. According to the research, strategically placing green infrastructure (GI) in flood-prone areas can greatly increase urban resilience by lowering peak runoff volumes and delaying peak flows, shielding urban areas from flooding and the damages that come with it. The thesis also highlights how crucial it is to use a comprehensive, integrative planning strategy that integrates grey infrastructure and GI in order to optimize the advantages of both systems. Through an examination of effective models in cities like Barcelona and London, the study offers useful guidance on how Novara can apply comparable tactics to strengthen its climate resilience.

The research has wider ramifications that include community involvement and policy development. The thesis promotes, with the help of financial incentives and public-private partnerships, the incorporation of GI into urban development policies and regulatory frameworks. It is emphasized that involving local communities in GI projects is essential to guaranteeing sustainability and encouraging a sense of ownership among locals. Participating communities in the design and upkeep of green spaces allows cities to tailor these initiatives to local requirements and preferences, increasing their acceptability and efficacy. The thorough evaluation of green infrastructure (GI) in relation to climate change that is provided in this thesis offers policymakers, stakeholders, and urban planners a useful road map by demonstrating the crucial role that GI plays in developing resilient, sustainable, and livable urban environments in the face of persistent climate challenges.

The thesis explores in greater detail the socio-economic advantages of GI, which conventional urban planning frequently ignores. In addition to adding aesthetic value, creating green spaces also raises property values, draws in businesses, and encourages travel. Urban areas may benefit greatly from this economic boost, which can set up a positive feedback loop whereby increased investment in GI is bolstered by economic growth. In addition, there are significant advantages to both physical and mental health that come from green spaces. It has been demonstrated that having access to parks and natural areas lowers stress, enhances mental health, and promotes physical activity—all of which led to a healthier population and less expensive healthcare.

The research highlights the necessity of strong frameworks that facilitate the integration of GI into urban landscapes from a policy standpoint. This entails establishing maintenance funds to guarantee the longevity of GI projects, updating zoning laws to prioritize green space, and offering incentives to developers to incorporate GI into new projects. The thesis also emphasizes how crucial it is for environmental scientists, community organizations, policymakers, and urban planners to collaborate across disciplinary boundaries. This kind of cooperation guarantees the scientific soundness, economic viability, and social equity of GI projects.

Cities such as Barcelona and London offer Novara and other similar urban areas a model to follow. Large-scale green corridor construction in Barcelona has connected disparate habitats and lessened the effects of urban heat island syndrome, all of which have increased biodiversity in the city. Sustainable drainage systems, or SuDS, have been used successfully in London to manage stormwater, lowering the risk of flooding and improving the urban environment. These case studies demonstrate how multiple urban challenges can be addressed simultaneously by strategic, well-planned GI.

Furthermore, the study recommends that GI projects be managed adaptably and with continual observation. The challenge of climate change is dynamic and ever-changing, and in order to make sure that GI continues to meet present and future needs, its efficacy needs to be continuously evaluated. This calls for the monitoring of GI performance and the required adjusting of strategies through the use of cutting-edge technologies like remote sensing, GIS mapping, and predictive modeling. Cities can guarantee that their GI strategies continue to work in the face of shifting climatic conditions by implementing a flexible and adaptable approach.

To sum up, this thesis offers a thorough and in-depth analysis of how green infrastructure, especially in urban areas like Novara, can help mitigate the effects of climate change. The knowledge gathered from this study emphasizes how crucial GI is to building livable, sustainable, and resilient cities. Cities can effectively address the dual challenges of UHI and flood risks while reaping numerous socio-economic and health benefits by incorporating GI into urban planning, utilizing holistic and interdisciplinary approaches, and involving local communities. This study offers a clear and practical guide for using GI to create a sustainable urban future, making it an invaluable tool for stakeholders, legislators, and urban planners.

The provided Sankey diagram effectively illustrates the contributions of Green Infrastructure (GI) and Nature-Based Solutions (NBS) to various environmental benefits, focusing on their impacts on climate change mitigation, urban heat island reduction, and flood risk reduction. Here is a detailed analysis of the diagram:

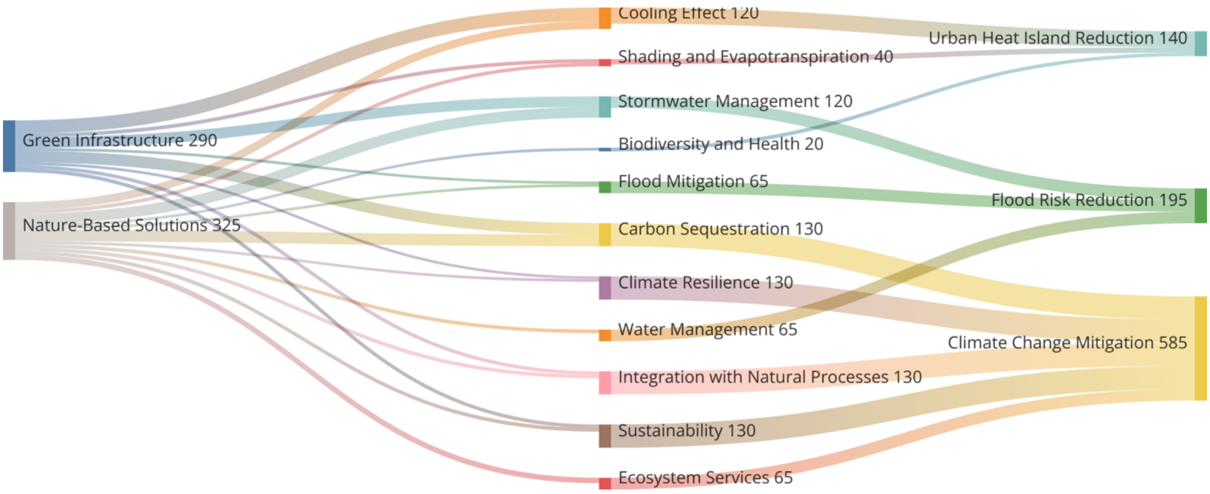


Figure 35: Interlinkages between GI and Nature-based solutions

Key Components

1. Green Infrastructure (GI): Strategies that include urban forests, green roofs, parks, and other green spaces.

2. Nature-Based Solutions (NBS): Approaches that leverage natural processes to address environmental challenges.

3. Environmental Effects: The resulting benefits of implementing GI and NBS.

The many ways that nature-based solutions and green infrastructure contribute to urban environmental sustainability are illustrated in this comprehensive Sankey diagram. It draws attention to the interrelated advantages by demonstrating how GI and NBS cooperate to manage flood risks, lessen urban heat islands, and mitigate climate change. The diagram is an effective visual aid for comprehending the many benefits of incorporating these tactics into urban development and planning.

7. Conclusion

7.1 Introduction

The present thesis offers a thorough assessment of the function of Green Infrastructure (GI) in reducing the effects of climate change, with a particular emphasis on the Urban Heat Island (UHI) phenomenon and flood hazards in urban regions such as Novara, Italy. Several important insights were discovered after a thorough analysis that included case studies, policy analysis, empirical data, and literature review. The study highlighted the many advantages of GI, which go well beyond its positive effects on the environment and include major improvements to socioeconomic status and health.

According to the Novara data, places with a lot of vegetation had much cooler temperatures than highly urbanized areas. This cooling effect is essential for lowering cooling energy consumption, which in turn lowers greenhouse gas emissions and the UHI phenomenon. Additionally, by filtering pollutants, the incorporation of GI into urban planning improves air quality and makes urban residents' lives healthier.

The evaluation of flood risks using flood risk maps and hydrological models showed that GI solutions are a more efficient way to manage stormwater than conventional grey infrastructure. By reducing peak runoff volumes and delaying peak flows, GI solutions like rain gardens, bioswales, and constructed wetlands help to lessen the severity of floods. Given that climate change is predicted to increase the frequency and severity of extreme weather events, this capability is especially important.

7.2 Contribution to policy making: what can Novara do

The study made clear how important it is to have strong legislative frameworks that facilitate GI's integration into urban environments. This entails establishing maintenance funds to guarantee the longevity of GI projects, updating zoning laws to prioritize green space, and offering incentives to developers to incorporate GI into new projects. The effective applications in cities like London and Barcelona offer useful information about how Novara can use comparable tactics to strengthen its climate resilience.

- **Policy Implications for Novara**

Given the findings of this thesis, several policy recommendations can be made for Novara to enhance its urban resilience through Green Infrastructure:

- **Incentivize Green Infrastructure Development**
- Financial Incentives

Novara should provide grants, tax breaks, or other financial incentives to developers and property owners who use GI in their projects. Urban forests, permeable pavement, green roofs, and other sustainable practices are examples of this.

- Public-Private Partnerships

Promote joint ventures between governmental and private entities to finance and sustain GI initiatives. By combining resources and knowledge from both industries, these alliances can increase the viability and sustainability of GI initiatives.

- **Integrate GI into Urban Planning**
- Revised Zoning Laws

Revise the zoning ordinance to require new developments to include a specific amount of green space. This can guarantee that, rather than being an afterthought, GI is an essential part of urban growth.

- Master Plans

Create and carry out thorough urban master plans that give GI top priority. Urban development should be in line with sustainability objectives by following these plans, which should include precise deadlines and targets for GI implementation.

- **Establish Maintenance Funds**
- Dedicated Funds

To guarantee the durability and efficacy of GI projects, set aside money specifically for maintenance. Green spaces require ongoing maintenance to function well, and dedicated funding can keep these initiatives from deteriorating over time.

- **Promote Community Engagement**
- Public Awareness Campaigns

Start campaigns to inform locals of the advantages of GI and the ways in which they can support the upkeep and expansion of green spaces. Public awareness raising has the potential to encourage community support and involvement in GI initiatives.

- Community Involvement

Include the community in the design and execution of GI initiatives. Volunteer maintenance programs, community gardens, and neighborhood tree-planting campaigns can increase community ownership and guarantee that GI projects address local needs.

- **Foster Interdisciplinary Collaboration**
- Cross-Sector Collaboration

Promote cooperation between community organizations, legislators, environmental scientists, and urban planners. Multidisciplinary methods can guarantee the scientific soundness, economic viability, and social equity of GI projects.

- Knowledge Sharing

Encourage cities to share best practices and information with one another. By customizing their approaches to the unique circumstances of Novara, other cities that have adopted GI can teach us about their triumphs and setbacks.

- **Implement Monitoring and Evaluation Systems**
- Advanced Technologies

Make use of cutting-edge tools like predictive modeling, GIS mapping, and remote sensing to continuously track the effectiveness of GI projects. This data-driven strategy can assist in pinpointing areas in need of development and guarantee that GI tactics continue to be successful.

- Adaptive Management

Adopt an adaptive management strategy that enables GI strategies to be continuously improved based on monitoring outcomes. Novara's adaptability can aid in addressing evolving issues and shifting weather patterns.

To sum up this thesis has given Novara's stakeholders, legislators, and urban planners a useful road map by demonstrating the vital role that green infrastructure plays in developing resilient, sustainable, and livable urban environments. Novara can effectively address the dual challenges of UHI and flood risks while reaping numerous socio-economic and health benefits by incorporating GI into urban planning, adopting holistic and interdisciplinary approaches, and involving local communities. In light of the ongoing climate challenges, the research's conclusions and recommendations provide a framework for utilizing GI to construct a sustainable urban future. Novara can set an example for urban sustainability and resilience through proactive policy making and community involvement, highlighting the revolutionary potential of green infrastructure in the fight against climate change.

7.3 Limitations of the Thesis and Future Research Prospects

Limitations of the Thesis

While this thesis provides comprehensive insights into the role of Green Infrastructure (GI) in mitigating climate change impacts in urban environments, it is essential to acknowledge certain limitations:

1. **Data Limitations**

- Temporal and Spatial Resolution

Satellite imagery and data, which might not have captured all temporal variations or the smallest spatial details, were used in the analysis. The inadequacy of the seasonal variations and short-term weather accounting may have an impact on the accuracy of the flood risk and Urban Heat Island (UHI) assessments.

- Data Availability

Certain datasets were scarce or difficult to obtain, in particular high-resolution local climate data and detailed hydrological data. The depth and accuracy of the UHI analysis and flood risk modeling may have been impacted by this restriction.

2. Methodological Constraints

- Model Assumptions

Certain assumptions made by the algorithms for analyzing UHI effects and the hydrological models (like HEC-RAS) used for flood risk assessment may not always hold true. The results may become uncertain as a result of these assumptions.

- Simplification of Complex Systems

Urban system integration of GI is intrinsically complicated. Despite being thorough, this study may have missed some complex dynamics because it had to simplify some interactions and feedback mechanisms in order to make the modeling work.

3. Geographical Specificity

- Focus on Novara

The results are unique to Novara, Italy, and although they provide insightful information, it's possible that they won't apply as well to other cities with dissimilar climatic, geographic, and socioeconomic circumstances. The results' generalizability is limited by Novara's particular qualities.

4. Limited Scope of Socio-Economic Analysis

- Broad Socio-Economic Impacts

Although socio-economic benefits are mentioned in passing in the thesis, a more thorough examination of the economic valuation of GI and its long-term socio-economic effects was outside the purview of this investigation. To fully quantify these benefits, more research is required.

Future Research Prospects

Despite these limitations, the thesis opens several avenues for future research that can build on its findings:

1. Longitudinal Studies

- Long-Term Impact Assessment

Longitudinal studies that track the long-term effects of GI on UHI mitigation, flood risk reduction, and overall urban resilience should be the focus of future research. These kinds of studies can offer more conclusive proof of the long-term advantages of GI.

2. Enhanced Data Collection and Modeling

- High-Resolution Data

Acquiring temporal and spatial data with higher resolution can enhance the precision of flood risk and UHI models. Local climate monitoring stations and cutting-edge remote sensing technologies can improve the quality of the data.

- Integrated Modeling Approaches

A comprehensive understanding of the effects of GI may be achieved by creating more integrated modeling techniques that incorporate hydrological, climatological, and socioeconomic factors. Artificial intelligence and machine learning can be used to improve model predictions.

3. Comparative Studies

- Cross-City Comparisons

Finding best practices and flexible GI strategies can be aided by conducting comparative studies across various cities with diverse climates, geographies, and urban structures. The results of this comparative approach may be more broadly applicable.

- Policy and Governance Models

Analyzing various governance models and policy frameworks supporting the implementation of GI can provide valuable insights into the best practices for advancing urban sustainability.

4. Economic Valuation of GI

- Cost-Benefit Analysis

In-depth cost-benefit analyses should be a part of future research to measure the financial advantages of GI, such as lower healthcare costs, higher property values, and energy savings. These studies can offer strong justifications for legislators to fund GI.

- Funding Mechanisms

Examining novel funding options like ecosystem service markets and green bonds can offer workable answers for GI project funding.

5. Community Engagement and Social Equity

- Participatory Approaches

Examining participatory strategies for GI planning and execution can show how community involvement can improve the sustainability and success of projects. Benefit distribution can be guaranteed if social dynamics and equity implications of GI are understood.

- Behavioral Studies

Researching how green spaces affect community health and well-being and other behavioral effects of GI can shed light on the human aspects of urban sustainability.

6. Technological Innovations

- Smart GI Solutions

Future studies could investigate how smart technologies, like Internet of Things-enabled sensors for in-the-moment environmental condition monitoring, can be integrated with GI. These developments can improve GI systems' upkeep and performance.

- New Materials and Techniques

Examining novel building materials and methods for green infrastructure (GI), like modular green walls and sophisticated bio-composites, can improve the scalability and efficacy of GI solutions.

7.4 Conclusion

A strong foundation for comprehending the function of green infrastructure in reducing the effects of climate change in urban settings has been established by this thesis. The study recognizes its limitations but also points out important avenues for future research to build on these conclusions. Scholars and practitioners can further advance the field of urban sustainability and ensure that cities like Novara can thrive in the face of climate change by addressing the limitations that have been outlined and pursuing the suggested research directions.

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