LUISS

Department of Law
Master of Science in Law, Digital Innovationand Sustainability

Course of Earth Science, Sustainable Development and Climate Change impacts

Nature-based Solutions: an empirical analysis of public health and well-being impacts in the Mediterranean region

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Academic year 2022/2023

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Introduction

1.1 Climate change and urban heat islands: how are they impacting our health?

"Climate change is the single biggest health threat facing humanity". This is how climate change is described in the World Health Organisation's 2021 report, which calls on governments and politicians to “act urgently” on the climate and health crisis, before it is too late[1,2,3].

According to the IPCC[4], the dominant cause of observed warming since the mid-20th century is human influence in the form of greenhouse gas emissions. This is changing the environment in which we live, while damaging the health of the planet's inhabitants through air pollution, disease, extreme weather events, forced displacement, food insecurity and mental health pressures. According to the WHO, the consequences of climate change take the lives of some 13 million people each year[5].

Cities are major contributors to CO_2 emissions. Between 60 and 80 percent of the energy produced worldwide is used by cities, which also produce nearly an equivalent amount of CO_2 emissions. However, they are also the most vulnerable to climate change risks[6,7,8]. For instance, heat waves are more strongly felt in urbanised areas due to urban heat island effects (UHI). This occurs because urban areas characterised by high vertical densities correspond to textiles structured on a very dense street network, composed of a building typology with a high vertical development in proportion to the footprint on the ground; this conformation optimises the capture and trapping of solar radiation, favouring the storage of heat during the day and leading to higher temperatures during the night, when the heat is slowly released towards the sky. The average annual temperature difference between urban and rural areas ranges from 3.5 to 4.5 °C and is expected to increase by 1 °C per decade.

In this way, urban populations are scientifically even more at risk from global warming and rising temperatures. This is even more alarming when one considers that, according to future climate change scenarios, scientists predict that extreme heat waves will become more frequent and severe[9]. UHIs have a negative impact on society, especially on community health, causing heat-related deaths and illnesses such as

[1]World Health Organization. (2021) 2021 WHO health and climate change global survey report. (https://www.who.int/publications/i/item/9789240038509)
[2] World Health Organization. (2021) Climate change. World Health Organization. Retrieved from https://www.who.int/health-topics/climate-change#tab=tab_1.
[3] World Health Organization. (2021) Climate change and health. Retrieved from https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.
[4] Intergovernmental Panel on Climate Change [IPCC]. (2014). Climate Change 2014 Synthesis Report. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf.
[5] United Nations [UN]. (2021). Fast facts: Health. Retrieved from https://www.un.org/sites/un2.un.org/files/2021/08/fastfacts-health.pdf
[6] Kamal-Chaoui, L., and Alexis, R. (eds.). (2009). Competitive Cities and Climate Change. OECD Regional Development Working Papers N° 2. OECD publishing. (https://www.oecd.org/cfe/regionaldevelopment/44232251.pdf)
[7] Stern, N. (2006). The economics of climate change: The Stern review. Cambridge University Press.
[8] Bulkeley, H. (2013). Cities and climate change. Routledge. (https://doi.org/10.4324/9780203077207)
[9] European Centre for Medium-Range Weather Forecasts [ECMWF]. Urban heat islands and heat mortality. Demonstrating heat stress in European cities. ECMWF Stories. Retrieved from https://stories.ecmwf.int/urban-heat-islands-and-heat-mortality/index.html

general malaise, cardiovascular and respiratory problems, heat cramps, chronic stress and heat stroke. Particularly at risk in these events are the most sensitive population groups, such as children and the elderly. The latter, in particular, being in most cases already in poor health, are more likely to be more sensitive to high heat[10].

In general, all urban areas are affected by UHI, but Mediterranean cities are considered particularly prone to it. The Mediterranean climate, characterised by hot, dry summers and mild, wet winters, can increase the likelihood of UHI. In addition, high summer temperatures and lack of precipitation can exacerbate the phenomenon, through increased energy consumption, thus degrading air quality and negatively affecting occupants' health[11]. The Mediterranean area is among the most sensitive to climate change, with projected annual temperature increases of 1-5 °C until 2100, a range that increases in the case of large cities in the basin.

At national and European level, efforts have just begun to implement efficient solutions to cope with and adapt to climate change, which will reduce the prevalence of heat island phenomena and improve human health. Creating so-called green-blue infrastructure, which includes increased plant cover, also known as Nature-based Solutions (NbS), is one strategy to prevent and minimize urban heat stress. Nature-based solutions (NbS) are described as "solutions to societal challenges that are inspired and supported by nature, that are cost-effective and that simultaneously provide environmental, social and economic benefits to help create resilience"[12]. To achieve one or more targeted ecosystem services, these solutions could include design components that mimic, enhance, maintain or support nature. Increasing the reflectivity of surfaces, such as reflective or cool infrastructure, or increasing surface vegetation, such as green roofs, urban forests and vegetated vertical surfaces, are two examples of NBS. The benefits are manifold, namely reducing the energy consumption of buildings and the resulting carbon dioxide emissions, moderating the microclimate and reducing the health impacts on citizens due to extreme heat events[13].

Scientists, research funders, and stakeholders from the European network BiodivERsA came up with a three-type categorization for NbS. Type 1 involves no or limited ecological intervention, with the aim of preserving or enhancing the supply of a variety of ecosystem services both inside and outside of these conserved ecosystems. Type 2 relates to the design and use of management methodologies that create resilient, multifunctional ecosystems and landscapes that improve the supply of chosen ecosystem services. Type 3 consists of the management of ecosystems in a very invasive manner or even the creation of new ecosystems.

[10] U.S. Environmental Protection Agency [EPA]. Heat island impacts. Retrieved from https://www.epa.gov/heatislands/heat-island-impacts
[11] Donateo, A., Palusci, O., Pappaccogli, G., Esposito, A., Martilli, A., Santiago, J.L. and Buccolieri, R. (2023). The Urban Heat Island in a Typical Mediterranean City. (http://dx.doi.org/10.2139/ssrn.4403986)
[12] Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., Geneletti, D., and Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science & Policy, 77, 15–24. (https://doi.org/10.1016/j.envsci.2017.07.008)
[13] Hayes, A.T., Jandaghian, Z., Lacasse, M.A., Gaur, A., Lu, H., Laouadi, A., Ge, H. and Wang, L.. (2022). Nature-Based Solutions (NBSs) to Mitigate Urban Heat Island (UHI) Effects in Canadian Cities. Buildings, 12(7), 925. (https://doi.org/10.3390/buildings12070925)

Type 3 is linked to concepts such as green and blue infrastructure[14]. Hence, the latter type is taken into account in the following analysis as the implementation of green infrastructure succeeds in reducing heat islands in Mediterranean cities while having a positive impact on human health.

In the first chapter, the problem will be introduced, explaining the concepts of urban heat islands and Nature-based Solutions, highlighting the positive benefits they can bring to society. Then, European and national policies implemented with the aim of increasing the application of green solutions will be explored. Finally, the parameters used in the analysis of NbS impacts will be presented. In the second chapter, case studies will be presented, namely the two selected Mediterranean cities: Barcelona and Turin. For each, an initial general overview will be made with a focus on the current socio-health situation. Next, the plans introduced by the cities to mitigate/combat the effects of climate change will be briefly described. Finally, specific implemented NbS projects will be discussed in detail for each of them. To conclude, in the third chapter, conclusions will be drawn, discussing the data collected in the previous chapter and through interviews.

1.2 Research Problem and Research Question

The impacts of climate change seriously threaten cities and inhabitants all over the planet. In this context, urban cities are the first to face this challenge, as their rapid development has led to environmental deterioration processes that threaten the living conditions of their inhabitants[15]. Increasingly, urban areas are exposed to extreme events caused by climate change and the devastation of ecosystems. In particular, the phenomenon of heat urban islands, caused by the significant rise in temperatures in urban settings, is increasing dramatically. This has repercussions not only on an environmental level, but also on a social level[16]. The socio-health consequences of heat urban islands include[17,18,19]:

- Health issues: higher temperatures can lead to heat exhaustion and heat stroke, particularly among vulnerable populations such as the elderly and those with pre-existing health conditions. This can lead to increased hospitalization and even death.
- Reduced quality of life: high temperatures can make it uncomfortable for people to spend time outdoors, reducing opportunities for physical activity and social interaction.

[14] Nature-based solutions: New Influence for Environmental Management and Research in Europe – BiodivERsA. Retrieved from https://www.biodiversa.org/898/download
[15] Guida, C., Gargiulo, C., Papa, R., and Carpentieri, G. (2022). Vulnerability and Exposure of Mediterranean Coastal Cities to Climate Change-Related Phenomena. Environmental Science Proceedings, 21, 79. (https://doi.org/10.3390/environsciproc2022021079)
[16] Dentico, N. (2022, January10th). Gli effetti sulla salute di un'urbanizzazione senza criteri. Altreconomia. (https://altreconomia.it/gli-effetti-sulla-salute-di-unurbanizzazione-senza-criteri/)
[17] Heaviside, C., Macintyre, H. and Vardoulakis, S. (2017). The Urban Heat Island: Implications for Health in a Changing Environment. Current Environmental Health Reports, 4, 296-305. (https://doi.org/10.1007/s40572-017-0150-3)
[18] U.S. Environmental Protection Agency [EPA]. Heat island impacts. Retrieved from https://www.epa.gov/heatislands/heat-island-impacts
[19] Heaviside, C. (2020). Urban Heat Islands and their Associated Impacts on Health. Environmental Change Institute, University of Oxford. (https://discovery.ucl.ac.uk/id/eprint/10106446/1/Heaviside_Urban-Heat-Island-and-Health-MSS06_accepted.pdf)

- Economic impacts: heat urban islands can increase energy costs for air conditioning and cooling, particularly for low-income households that may not have access to air conditioning.

In all likelihood, these problems will get even worse in the coming years. In fact, according to some estimates, the UN predicts that the level of urbanisation will reach almost 70 per cent by 2050[20].

In this scenario, the Mediterranean basin is one of the most sensitive regions to global warming and urbanisation. For this reason, it has been defined a "hot-spot[21]", based on the results of global climate change projection scenarios. During the 20th century, the air temperature increased by almost 2°C. The consequences of warming in the entire Mediterranean basin include much more frequent and intense heat waves and longer periods of drought.

Cities must therefore strive to implement solutions that preserve cities, their ecosystems and the health of their citizens. In this perspective, the negative social consequences of heat urban islands can be mitigated by incorporating Nature-based Solutions into urban environments, which can provide a range of benefits for both individuals and communities as a whole.

The following study will investigate this problem in an effort to clarify how well NBS may reduce socio-health repercussions or perhaps how to create a set of impact evaluations that can take the socio-health component from the adoption of NBS into account. The main RQ is given below as follow:

RQ: How can Nature-based Solutions mitigate the negative effects of climate change, while having a positive impact on society in terms of healthy well-being?

1.3 Methodology

The methodology used for the following work is empirical, and replicable on different scales. Empirical research is defined as research whose conclusions are drawn on the basis of empirical evidence and are therefore "verifiable". This type of scientific investigation involves the collection and analysis of data from direct observation or experimentation. The aim is to discover new knowledge and test hypotheses through systematic observation, measurement, and data analysis. Empirical research is based on the principles of the scientific method, which involves formulating a hypothesis, designing a study to test the hypothesis, collecting and analysing data and drawing conclusions based on the results. The data collected in empirical research can

[20] Italia, U.N.R.I.C. (2020). UN 75 - I grandi Temi: Una demografia che cambia. ONU Italia. Retrieved from https://unric.org/it/un-75-i-grandi-temi-una-demografia-che-cambia/#:~:text=FUTURO%20URBANO&text=Oggi%2C%20circa%20il%2055%20per,per%20cento%20entro%20il%202050.

[21] Giorgi, F. (2006). Climate Change hot-spots. Geophysical Research Letters, Volume 33, Issue 8. (https://doi.org/10.1029/2006GL025734)

be quantitative (numerical data) or qualitative (non-numerical data), depending on the research question and the methodology used.

The thesis is divided into three parts:

1. Literature review
2. Case studies analysis
3. Results and discussion

In detail, a mixed qualitative and quantitative method is used in this research work. After choosing and defining the research problem and designating the specific objective to be analysed, an initial qualitative analysis was carried out. In this case, theoretical insights were gathered through an in-depth reading of various academic and scientific papers. These articles were consulted through the main databases of scientific publications, such as Elsevier ScienceDirect, JSTOR, SpringerLink and others. Then, through a quantitative analysis, numerical data were collected from statistical databases related to the main indicators to be analysed on the cities under study. After data collection, tables were created in which data for specific years were entered. In some cases, since the indicator of interest is not directly available, it is calculated by acquiring other relevant indicators. Finally, in order to gather more specific data and corroborate the conclusions, some external opinions are heard. Interviews are then conducted with the experts currently working on the projects, asking them various questions. For the city of Barcelona, the responsible for the Barcelona Natural Plan, and the responsible for the Trees for Life Project, are interviewed. Currently, both are fully involved in the Project and are working on its implementation within the city. Instead, for the city of Turin, we interviewed Dr. Roberta Molinar, contact person for social inclusion and active citizen participation interventions within the Mirafiori Community Foundation. The Foundation, created with the aim of improving the Mirafiori district from an environmental and social point of view, is working on the proGIreg project with the aim of regenerating the area through the implementation of nature-based solutions. The method used for the interviews was the semi-structured interview. A semi-structured interview is a qualitative research technique that combines a series of open questions (questions that invite debate) with the chance for the interviewer to go deeper into certain topics or replies. The main tools used are therefore scientific evidence, research on various databases and contributions from various experts.

The cities selected for the study were chosen to achieve a geographical distribution in the Mediterranean region. An additional criterion for the selection was the availability of socio-environmental data on different moments in time. These criteria allowed for the selection of two cities in total: Barcelona (Spain) and Turin (Italy). The main goal of the study is to analyze green infrastructure on only one scale, namely the areal scale, within the three cities. The type of Nature-based Solution analyzed is Type 3 falling within the green built environment.

Reference parameters for the analysis

In the following research, the dimension of analysis that will be considered is the socio-health one. This means, that the data analysed will refer mainly to social and health aspect of the cities. This will help us to understand the consequences of the application of NBS in the two case studies.

For example, the parameters used for the purpose of the analysis will refer to the quality of life of citizens, to various indicators concerning diseases directly related to environmental factors (such as cardiovascular diseases, diseases related to a person's physical appearance, etc.). In order to have a more comprehensive view of the health scenario, environmental parameters such as the pollution index in the areas of interest, will also be taken into account.

CHAPTER ONE - STATE OF THE ART ANALYSIS

2.1 Anthropocene and Urbanisation: Social and Health Impacts in the Mediterranean

The geological time scale is a hierarchy of shorter time periods used to classify Earth's history. Eons, eras, periods, epochs and ages are the names given to these divisions in descending order. These units are classified on the basis of fossils that can be discovered in the Earth's geological strata. By analysing them, scientists can determine which organisms belong to a specific part of the geological record. Stratigraphy is the study of these relationships[22].

Currently, we are officially in the Holocene epoch, which began approximately 11,700 years ago after the last great Ice Age. However, many scientists claim that around 1950 with the Great Acceleration, a new epoch began: the Anthropocene[23]. Although the term "Anthropocene" has not yet been formally adopted by the International Union of Geological Sciences (IUGS), it currently denotes the most recent time in Earth's history when human activities started to significantly affect the planet's climate and ecosystems[24].

This acceleration is set to continue, and with it the Anthropocene period, until it is reversed. Human beings will increasingly continue to exert a strong influence on the environment and global ecology. The impacts are further exacerbated by strong global urbanization, namely the increasing concentration in urban settlements of the world's growing population, which stands as one of the main drivers and accelerators of the degradation of our planet. For example, cities are responsible for about 70 per cent of global CO2 emissions but are disproportionately and increasingly exposed to the impacts of climate change, since 90 per cent of urban areas, and most of the world's population, are located on coasts[25].

According to the Revision of World Population Prospects 2022, an annual UN report that examines the current and future state of the world's population, the population is expected to increase by 2 billion from the current 7.7 billion to 9.7 billion in 2050[26,27]. This will therefore lead to a further development of urban areas, as more and more people will choose to live in urban than in rural areas. Today, about 55% of the world's population lives in cities, and urbanisation is expected to reach almost 70% by 2050[28,29].

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[22] Education National Geographic. Anthropocene. Retrieved from https://education.nationalgeographic.org/resource/anthropocene/
[23] McNeill, J. R., and Engelke, P. (2016). The Great Acceleration: An Environmental History of the Anthropocene since 1945. The Belknap Press of Harvard University Press.
[24] Education National Geographic. Anthropocene. Retrieved from https://education.nationalgeographic.org/resource/anthropocene/
[25] Elmqvist, T., Andersson, E., McPhearson, T., Bai, X., Bettencourt, L., Brondizio, E., Colding, J., Daily, G., Folke, C., Grimm, N., Haase, D., Ospina, D., Parnell, S., Polasky, S., Seto, K. C., and Van Der Leeuw, S. (2021). Urbanization in and for the Anthropocene. Npj Urban Sustainability, 1, Article number 6. (https://doi.org/10.1038/s42949-021-00018-w)
[26] United Nations, Department of Economic and Social Affairs, Population Division. (2022). World population prospects 2022: Summary of results. Retrieved from https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf
[27] United Nations. Global issues. Population. Retrieved from https://www.un.org/en/global-issues/population
[28] The World Bank. (2022). Overview. Context. Retrieved from https://www.worldbank.org/en/topic/urbandevelopment/overview#:~:text=Today%2C%20some%2056%25%20of%20the,people%20will%20live%20in%20cities
[29] United Nations. (2018). Around 2.5 billion more people will be living in cities by 2050, projects New UN Report. Retrieved from https://www.un.org/en/desa/around-25-billion-more-people-will-be-living-cities-2050-projects-new-un-report

The continuing climate change caused by the increasing concentration of CO2 in the atmosphere exacerbates these changes. Consequently, the phenomenon of urbanisation has a significant impact on climate. Climate changes in the local area are often greater than those expected on a global scale, due to factors such as urban surface materials and topology, and emissions from domestic, commercial and transport activities[30]. These consequences on urban climate make cities attractive places for climate mitigation, because they make citizens more sensitive to incoming environmental changes.

Although Euro-Mediterranean cities have historically been distinguished by a compact structure, contemporary developments taking place in the form of urban sprawl is gradually changing their urban form. Throughout the 20th century, the Mediterranean region has experienced a fast-growing urbanization trend[31]. Indeed, in recent years, cities such as Rome, Barcelona, Athens, Tel Aviv, and Madrid have experienced significant urbanization. These events are seriously stressing the Mediterranean region's vulnerable ecosystem. Precisely, it has led to the construction of new infrastructure, such as skyscrapers and modern transport systems, as well as the influx of people seeking better job opportunities and a higher standard of living.

As written above, these changes are also heavily influencing the climate. In fact, the sharp rise in temperatures in recent years can be partly explained by the phenomenon of urbanisation. For example, new buildings and pavements cause temperatures to rise by up to 5°C. To confirm this, data from weather stations in urban and rural environments can be examined. Analysing them, those in urban environments often show a greater increase than rural weather stations, as shown in the example of Australia (Figure 1)[32].

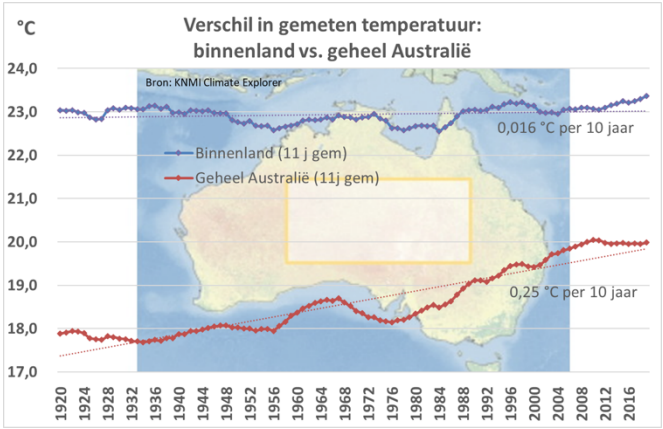

Figure 1: Difference in measured temperatures between rural weather stations (inside the rectangle) in blue and all-weather stations in Australia in red. (Source: KNMI Climate Explorer)

This increase in temperature that characterises the transition from rural to urban areas is a phenomenon that until recently was considered “normal”. Today, however, it is becoming increasingly dangerous when correlated with ongoing climate change. Urban heat islands are characterised by a real microclimate that is

[30] Grimmond, C.S.B, Warrd, H.C. and Kotthaus, S. (2015). How is urbanization altering local and regional climate? Handbook on Urbanization and Global Environmental Change. Routledge. (https://centaur.reading.ac.uk/52737/1/GrimmondWardKotthaus2016_Handbok.pdf)
[31] Lagarias, A., and Sayas, J. (2019). Is there a common typology of urban sprawl in Mediterranean cities? Revue d’Économie Régionale & Urbaine, Octobre(4), 813–850. (https://doi.org/10.3917/reru.194.0813)
[32] Ragusa, E. (2020). L'urbanizzazione spiega parte dell'aumento della temperatura. Attività Solare. https://www.attivitasolare.com/lurbanizzazione-spiega-parte-dellaumento-della-temperatura/

generated within built-up areas and that leads to temperature increases of up to five degrees[33], resulting in increased energy consumption, decreased air quality and negative impacts on society well-being[34].

In addressing the issue of social welfare, it is crucial to analyse the significant impact that increasing anthropisation has had on human society over the years, in order to understand how important is to take action to mitigate and resolve these impacts.

Often, problems in cities impact mainly on the poor social class but then affect other inhabitants, even those belonging to higher social classes. As the trend of urbanisation continues, this spillover effect increases and takes on a global dimension as more and more of the world's populations are affected, putting a strain on social systems and resources[35].

Although city life is often associated with better access to health services due to the presence of more specialists, life in urban areas can also have a dark side. Chronic stress due to air pollution, noise and other factors can affect the general health and well-being of urban residents. This can contribute to health problems of all kinds: stress, lung problems, high blood pressure, obesity, low birth weight and even depression.

Pollution from greenhouse gas emissions inevitably causes various respiratory problems, such as asthma and lung diseases. According to some scientific studies, exposure to polluted air for even a single day can have serious effects on general health. The World Health Organisation has estimated that 6.5 million people, or 11% of all global deaths, have died due to indoor and outdoor air pollution[36].

City life often also leads to increased feelings of loneliness and isolation among urban residents who, when moving to a new place, are unable to carry on their previous social relationships. In several cases, this can lead to social isolation, which has an important impact on mental health.

Urban dwellers also suffer from overnutrition and obesity, which often contribute to the spread of chronic diseases such as cancer, diabetes and heart disease. This problem is caused by increased calorie intake and decreased physical activity, historically associated with wealth. However, in recent years, international agencies have noticed an increase in weight even among the poor and middle class[37]. This is primarily a

[33] Ramaccioni, A. (2021). Isole di Calore, è emergenza in città. Stradenuove. (https://www.stradenuove.net/isole-di-calore-e-emergenza-in-citta/)
[34] Santamouris, M. (2020). Recent progress on urban overheating and heat island Research. Integrated assessment of the energy, environmental, vulnerability and health impact. Synergies with the global climate change. Energy and Buildings, Volume 207, 109482. (https://doi.org/10.1016/j.enbuild.2019.109482)
[35] Alirol, E., Getaz, L., Stoll, B., Chappuis, F., and Loutan, L. (2011). Urbanisation and infectious diseases in a globalised world. The Lancet Infectious Diseases, Volume 11, Issue 2, 131-141. (https://doi.org/10.1016/S1473-3099(10)70223-1)
[36] World Health Organization. (2016). World Health Organization releases country estimates on air pollution exposure and health impact. Geneva: World Health Organization. Retrived from https://www.who.int/news/item/27-09-2016-who-releases-country-estimates-on-air-pollution-exposure-and-health-impact
[37] World Health Organization. (2000). Obesity: Preventing and managing the global epidemic. WHO Technical Report Series. (https://apps.who.int/iris/handle/10665/42330)

consequence of the lack of physical space; hence, green urban areas and adequate infrastructure, continuous workplace, excessive energy intake and low energy expenditure[38].

The cities themselves, however, could succeed in mitigating the most disastrous effects through various strategies[39,40]:

- Massively increase the amount of green space in urban areas, such as parks and gardens, which can provide shade and help cool the surrounding area through evaporative cooling;
- Reduce vehicular traffic by investing in public transport and sustainable mobility can help decrease the amount of heat generated by vehicles and improve air quality.
- Initiate a campaign of urban planning interventions that aim as far as possible to replace the materials used up to now with more innovative ones that retain less heat and reflect more sunlight.

2.2 Urban Heat Islands (UHI): what they are, types and causes

Urban areas tend to have higher temperatures than surrounding rural areas, mainly due to human activities such as cooling, heating, transport, and air pollution, as well as the materials and density of urban infrastructure. This phenomenon is known as the Urban Heat Island effect (UHI), which contributes significantly to climate change and is therefore considered one of the greatest problems of the 21st century facing mankind today. Heat islands are called "islands" because they represent areas within a larger area (such as a city) that behave as separate thermal islands. This phenomenon is similar to that which occurs on an island surrounded by water, where the temperatures inside the island can be different from those outside the island.

The UHI effect, which is the most obvious aspect of urban climate caused by urban development and human activity, is widely recognised as a heat build-up phenomenon. Urban heat release, the characteristics and structure of the underlying surface, vegetation cover, population density and meteorological conditions are all closely related to the UHI effect.

One of the factors that has the greatest impact on the formation of urban heat islands is urbanisation. Urbanisation is defined by Oke[41] as an anthropic alteration of surface materials due to the suppression of vegetation, changes in albedo and soil sealing, which affects the local energy balance and thus contributes to the formation of urban heat islands (UHI).

[38]Arundell, L., Sudholz, B., Teychenne, M., Salmon, J., Hayward, B., Healy, G. and Owen, N. (2018). The impact of activity-based working (ABW) on workplace activity, eating behaviours, productivity, and satisfaction. International journal of environmental research and public health, Volume 15, Issue 5, 1005. (https://doi.org/10.3390/ijerph15051005)
[39]U.S. Environmental Protection Agency. (2008). Reducing urban heat islands: Compendium of strategies. Draft. (https://www.epa.gov/heat-islands/heat-island-compendium)
[40] Ibidem.
[41]Oke, T. R. (1982). The energetic basis of the urban heat island. Quarterly Journal of the Royal Meteorological Society, Volume 108, Issue 455, 1–24. (https://doi.org/10.1002/qj.49710845502)

Different types of urban heat islands can be defined based on differences in urban and rural surface cooling and heating rates[42]. The first type are surface heat islands (UHI_{Surf}), which are understood as the rising temperatures of materials due to the incidence of solar radiation on their surfaces. They are also influenced by the physical-technical properties of materials that define their ability to retain or repel solar energy. The second type are sub-surface urban heat islands (UHI_{Sub}) where heat diffusion occurs underground. The third type are canopy layer urban heat islands (UHI_{UCL}) which form in the atmosphere below the tops of buildings and trees. Finally, there are the boundary layer urban heat islands (UHI_{UBL}) where the alteration of the climate is due to the convergence of heat from local areas and the warmer air above.

Rising temperatures in towns and cities and the subsequent formation of urban heat islands are generated by several causes. As was already noted, the thermal differential of closely connected components that varies depending on the unique characteristics of each urban center causes the urban heat island. The scale of the city (urban and population density), its functions (water and energy consumption, GHG and pollutants, etc.), its conformation (city geometry, construction materials, and vegetation covering), as well as urban growth, should all be taken into account.

However, physical location (the climatic zone, topography, etc.), temporal timing (day, night), and weather conditions all have an impact on how intense the event is (clouds, wind, solar radiation, rainfall, humidity, etc.). City size, city services, and city form are the three key areas on which mitigation strategies are primarily focused.

2.2.1 The main impacts of Urban Heat Islands

Although urban heat islands have been a recognised phenomenon since the 19th century, scientists have only recently begun to take a serious interest in them[43]. As a result, several cities in Europe and other parts of the world have been the focus of research and evaluation to analyse the effects of urban heat islands, understanding their negative and/or positive social, economic, and environmental consequences.

From a social point of view, many studies have shown powerful negative effects of urban heat islands. Increased exposure to extreme heat, due to the urban heat island effect, threatens urban settlements and its rapidly growing population worldwide. Globally, urban exposure has increased by almost 200%, affecting about 1.7 billion people. Total urban warming has increased exposure rates by 52% compared to population

[42] Oke, T. R. (1995). The heat island of the urban boundary layer: Characteristics, causes and effects. Part of NATO ASI Series. Volume 277. (https://doi.org/10.1007/978-94-017-3686-2_5)

[43] Stewart, I. D. (2019). Why should urban heat island researchers study history? Urban Climate, 30, 100484. (https://doi.org/10.1016/j.uclim.2019.100484)

growth alone. This demonstrates the urgent need for action to introduce local adaptation and early warning systems to reduce social damage from exposure to extreme heat[44].

Exposure to dangerously high temperatures can endanger health and urban development, causing decreases in economic productivity and increasing morbidity and mortality. However, the damage caused is highly unequal and inequitable, as vulnerability to heat is not the same for all urban dwellers. Elderly people are more sensitive to heat, but so are poor or socially isolated people[45]. In fact, poverty hinders adaptation in many ways: inferior housing can overheat at lower temperatures, while the cost of water or electricity creates an obstacle to mechanical cooling. Evidence of this is the 22,000 people, half of them elderly, who were taken to hospital with symptoms of heatstroke during the 2018 heat wave in Japan, where record temperatures exceeded 41 °C. Or in Paris, 90 per cent of the people who died during the 2003 heat wave lived alone[46].

UHIs also lead to an increase in deaths from cardiovascular and respiratory diseases and are also associated with more suicides, related to an increase in chronic stress. In this scenario, providing healthcare is complicated as the demand for care increases and not all hospitals are designed to cope with heat as they are built with insulation to retain heat and subject to high internal heat gain by patients, staff and equipment. This leads to increased use of air conditioning which, in turn, emits greenhouse gases and contributes to increased pollution, producing waste heat that adds to urban heat islands and increasing costs for households and businesses.

As a result, there is an urgent need to evaluate how urban features affect the link between temperature and health since urban populations are more susceptible to heat-related illnesses, particularly in a warming world. In cities with larger levels of inequality, exposure to air pollution, lack of green space, and access to health services, the impacts of heat on mortality are more pronounced. Urban planning and public health actions can be carried out using these results[47].

Environmentally, UHIs have a negative impact on biodiversity by, for example, reducing the availability of habitats for flora and fauna. In addition, urban vegetation can be damaged by excessive heat and lack of available water, compromising the ability of cities to provide ecosystem services. UHIs can also significantly affect climate change as they require more energy to cool buildings and operate air-conditioning systems. This increases the emission of greenhouse gases and contributes to the greenhouse effect[48]. The demand for more

[44] Tuholske, C., Caylor, K., Funk, C., Verdin, A., Sweeney, S., Grace, K., Peterson, P., & Evans, T. (2021). Global urban population exposure to extreme heat. Proceedings of the National Academy of Sciences, 118(41). (https://doi.org/10.1073/pnas.2024792118)
[45] Tong, S., Prior, J., McGregor, G., Shi, X., & Kinney, P. (2021). Urban heat: An increasing threat to global health. BMJ. (https://doi.org/10.1136/bmj.n2467)
[46] The Lancet. (2018). Heatwaves and health. The Lancet, Volume 392, Issue 10145. (https://doi.org/10.1016/s0140-6736(18)30434-3)
[47] Rosenzweig, C., Solecki, W., Romero-Lankao, P., Mehrotra, S., Dhakal, S., and Ali Ibrahim, S. (Eds.). (2018). Climate change and cities: Second assessment report of the Urban Climate Change Research Network. Cambridge University Press. (https://doi.org/10.1017/9781316563878.012)
[48] Grimmond, S. U. E. (2007). Urbanization and global environmental change: Local effects of urban warming. The Geographical Journal, Volume 173, Issue 1, p. 83-88. (https://doi.org/10.1111/j.1475-4959.2007.232_3.x)

energy also has a major negative economic impact, leading to losses that inevitably affect both households and businesses.

In summary, the impact of urban heat islands on the environment, economy, and social well-being of cities and their inhabitants is significant. Therefore, it is essential to address and mitigate their effects. Mediterranean cities, in particular, are vulnerable to UHI due to unique climatic conditions. Some contributing factors include high temperatures during summers, limited green spaces and vegetation, urban sprawl, and high population density leading to increased energy consumption and air pollution, exacerbating UHI.

2.3 Nature-based Solutions

In the framework of what has been analysed in the previous paragraphs, thus the strong impact that the phenomenon of urbanisation has had and is having on cities and the consequent generation of heat islands, according to Raymond (2017), Hayes (2022), Cohen-Shacham (2016) a direct solution to mitigate social impacts within urban areas seems to be the implementation of Nature-based Solutions (NbS) in urban planning.

Nature-based solutions are initiatives to safeguard, sustainably manage, or rehabilitate natural ecosystems that effectively and adaptively address societal issues like climate change, human health, food and water security, and disaster risk reduction while enhancing both human well-being and biodiversity[49].

At the policy level, NbS started to attract the attention of science-based organisations, such as The Nature Conservancy and the International Union for Conservation of Nature in the early 2000s[50]. Specifically, the IUCN was the first scientific community to give a clear definition of what NbS are, namely "*actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefit"*.

Subsequently, the World Bank, as part of its Strategic Framework for Climate Change and Development, also helped to secure investments of around USD 6 billion in projects that supported nature-based solutions for the increased conservation and sustainable use of natural capital.

It is important to emphasise the important role that the European Union played in signing the Paris Agreement, the New Urban Agenda and the Sendai Framework, within which special attention is paid to the role that Research and Innovation play in the implementation of NbS. These are also crucial for the achievement of some SDGs. For instance, from the point of view of implementing social benefits, NbS would increase access

[49] World Bank. (2022). What you need to know about nature-based solutions to climate change. Retrieved from https://www.worldbank.org/en/news/feature/2022/05/19/what-you-need-to-know-about-nature-based-solutions-to-climate-change
[50] IUCN. Nature-based solutions. Retrieved from https://www.iucn.org/our-work/nature-based-solutions

to green spaces, thus meeting both SDG 10 (Reduce inequalities within and between societies) and SDG 3 (Improve health and well-being)[51].

Besides, the European Commission has recently embraced the use of NbS, as a way to foster biodiversity and make Europe more climate-resilient[52]. In the presentation "Innovating with nature", NbS are defined as "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*[53] *"*.

The EU must therefore provide the evidence for nature-based solutions, enhance the policy-level framework for these solutions, create a community for European research and innovation, advance the creation, adoption, and dissemination of novel nature-based solutions, and incorporate nature-based solutions into global research and innovation in order to achieve the current policy goals. Currently, two components of NbS are used to accomplish these goals:

1. EU's funding programme Horizon 2020;
2. BiodivERsA ERA-Net: a network of national research programmes on biodiversity across Europe that organises international research funding on a competitive basis. Work will be continued in the upcoming Biodiversity Partnership under Horizon Europe, the EU's next framework programme (2021-2027).

2.3.1 NBS Types

NbS are applied in a wide variety of sectors to address a plethora of social and environmental problems. Typically, interventions vary according to two factors[54]:

1. The required level of biodiversity and ecosystem engineering involved in NbS;
2. The level of improvement in ecosystem services achievable with NbS

[51] Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., and Vandewoestijne, S. (2017). Nature-based solutions in the EU: Innovating with nature to address social, economic and environmental challenges. Environmental Research, Volume 159, p. 509–518. (https://doi.org/10.1016/j.envres.2017.08.032)
[52] European Commission. (2015). Nature-based solutions: Research and innovation policy agenda. Retrieved from https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions/research-policy_en.
[53] Ibidem.
[54] Eggermont, H., Balian, E., Azevedo, J. M., Beumer, V., Brodin, T., Claudet, J., Fady, B., Grube, M., Keune, H., Lamarque, P., Reuter, K., Smith, M., van Ham, C., Weisser, W. W., & Le Roux, X. (2015). Nature-based solutions: New Influence for Environmental Management and research in Europe. GAIA - Ecological Perspectives for Science and Society, Volume 24, Number 4, p. 243–248. (https://doi.org/10.14512/gaia.24.4.9)

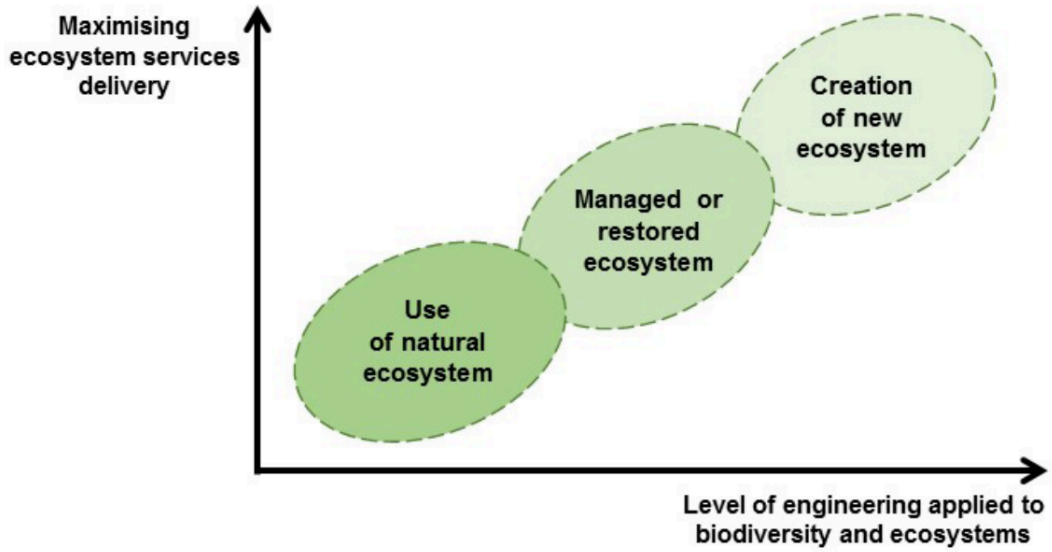

Figure 2: A typology of NbS showing three main categories of solutions based on natural, restored and new ecosystems (Source: IUCN, 2016)

This typology of application identifies three main types of NbS and one hybrid solutions:

- **Type 1: minimal or no intervention in ecosystems**. Approaches that maximize the ecosystem services already provided by natural or protected ecosystems while using the least number of technical techniques. These solutions primarily come under the category of governance since they entail professional involvement as well as social and institutional elements. For instance, strategies to boost fish populations in a healthy wetland to improve food security.

- **Type 2: some intervention in ecosystems and landscapes**. Solutions centered on the creation of sustainable management protocols and practices for managed or restored ecosystems that involve a minimal amount of engineering intervention and increase of ecosystem services. For instance, restoring conventional agroforestry systems based on commercial tree species can aid in the reduction of poverty.

- **Type 3: management of ecosystems in extended ways**. Solutions that involve the development of new ecosystems, the least amount of ecosystem service enhancement, and the most amount of engineering to achieve them. Type 3 can in turn be divided into seven categories[55]:

    1. Green space
    2. Trees and shrubs
    3. Soil conservation and quality management
    4. Blue-green space establishment or restoration
    5. Green built environment
    6. Natural or semi-natural water storage and transport structures

[55] UNaLab, Urban Nature Labs. Types of Nature-Based Solutions. Retrieved from https://unalab.eu/en/types-nature-based-solutions

7. Infiltration, filtration, and biofiltration structures

- **Hybrid solutions**: they can be implemented depending on the scenario under consideration. They combine natural features with green infrastructure in a way that is better for the environment and people. The hybrid type can be developed as a Type 3 NBS but, if well established, can later be referred to as a Type 1.

2.3.2 NbS Approaches Categories

Nature-based solutions for climate change adaptation and disaster risk reduction can be regarded as an "umbrella concept" encompassing several established nature-based approaches aimed at increasing resilience to climate change and improving human well-being. The IUCN defines several categories of approaches[56]:

Category of NbS approaches	Examples
Ecosystem restoration approaches	Ecological restoration Ecological engineering Forest landscape restoration
Issue-specific ecosystem-related approaches	Ecosystem-based adaptation Ecosystem-based mitigation Climate adaptation services Ecosystem-based disaster risk reduction
Infrastructure-related approaches	Natural infrastructure Green infrastructure
Ecosystem-based management approaches	Integrated coastal zone management Integrated water resources management
Ecosystem protection approaches	Area-based conservation approaches including protected area management

Figure 3: Category of NBS approaches (Source: IUCN, 2016)

2.3.3 Type 3 NbS Applications

In this study, the cases that will be considered in the second chapter involve the implementation of Type 3 NbS. In order to analyse the positive social impacts that NbS have in urban areas in the Mediterranean, Type 3 was selected as numerous studies have shown how the encounter between green spaces and citizens can improve the physical and mental health of the community[57].

[56] IUCN. (2016). Nature-based solutions to address global societal challenges. (https://doi.org/10.2305/iucn.ch.2016.13.en)
[57] Ibidem.

Extensive and intensive **green roofs** might be considered Type 3 NbS. The former are compact systems with a small layer of substrate covered with quickly spreading, low-growing flora. The latter are heavier greening systems with a thicker growth media and a greater variety of plant life, such as perennials, shrubs, and small trees. Some of the benefits of greening roofs are environmental, as vegetation improves air quality and mimics CO2 emissions, and at the same time social, as citizens can benefit from more green spaces. On the other hand, disadvantages include the initial investment costs for implementation and for ongoing maintenance.

Another example could be **urban parks**, namely oases in the urban environment, with positive effects on the urban climate, social recreation and biodiversity. In addition to the environmental benefits provided, there are numerous social ones that the city can benefit from. These include protecting the health of citizens and improving the quality of life by mitigating rising temperatures.

Finally, a third example that can be given is the **group of trees.** This solution consists of planting trees in urban areas of the city, in different configurations according to the needs of the specific context. They can function well as a contrasting element in heavily populated regions or as a design element for shady squares and courtyards. Urban tree groups offer several benefits, including better water management and, from a social point of view, a reduction in fatal accidents and urban heat stress.

The techniques indicated above are excellent for helping to reduce and mitigate urban heat islands while also providing all the other advantages listed above. Green spaces actually help in the fight against the heat island effect by interfering with the local microclimate and lowering the excessive temperature rise caused by the presence of large areas covered in impermeable materials. And last, vegetation makes soil more permeable, which helps precipitation drainage.

2.3.4 The link between NbS and ecosystem services (ES) and the benefits

As mentioned in the previous sections, Nature-based Solutions play a key role in addressing the most critical societal challenges, bringing additional environmental, social and economic benefits compared to other solutions.

From a social perspective, the relationship between nature and society is often considered superficially. Yet for a society to be healthy, it needs clean air, clean water, food, and other resources provided as “ecosystem services”. Today, however, numerous scientific studies[58,59] ,show how the environment within urbanised cities

[58] Braubach, M., Egorov, A., Mudu, P., Wolf, T., Ward Thompson, C., Martuzzi, M. (2017). Effects of Urban Green Space on Environmental Health, Equity and Resilience. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (eds) Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions. Springer, Cham. (https://doi.org/10.1007/978-3-319-56091-5_11)
[59] Galea, S., Freudenber, N., Vlahov, D. (2005). Cities and population health. Social Science & Medicine, Volume 60, Issue 5, p. 1017-1033-(https://doi.org/10.1016/j.socscimed.2004.06.036)

is actually harming humans. In fact, it is evident how the modern urban lifestyle is highly associated with chronic stress, insufficient physical activity and consequent increase in disease and exposure to anthropogenic environmental hazards. This scenario can be reversed by the implementation of green areas, such as parks, green roofs, which can promote physical and mental health and reduce morbidity and mortality among city dwellers, providing psychological relaxation and stress relief, stimulating social cohesion and reducing exposure to air pollutants, noise and excessive heat.

The conservation of biodiversity is essential for the provision of ecosystem services that support human life. Natural ecosystems provide a wide range of services, such as climate regulation, water and air purification, soil fertilisation and the production of food, timber and other products. To preserve these services, the introduction of NbS is crucial.

The relationship between Nature-based Solutions (NBS) and Ecosystem Services (ES) is closely linked to the health of communities. The implementation of NBS can lead to a wide range of ES that contribute to the health of people and communities. The creation of urban parks and gardens can improve air and water quality, reduce local temperatures, provide a natural environment for exercise and reduce stress. This is because, these infrastructures perform purely regulatory services: regulation of temperature, humidity, filtration, sequestration, storage of air pollutants and regulation of the hydrological and water cycle.

Furthermore, NBSs can help prevent diseases transmitted by insects and other animals, as the natural habitat of their predators helps control their population. The promotion of NBSs can therefore contribute to improving the health of communities, both physically and mentally. In conclusion, the relationship between NBS and ES is important for the wellbeing of communities and the creation of a more sustainable and resilient future.

2.3.4.1 Health Benefits

Contact with nature can affect human health through multiple pathways, the main ones being air quality, physical activity, social cohesion and stress reduction[60].

[60]Hartig, T., Mitchell, R., de Vries, S., and Frumkin, H. (2014). Nature and health. Annual Review of Public Health, Volume 35, Issue 1, p. 207–228. (https://doi.org/10.1146/annurev-publhealth-032013-182443)

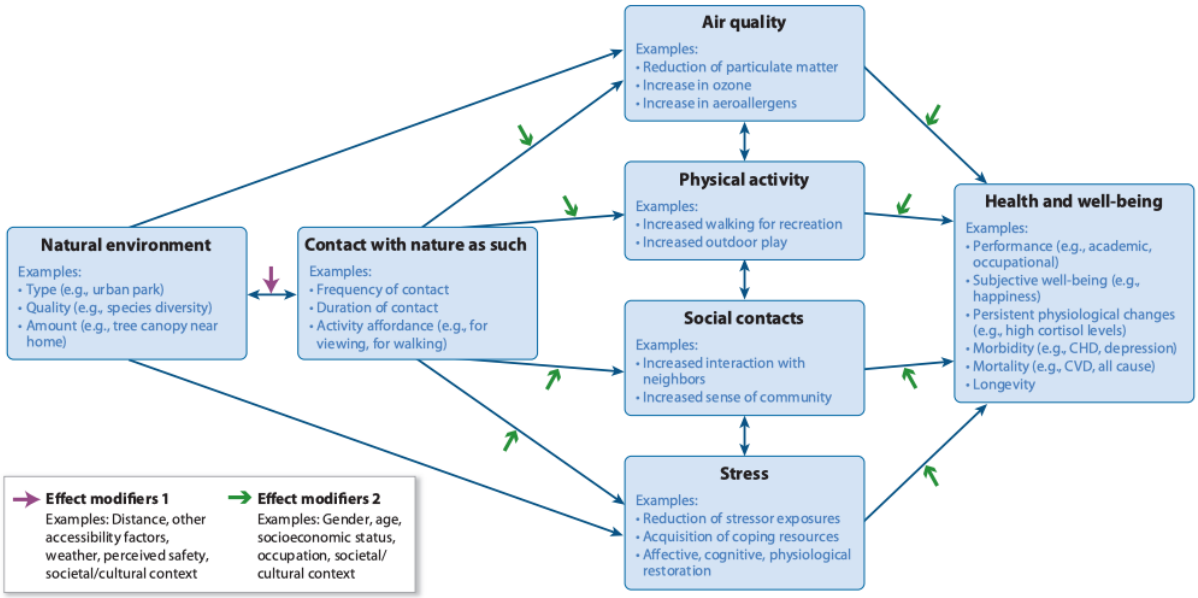

Figure 4: Social impacts of the natural environment (Source: Nature and Health, Annual Review of Public Health, 2014)

With regard to ***air quality***, the introduction of trees and shrubs can reduce the levels of gaseous air pollutants and particulate matter (PM). Gases are removed through absorption systems in leaf stomata, while PM is removed through deposition on leaves and other plant surfaces[61]. Since trees can reduce air movement, they can hinder the localised dispersion of pollutants. Indoor plants can also affect indoor air quality, an important observation since, especially in urban cities, citizens sometimes spend up to 90 per cent of their time indoors. Vegetation also indirectly improves air quality. During the summer months, trees provide shade and thus cool urban environments by reducing the energy needs of buildings. The reduction of energy needs for cooling in summer is about three times higher than the energy needs for heating in winter[62]. At the same time, however, there may be negative impacts on health. Indeed, some plants can be a source of hydrocarbons. Releasing pollen can lead to aggravation of allergies and asthma in susceptible persons. However, this can be mitigated by choosing plants with low pollen production[63]. Thus, the overall impact of vegetation on air quality is a function of several processes operating in opposite directions. But, careful selection of flooding species, planting design and vegetation maintenance can optimise the beneficial effects on air quality.

Physical activity also produces benefits for people's physical and mental health. The outdoor environment influences the degree to which an individual engages in activity based on the presence of spaces suitable for the performance of certain types of activity. Thus, green space promotes increased physical activity, but at the

[61] Beckett, K. P., Freer-Smith, P. H., and Taylor, G. (2000). The capture of particulate pollution by trees at five contrasting urban sites. The International Journal of Urban Forestry, Volume 24, Issue 2-3, p. 209–230. (https://doi.org/10.1080/03071375.2000.9747273)
[62] Brack, C. L. (2002). Pollution mitigation and carbon sequestration by an urban forest. Environmental Pollution, Volume 116, Supplement 1. (https://doi.org/10.1016/s0269-7491(01)00251-2)
[63] Benjamin, M. T., and Winer, A. M. (1998). Estimating the ozone-forming potential of urban trees and shrubs. Atmospheric Environment, Volume 32, Issue 1, p. 53–68. (https://doi.org/10.1016/s1352-2310(97)00176-3)

same time may hinder it depending on the type of activity in question[64]. In the work environment, green space is unimportant for the amount of physical activity. For active transport, green spaces make it more attractive to use modes of transport other than the car, bus, metro, such as walking or cycling. However, this is also influenced by the availability of infrastructure and citizens' perception of the green space present (e.g. safety, maintenance). For leisure, namely recreation and sports, large amounts of green space tend to go hand in hand with greater societal involvement. In general, there is a positive association between physical activity and green spaces.

A positive relationship is also evident for ***social cohesion***[65]**.** Shared norms and ideals, healthy bonds and a sense of acceptance and belonging are all examples of social cohesion[66]. Consequently, the term "social cohesion" refers more to neighbourhoods than to specific individuals and is more likely to be influenced by the physical attributes of the neighbourhood, such as the quantity and quality of green areas and other natural features. The little research conducted so far in this field indicates a positive link between social cohesion and the natural environment. The overall association between environmental exposure and health may be mediated by social cohesion, sense of safety, aggressive behaviour and crime rates.

Finally, with regard to ***stress levels***, nature can reduce the risk of long-term stress-related disorders and promote a number of intermediate outcomes, including improved subjective well-being. Nature can help individuals do this by reducing their exposure to difficult environmental situations or by helping them rebuild their adaptive capacities. The psycho-evolutionary theory[67] and the attention restoration theory[68] both explain how nature can facilitate faster and more complete repair than other environments. According to the first theory, being in nature has benefits that discourage negative thoughts and feelings and promote physiological activity in those under acute stress. The second argues that effortless attention, engaged by intrinsically interesting aspects of nature, allows a fatigued neurocognitive mechanism to rest and direct attention. Published studies to date report restorative and restorative benefits of nature.

2.3.4.2 Environmental and Economic benefits

At the **environmental level**[69], scientific evidence has shown that green areas are excellent climate mitigation factors that can contain Urban Heat Islands. By acting on soil sealing, quantity and type of vegetation,

[64] Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F., and Martin, B. W. (2012). Correlates of physical activity: why are some people physically active and others not? The Lancet, Volume 380, Issue 9838, p. 258–271. (https://doi.org/10.1016/s0140-6736(12)60735-1)
[65] Holt-Lunstad, J., Smith, T. B., and Layton, J. B. (2010). Social relationships and mortality risk: A meta-analytic review. PLoS Medicine, 7(7). (https://doi.org/10.1371/journal.pmed.1000316)
[66] de Vries, S., van Dillen, S. M. E., Groenewegen, P. P., and Spreeuwenberg, P. (2013). Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. Social Science & Medicine, Volume 94, p. 26–33. (https://doi.org/10.1016/j.socscimed.2013.06.030)
[67]Altman, I., and Wohlwill, J. F. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman & J. Wohlwill (Eds.), Human *Behavior and Environment, Vol. 6: Behavior and Natural Environment*. Plenum Press, 85-125.
[68] Kaplan, R., and Kaplan, S. (1995). The experience of Nature: A psychological perspective. Ulrich's Bookstore.
[69] Kabisch, N., Korn, H., Stadler, J., and Bonn, A. (2017). Nature-based solutions to climate change adaptation in urban areas linkages between science, policy and Practice. Springer International Publishing. (https://doi.org/10.1007/978-3-319-56091-5_1)

significant temperature drops can be recorded, especially during daylight hours. This results in enormous benefits, such as the prevention of climate change, improved air quality and a contribution to the maintenance of biodiversity.

Lastly, as far as **economic benefits** are concerned, the introduction of urban gardens may lead to the creation of employment centres for the integration of citizens and their environmental and food education. These solutions would also generate increased cash flow from new investments, tourism flows, as well as new jobs.

2.4 NBS Law and Policy

To adapt to climate change and reduce the risk of environmental and social disasters, NBS must be supported by favourable conditions. To manage the risks and hazards to which humanity is now more regularly and severely exposed, legislation and policy have a key role to play. As has been emphasised so far, NbS can reduce social and environmental vulnerabilities while providing a range of co-benefits, including preventing climate change, improving human health and well-being, and generating employment and business opportunities. The framework for the design, implementation and monitoring of NBS initiatives in each context is provided by law and policy[70].

Moreover, the study from the International Federation of Red Cross Crescent Societies (IFRC) and WWF highlights the benefits provided by NBS and how law and policy can be enablers through[71]:

- Establishing policies for conservation, sustainable management and restoration of nature;
- Establishing government mandates responsible for conservation, sustainable management and restoration of nature;
- Defining roles and responsibilities of groups involved in conservation, sustainable management and restoration of nature;
- Establishing coordination mechanisms to implement NBS;
- Imposing legal duties or obligations on relevant actors about how they conserve sustainably;
- Sustainably manage and restore nature.

Hence, a desk-based review was conducted to identify the EU and International policy instruments of highest relevance for enhancing the use of NBS. In the context of this analysis, “policy instruments” refers to various directives, strategies, programmes and funding instruments at EU and international level.

[70] IUCN. (2022). Enhancing legal and policy frameworks for nature-based solutions in the western balkans. Retrieved from https://www.iucn.org/story/202207/enhancing-legal-and-policy-frameworks-nature-based-solutions-western-balkans
[71] IFRC, WWF. (2022). Working with nature to protect people. How nature-based solutions reduce climate change and weather-related disasters. (https://www.ifrc.org/sites/default/files/2022-05/IFRC_%26_WWF_V_6-LR.pdf)

2.4.1 Review of EU Policy Framework

As numerous scientific studies have shown, nature-based solutions can address fundamental societal issues. For this reason, nature-based solutions for climate change adaptation and disaster risk reduction can be considered an "umbrella concept" encompassing a number of established nature-based approaches (see 2.3.1 NBS Categories). Each of these is related to a specific EU policy sector[72,73].

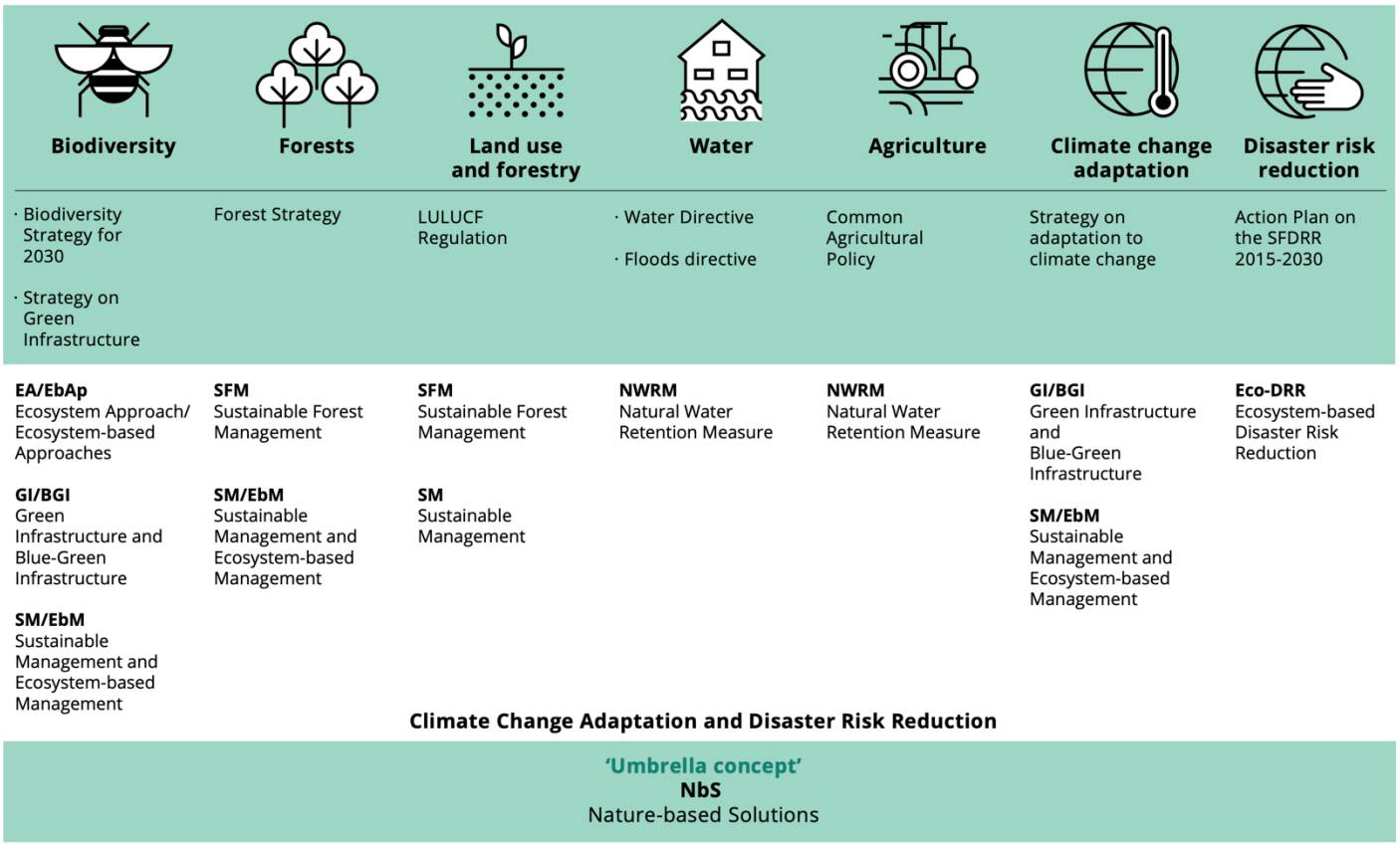

Figure 5: Umbrella concept of NbS. (Source: EEA Report, 2021)

Overall, NBS are either explicitly or implicitly supported primarily by policies in the EU environmental and climate change legislative framework.

- **European Green Deal:** it shows strong explicit support for NBS for both Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR), placing NBS at the heart of work on climate adaptation and mitigation and emphasising the role of NBS in ensuring healthy and resilient seas and oceans.
- **Bioeconomy Strategy:** the update version, published in 2018, increases the consideration of NBS for the mitigation and adaptation to climate change. The strategy outlines NBS as a tool to rehabilitate

[72] European Environment Agency. (2021). Nature-Based Solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction. EEA Report. (https://www.eea.europa.eu/publications/nature-based-solutions-in-europe)
[73] Network Nature. Taking nature-based solutions up the policy ladder: from research to policy action. Retrived from https://networknature.eu/sites/default/files/uploads/networknature-nbs-knowledgebrief01.pdf

urban brownfield sites, apply nature-based remediation solutions and stimulate green infrastructure to reduce urban pressure on agricultural and forest land as well as to solve complex soil pollution.

- **EU Biodiversity Strategy for 2030:** highlights the value and importance of NBS in fighting biodiversity loss, climate change and other critical challenges, and promises funding for investment in NBS.
- **Strategy on Green Infrastructure:** it outlines the value of NBS for biodiversity enhancement in an urban environment.
- **Forest Strategy:** the use of NBS turns out to be critical for improving, restoring, and maintaining the resilience and adaptive capacity of forest ecosystems to perform relevant ecological, economic and social functions (now and in the future) and not to cause damage to other ecosystems.
- **Regulation on land use, land use change and forestry:** it highlights the importance of NBS as a safeguard against the negative impacts on biodiversity and nature protection.
- **Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030:** it enhances and promotes disaster risk management and its integration in EU policies. The Action Plan presents ways that risks can be reduced through working with nature, while also providing human, biodiversity and climate benefits.
- **EU Strategy on Adaptation to Climate Change:** the updated strategy published in February 2021 explicitly recognises NBS as an essential tool for CCA and DRR. NBS are highlighted as a cross-cutting priority area to support the further development and implementation of climate adaptation strategies at all levels of governance.
- **Floods Directive:** it recognises the value of Nb as useful tools in natural, rural and urban areas to mitigate flood risks in watersheds and as a potential water retention approach that can be used in risk management plans.
- **Water Framework Directive:** in this framework NBS contribute directly to the aims of the Directive through integrated water management in terms of quality and quantity, which supports compliance with requirements for good ecological, physicochemical, and other statuses of surface waters and groundwater set by the WFD, as well as the active participation of stakeholders through co-design of NBS measures for water security.
- **Urban Agenda for the EU:** it makes explicit reference to NBS for the protection of species and habitats as well as climate change adaptation and disaster risk reduction. The focus of the agenda is on urban sprawl, development of brownfield sites and renaturalising or "greening" urban areas.
- **Farm-to-Fork Strategy:** aiming to make food system fair, healthy and environmentally friendly, NBS are explicitly recognized for their ability to help deliver better climate and environmental results and increase climate resilience.
- **Common Agricultural Policy:** it provides medium support for NBS for CCA and DRR.

EU policies, strategies, and approaches	Level of NBS support	Type of integration
European Green Deal	Strong	Explicit
Biodiversity Strategy for 2030	Strong	Explicit
Bioeconomy Strategy	Medium	Explicit
Forest Strategy	Medium	Implicit
Green Infrastructure Strategy	Strong	Explicit
LULUCF Regulation	Medium	Implicit
Action Plan on the Sendai Framework	Strong	Explicit
Adaptation Strategy	Strong	Explicit
Common Agricultural Policy	Medium	Implicit
Farm-to-Fork Strategy	Medium	Explicit
Water Framework Directive	Medium	Implicit
Floods Directive	Strong	Implicit
Urban Agenda	Medium	Explicit

Table 1: Support and integration of NBS in EU policies (Source: EEA Report, 2021)

2.4.2 Review of International Policy Framework

At the international level, the use of nature-based solutions has been promoted in important global agreements and in the broader international policy arena for issues such as climate, biodiversity, environment and disaster risk. All the political agreements, that will be analysed, recognise at different levels the prominent role that ecosystems play in promoting sustainable development and building resilience against disasters and climate change[74,75].

- **Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR):** it recognises the role of ecosystems and the environment as a cross-cutting issue in disaster risk reduction, emphasising that ecosystems must be considered in risk assessments, risk governance and investments in resilience.
- **2030 Agenda for sustainable development and Sustainable Development Goals (SDGs):** SDGs 6, 12, 13 and 14 also address the biological diversity of ecosystems, the services they provide and the adaptive and resilience they offer to society. Furthermore, it is recognised that climate change adaptation and disaster risk reduction through tools such as NBS contribute to or are integrated into all SDGs.
- **United Nations Framework Convention on Climate Change (UNFCCC):** it clearly addresses both climate change adaptation and disaster risk reduction, thus explicitly supporting NBSs. Many of the

[74] European Environment Agency. (2021). Nature-Based Solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction. EEA Report. (https://www.eea.europa.eu/publications/nature-based-solutions-in-europe)
[75] Network Nature. Taking nature-based solutions up the policy ladder: from research to policy action. Retrived from https://networknature.eu/sites/default/files/uploads/networknature-nbs-knowledgebrief01.pdf

determinated national contributions (NDCs) submitted to the UNFCC include NBSs. 104 of the 168 NDCs include NBSs in the adaptation section, 77 in the adaptation and mitigation section and 27 only in the mitigation plans.

- **United Nations Convention on Biological Diversity (CBD):** in 2019, Parties to the Convention on Biological Diversity presented possible targets and indicators for the post-2020 Global Biodiversity Framework related to the interconnections and interdependencies between biodiversity and climate change. These include NBS as effective ways to ensure resilience and minimise the negative impacts of climate change on biodiversity.
- **United Nations Convention to Combat Desertification (UNCCD):** since 2008 it has recognised the role of ecosystem services (especially in dryland ecosystems) in mitigating drought and preventing desertification. It also emphasises the synergies between the problems of desertification/land degradation and drought and climate change adaptation and biodiversity conservation.
- **New Urban Agenda – Habitat III:** the agenda clearly supports climate change adaptation and disaster risk reduction and promotes the adoption of NBS.
- **Ramsar Convention (Convention on Wetlands):** the latest Resolution of the Parties addresses the conservation and restoration of peatlands for climate change adaptation, disaster risk reduction and biodiversity enhancement to contribute to the achievement of the SDGs. This is why the Convention has been judged to offer an increasing level of support for NBS.

International policies, strategies, and approaches	**Level of NBS support**	**Type of integration**
SFDRR	Strong	Explicit
SDGs	Medium	Implicit
UNFCCC	Strong	Explicit
CBD	Strong	Explicit
UNCCD	Medium	Implicit
New Urban Agenda	Strong	Explicit
Ramsar Convention	Medium	Implicit

Table 2: Support and integration of NBS in International policies (Source: EEA Report, 2021).

2.5 NBS knowledge gaps and main social challenges

In recent years global and EU policies on sustainable development, disaster risk, climate and environmental issues have increasingly embedded NBS. Despite this, there are still numerous knowledge gaps that hinder the adoption and implementation of NBSs[76,77]:

[76] Davis, M., Abhold, K., Mederake, L. and Knoblauch, D. (2018). Nature-based solutions in European and national policy frameworks. Deliverable 1.5, NATURVATION. Horizon 2020 Grant Agreement No. 730243, European Commission. (https://www.ecologic.eu/sites/default/files/publication/2018/naturvation_report_1_5_final_110618.pdf)

[77] Network Nature. Taking nature-based solutions up the policy ladder: from research to policy action. Retrived from https://networknature.eu/sites/default/files/uploads/networknature-nbs-knowledgebrief01.pdf

- The **use of multiple concepts** is a source of confusion for both policymakers and practitioners.
- Decision makers' and investors' confidence may decline, eroding their support for NBS projects, due to a **lack of standards, technical and operational competence, knowledge, and financing for NBS implementation.**
- A significant problem that needs to be solved is **quantifying the effects, advantages, and cost-effectiveness of NBS**. In fact, the current data gap is exacerbated by how difficult it is to gather and evaluate data on the potential for their mitigation and the measurement of benefits.
- **Limited availability and poor quality of information** regarding the carbon storage and sequestration potential of different habitats.
- **Lack of accessibility to best practices and knowledge** may contribute to considering NBS as a non-viable option.
- **Accessing investment funding** for NBS is one of the main problems for public authorities involved in NBS implementation to date.

Particularly, evaluating the impact of NBS requires the collaboration of various actors, which is precisely why it is sometimes difficult to assess its real impact[78].

Through project work with stakeholders in cities and regions, the main barriers from a professional standpoint are found. A lack of implementation monitoring vs performance monitoring (which might lead to the loss of vital data) and short time periods that distribute and decentralize data among numerous agencies are a few of them.

From a scientific point of view, the inability to distinguish between the process and the outcome, the gaps in the methodology for monitoring and the stages of intervention implementation (micro, meso, macro, etc.), and the longer time frame for measuring effects are the main shortcomings of the monitoring process from a scientific perspective. The absence of long-term evaluations to evaluate impacts over time and assure consistency of monitoring measures. issues with utilizing less technical terminology to involve stakeholders in the data collection and monitoring process. Due in part to the different stakeholder perspectives on how stakeholders value NBS and the associated benefits, it is challenging to quantify intangible effects (like aesthetic pleasure) and spillovers (the effects of an NBS intervention may extend beyond the treated area or group), as well as account for trade-offs.

[78]European Commission, Directorate-General for Research and Innovation. (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners. Publications Office of the European Union. (https://data.europa.eu/doi/10.2777/244577)

The citizen monitoring experience is restricted, and information acquired about the effects of NBS is usually not made public or presented in a user-friendly way. Moreover, a social acceptability issue may result from this.

In addition to the gaps present on a policy level, there are several societal challenges that may impede the successful implementation of NBS[79].

Firstly, community involvement. The introduction of NBS often requires the cooperation of many stakeholders, including local residents and communities. In some cases, communities may be reluctant to participate in such projects if they are not adequately involved in planning and decision-making. This can be mitigated through transparent communication and active participation of communities from the beginning of the planning process.

Solutions could create conflicts of interest among stakeholders if they have different needs and objectives. For example, landowners might be reluctant to hand over land for other purposes, while real estate agents might prefer to use the land for other purposes. In this case, through negotiation and the active involvement of the parties in planning and design, conflicts could be resolved.

Other types of challenges that might slow down the implementation of NBS refer to the difficulty of access to financing or the influence of climate change. Often, investments might not be significant and thus not cover the total project costs. Funding could be increased through public-private partnerships and the search for alternative funding sources. While climate change influences the effectiveness of NbS through changing precipitation patterns or increasing the frequency of extreme events such as floods and droughts. This may necessitate the modification of existing projects to adapt to new environmental and climatic conditions.

2.6 Impact assessment method

As mentioned in the previous paragraphs, NBSs bring economic, environmental, and social benefits while building resilience and benefiting biodiversity. However, to better understand the strengths and weaknesses of NBSs, it is important to use an impact assessment method looking at real case studies. This allows us to gather data and evidence on the performance of NBSs in different urban contexts. In turn, this evidence can support smart policy decisions and adaptive co-management aspects of NBS management once installed, as well as improve the sustainability, well-being, and resilience of cities.

[79] EPA Network and Enca. (2020). Discussion paper from the Climate Change Interest Groups of the European Network of the Heads of Environment Protection Agencies (EPA Network) and Heads of European Nature Conservation Agencies (ENCA). Recommendations for overcoming barriers to mainstreaming the delivery of Nature-based Solutions. (https://epanet.eea.europa.eu/reports-letters/reports-and-letters/nature-based-solutions_interest-group-climate-change-and-adaptation.pdf)

In this case, in order to answer to the research question *"How can Nature-based Solutions mitigate the Urban Heat Island phenomenon in Mediterranean cities? And how can they have a positive impact on society in terms of healthy well-being?"* several parameters will be considered[80]. In more detail, the indicators considered belong to two categories: **health and well-being and green management**. The metrics were inferred from the monitoring and evaluation plans of several projects financed by the EU's Horizon 2020 Research and Innovation Programme. The indicators are then modified to fit the case study under consideration and the available data. Impacts are evaluated using quantitative and qualitative criteria in order to examine particular and specific qualities and provide exact answers. Due to the diversity of them, identifying and choosing such precise specifications may be a very challenging procedure. In this case, the choice was made on the basis of the *principle of simplification*, namely choosing a limited number of meaningful, relevant and feasible indicators to collect in order to provide useful information for the achievement of your objectives.

Health and well-being

1. **Self-reported mental health and wellbeing**

Description and justification	This indicator of mental health status is based on a validated and widely used questionnaire. A growing amount of evidence has shown a positive association between exposure to green spaces and general mental health and self-perceived well-being.
Definition	Self-reported mental health and wellbeing status
Strengths and weaknesses	+ Validated and widely used questionnaire to assess mental health status. - Self-reported
Measurement procedure and tool	Survey conducted on a sample of the general population
Scale of measurement	General population in residential neighbourhoods
Data collection frequency	Twice, before and after NBS implementation
Level of expertise required	Low
SDGs connection	Good health and wellbeing

2. **Morbidity, Mortality and Years of Life Lost due to poor air quality**

Description and justification	Air pollution has been related to numerous adverse health effects, typically expressed in several morbidity and mortality endpoints. Although the

[80] European Commission, Directorate-General for Research and Innovation. (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners. Publications Office of the European Union. (https://data.europa.eu/doi/10.2777/244577)

	impact of these health effects may seem low at the individual level, the overall public health burden is considerable as the entire population is exposed.
Definition	Reduction in life years (y) due to premature mortality compared to standard life expectancy. (Morbidity): Long-term (annual) incidence of chronic bronchitis due to poor air quality, calculated using atmospheric data of NO2 and PM10. (Mortality): Long-term (annual) incidence of mortality due to poor air quality, calculated using atmospheric data of PM2.5, PM10, O3 and NO2.
Strengths and weaknesses	+ Easy to define - The method needs corresponding air pollutant concentration, demographic and epidemiological input data
Measurement procedure and tool	The following aspects are usually considered: (i) the pollutants involved, and their air concentration levels, (ii) the health indicators analysed in terms of morbidity and mortality, (iii) the age groups affected and (iv) the time of exposure. The health response is usually calculated by: $\Delta R = IR \times CRF \times \Delta C \times Pop$ - ΔR is the response as a result of the number of adverse implications (cases, days or episodes) on all health indicators; - IR is the annual base morbidity/mortality rate (%); this information is available from the National Statistical Institute of each country; - CRF is the correlation coefficient between the change in concentration of the pollutant and the probability of incurring a specific health indicator (%; i.e. the relative risk (RR) associated with a change in concentration of 1 μg m-3); - ΔC indicates the change in pollutant concentration (μg m-3) after adoption of the adaptation/mitigation measure;

	- Pop is the population unit per age group exposed to the pollution.
Scale of measurement	From street to metropolitan scale
Data collection frequency	Daily, weekly, monthly or annually
Level of expertise required	Moderate
SDGs connection	SDG 3, SDG 15

3. Cardiovascular diseases (prevalence, incidence, morbidity and mortality)

Description and justification	Accumulating evidence supports the idea that ecological characteristics such as diurnal light and day cycles, sunlight exposure, seasons, and geographical features of the natural environment such as altitude, latitude and green spaces are important determinants of cardiovascular health and CVD risk. Recent studies and systematic reviews of empirical evidence have found support for the association between access to and use of green spaces and the prevalence and mortality of cardiovascular diseases and risks, as well as improved recovery rates from cardiovascular diseases.
Definition	Cardiovascular diseases (CDV): generally refers to conditions that involve narrowed or blocked blood vessels that can lead to a heart attack, chest pain (angina) or stroke Prevalence: it is a measure of the burden of disease in a population in a given location and at a particular time, as represented in a count of the number of people affected. Prevalence is a function of both the incidence and duration of disease. Incidence: it represents how quickly new cases occur relative to population size and the passage of time. Morbidity: it refers to the state of being diseased and the severity and impact of disease. Mortality: it is the number of deaths due to a disease during a specific time divided by the number of

	persons in that population at the beginning of the time period.
Strengths and weaknesses	+ Recent studies show that residential proximity to vegetation is associated with lower levels of stress, diabetes mellitus, stroke, and cardiovascular diseases - Limited empirical evidence as to the contribution of mechanisms involved in the beneficial cardiovascular effects of greenery
Measurement procedure and tool	Epidemiological data
Scale of measurement	-
Data collection frequency	Before and after NBS implementation
Level of expertise required	Medium-high
SDGs connection	SDG-3, SDG-11

4. Quality of Life

Description and justification	It indicates the global level of perceived quality of Life. It is capable to describe initial planning problems like perceived health in urban areas. Understanding NBS evaluation and NBS perceived benefits would be a major step in promoting existing NBS, as well as a key to success for new NBS projects
Definition	World Health Organization defines Quality of Life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns.
Strengths and weaknesses	+ Diagnostic tool to understand how people in a given area perceive and assess the benefits of NBS around where they live
Measurement procedure and tool	Indicator as a diagnostic tool: - To assess the overall satisfaction of individuals regarding their environment or existing NBS in their environment;

	- To assess users' satisfaction if a given NBS is targeted. As an assessment tool: - To measure the efficiency of an NBS after its implementation by comparison with environmental quality of life before the NBS implementation.
Scale of measurement	City; neighbourhood; object
Data collection frequency	Before and after NBS implementation
Level of expertise required	Medium calculation difficulty and required data
SDGs connection	SDG-3, SDG-11

5. Hospital admissions due to high temperature during extreme heat events

Description and justification	Heat waves are the most significant weather-related cause of human mortality worldwide.
Definition	The number of hospital admissions per 100 000 inhabitants due to high temperature during extreme heat events from baseline values.
Strengths and weaknesses	+ Easy to measure - Difficulties in ruling out other causes for hospital admissions
Measurement procedure and tool	This metric can easily be evaluated using public health data regarding daily emergency room admissions. These data can be used either to evaluate total emergency room admissions, or to assess hospital admissions for specific disease categories such as heat stroke, dehydration and cardiac arrest.
Scale of measurement	District to metropolitan scale
Data collection frequency	Before and after NBS implementation
Level of expertise required	Low to moderate
SDGs connection	SDG-3, SDG-13

6. Incidence of obesity

Description and justification	With the abundance of convenient, palatable, energy-dense foods and the decreasing demand for physical activity in habitual lifestyles, the contemporary environment is shifting the energy

	balance in favour of weight gain. In adults, obesity is associated with an increased risk of cardiovascular disease, type 2 diabetes and all-cause mortality. Most of the associated mortality and morbidity are mediated by major obesity-related chronic diseases, such as cardiovascular disease, diabetes and cancer. Studies have found that most research undertaken has found a positive association between green space and obesity-related health indicators, but that the relationship varies by age, socioeconomic status and type of green space measure, and results are inconsistent and conflicting across studies. In addition to objective opportunities to access green space for physical activity and the availability and affordability of healthy food, the actual use of green space could be a factor in counteracting obesity.
Definition	Speed at which new cases of obesity occur in adults and children in relation to population size and the passage of time.
Strengths and weaknesses	+ Some evidence as to an association between exposure to nature and obesity-related health indicators - Inconsistent and mixed results across studies
Measurement procedure and tool	Epidemiological data
Scale of measurement	-
Data collection frequency	Before and after NBS implementation
Level of expertise required	Methodology and data analysis: high expertise in psycho-social research Quantitative data collection: no expertise
SDGs connection	Goal 3, goal 11

Additional parameters related to society and health-well being
Green Management

1. **Perceived quality of urban green, blue and blue-green spaces**

Description and justification	The perceived quality of the space is one of the factors influencing the success of the public space,

	especially in terms of user involvement in activities. The value of this indicator is seen in the evaluation and promotion of the social benefits of NBS in general and as a tool for monitoring specific aspects of individual NBS. The indicators that determine the quality of the area are: • Attractiveness of the area for a specific use (i.e. natural elements and their arrangement in green spaces can facilitate calmness and serenity, recovery from stress and improvement of mental fatigue); • Sense of safety of the place (i.e. good orientation in the place, appropriate lightness of the place and the setting of spatial components can motivate people to explore); • Access to green space (i.e. accessibility in terms of proximity to users' homes and perceived accessibility can affect the health of citizens, leading to a reduction in body mass index, overweight and obesity levels, improved mental health and well-being and increased longevity of the elderly); • Pleasantness of the place in terms of sounds, smells and microclimatic conditions (i.e. sensory stimulation is particularly important for elderly people with dementia as it can improve);
Definition	Self-reported perceptions of space quality of NBS
Strengths and weaknesses	+ Monitoring tool for NBS that can help to maintain, improve specific aspects of space design - The questionnaire needs to be adjusted to NBS specifics
Measurement procedure and tool	Scale inventory / Questionnaire
Scale of measurement	Survey adjusted according to the individual NBS and intended use

Data collection frequency	Before and during NBS implementation
Level of expertise required	Low
SDGs connection	SDGs 2,3,4,6,11,13,15,16

2. **Satisfaction with green and blue spaces**

Description and justification	Indicator of the quality of green and blue spaces. The quality of spaces is not only an important determinant for the use of these spaces, but also a potential modifier of the health effects of these spaces. It is hypothesised that the implementation of nature-based solutions can improve the availability and quality of green and blue spaces in the neighbourhood.
Definition	Self-reported satisfaction with the green and blue spaces in the neighborhood.
Strengths and weakness	+ Low consideration in previous studies of the quality of green spaces in the association between exposure to green space and health - Self-reported
Measurement and procedure	Survey to observe a potential change in the satisfaction of people
Scale of measurement	General population in residential neighbourhoods
Data collection frequency	Twice, before and after the implementation of NBS
Level of expertise required	Low
SDGs connection	SDG-3, good health and wellbeing and SDG-11, sustainable cities and communities

CHAPTER TWO – BARCELONA AND TURIN

3.1 Barcelona (BCN) – Trees for life: the rapid growth and the need for a new transformation

In the north-eastern corner of the Iberian Peninsula, in the Spanish Levant, Barcelona lies on a plain about 5 kilometres wide, bordered by the Mediterranean Sea to the east, the Collserola Mountains to the west, the River Besòs to the north and the River Llobregat to the south-west. It is the capital of Catalonia, one of the territory's 17 autonomous communities. It is the second largest city in Spain in terms of population, after the capital Madrid, the second largest industrial and financial centre and the largest commercial and tourist port. Barcelona has been the protagonist in the last decade of a rapid growth that has led it to have a population of about 1.6 million people and a density of 16 thousand people per km2, the fourth highest in Europe.

Barcelona has undergone rapid growth and urbanisation over the last two decades, due in particular to two major events that the city has hosted and that have allowed it to undergo a more radical transformation than any other city in Western Europe: the 2004 Olympic Games and the 2004 Universal Forum of Cultures. Huge investments were made to create new infrastructure. Urban renewal followed a culture-led approach, resulting in high quality architecture. This has led to a major gentrification phenomenon: run-down neighbourhoods of the city, such as El Raval, have been uplifted with the arrival of museums, bars, hotels; but elsewhere, large groups of less affluent people and/or immigrant communities have occupied the flats no longer desired by Spaniards[81].

The driving force behind Barcelona's urban revolution has been economic growth. Growth driven by the presence of the port, industrial zones and business tourism. For example, the port, the Zona Franca, is the largest and most active industrial area in Spain and one of the most dynamic in Europe. The industrial zone is undergoing a major transformation, with the development of numerous new infrastructure projects. However, this remarkable growth has occurred and continues to occur at the expense of the environment and society, bringing with it several consequences[82].

[81] Barcelona Field Studies Centre. Barcelona Urban Development and Change. Retrieved from https://geographyfieldwork.com/BarcelonaUrbanDetail.htm

[82] Vox. (2019). Barcelona's remarkable history of rebirth and transformation. How the city grew, from pre-Christian Romans to Cerdà to the 1992 Olympics. Retrieved from https://www.vox.com/energy-and-environment/2019/4/8/18266760/barcelona-spain-urban-planning-history

In fact, the city is currently suffering from a sharp increase in prices, particularly of real estate, gentrification is driving residents away, there are too many cars bringing noise, air pollution and congestion, and the creation of new infrastructure is threatening the city's flora and fauna. All this is accompanied by the formation of urban heat islands, caused by rising temperatures, which are affecting Spain, particularly Barcelona on an increasingly regular basis. In turn, the energy consumption associated with the increased demand for cooling urban spaces. These aspects worsen during the heat waves that are affecting Spain on an increasingly regular basis[83].

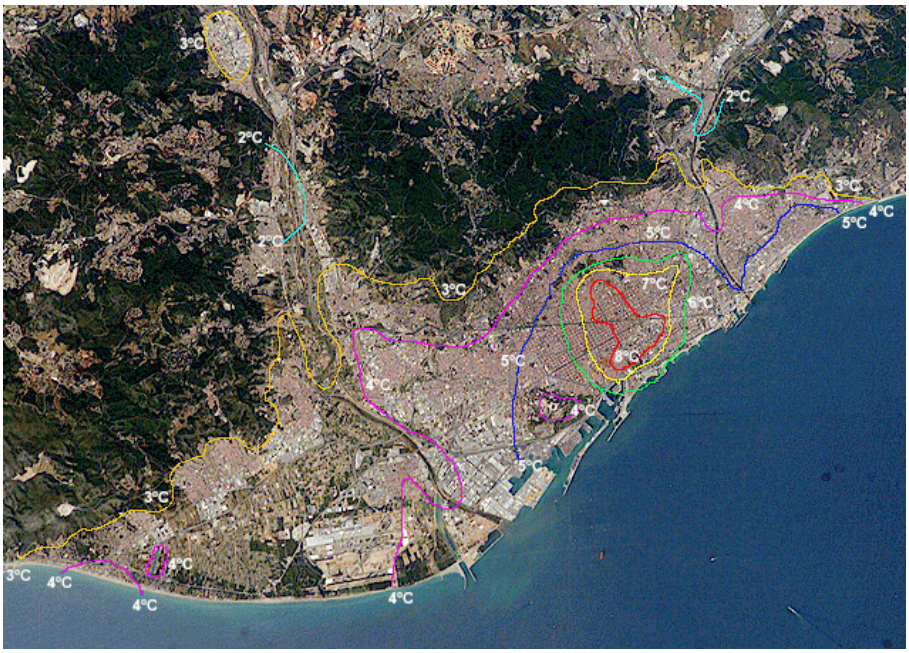

Figure 6: Barcelona's urban heat island effect leads to higher temperatures in the city than the surrounding rural areas. The difference is most marked at night during winter anticyclonic conditions. (Source: Barcelona Field Studies Centre)

In this context, as part of the Urban-CLIMPLAN project, the Centre for Land Use Policies (CPSV UPC) studied urban heat islands in the Barcelona metropolitan area and the main factors that cause them. The study analysed the spatial distribution of land surface temperature and land surface air temperature. Among the results of the project was the identification of the formation of nocturnal urban heat islands, which, from a scientific point of view, are particularly relevant to health due to the increased vulnerability of the population[84].

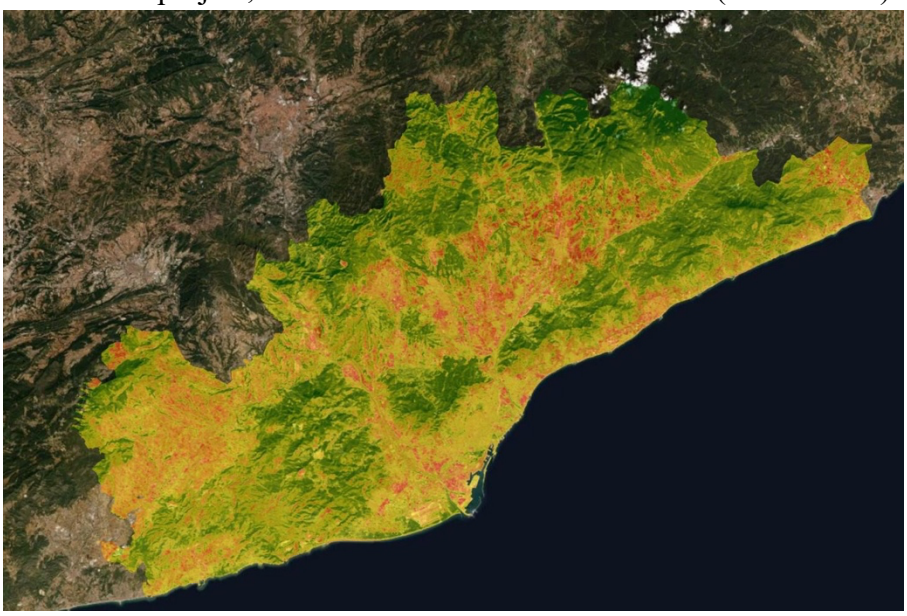
Figure 7: Barcelona's urban heat island (Source: CIT UPC)

A heat wave causes 27% higher deaths of elderly individuals in Barcelona. The date fluctuates depending on how long the heat wave lasts. Heat is a factor in 1.6% of summertime fatalities. As the elderly are the most

[83] Technology Center, UOC. (2019). Effects of the urban heat island on Barcelona metropolitan region. (https://cit.upc.edu/en/portfolio-item/heat-island-barcelona/)
[84] Barcelona Field Stuedies Centre. Barcelona's Urban Heat Island. Retrieved from https://geographyfieldwork.com/BarcelonaHeatIsland.htm

vulnerable, death rates grow as temperatures rise the older a population is. Deaths in extremely hot weather have increased by 15% for those aged 60 to 70, 17% for people aged 70 to 80, and 26% for people aged 80 to 90. Mortality rates for people over 90 years of age can reach 36%. Moreover, infants younger than one year old are quite susceptible.

Therefore, the main urgency now is to bring about a new change, in an inclusive and sustainable way, thus in a model for the 21st century, designed around people and public spaces.

3.1.1 Current environmental and health situation in BCN

In the last decades, these abrupt changes in the city have led to significant negative environmental and social consequences. In urban areas, social inequalities often also translate into health inequalities, as in the case of Barcelona. These are influenced by the environment and the infrastructure that is built, as well as socio-economic factors. To date, improving public health, thus reducing social inequalities, has become one of the main priorities of the city of Barcelona. Effectively monitoring and evaluating this data can be effective to then implement plans and solutions that address social inequalities in health and can help to improve health and social support in disadvantaged populations[85].

In general terms, in terms of **quality of life**[86], Barcelona ranks fourth, after New York, London and Los Angeles, among the 50 cities ranked in the Raking of Sports Cities 2021, prepared by the consultancy firm Burson Cohn and Wolfe. The Catalan capital is among the best cities in the world in the rankings for quality of life, safety and equity. Barcelona is a city where living well is easy. However, by analysing more specific indicators, contrasting results could be obtained.

In terms of **air quality**[87], considered the main environmental cause for human health, the Barcelona Public Health Agency assesses it. The results for 2018 show that levels are still above the WHO recommendations for NO2, particulate matter (PM10 and PM2.5), benzene, ozone and benzo(a)pyrene, and that the population potentially exposed to levels above the WHO recommendations (of 40 µg/m3 for NO2 and 20 µg/m3 for PM10) is 48% for NO2 and 95% for PM10.

However, these data vary between different parts of the city. People living in more central districts, although more affluent, find it more difficult to breathe clean air due to the presence of traffic, industry and other sources of pollution. In this regard, the potential exposure of the population to higher-than-normal levels of NO2 varies

[85] Daban, F., Pasarín, M.I., Borrell, C., Artazcoz, L., Pérez, A., Fernández, A., Porthé, V., Díez, E. and the Barcelona Health in the Neighbourhoods Group. (2021). Gaceta Sanitaria, Volume 35, Issue 3, p. 282-288. (https://doi.org/10.1016/j.gaceta.2020.02.007)
[86] Ajuntament de Barcelona. (2020). Barcelona en cifras 2020. Principales indicadores económicos del área de Barcelona. Retrieved from https://ajuntament.barcelona.cat/economiatreball/sites/default/files/documents/DataSheet2020_web_esp.pdf
[87] Agència de Salut Pública and Consorci Sanitari de Barcelona. (2020). Avaluació de la qualitat de l'aire a la ciutat de Barcelona. Informe 2018. Retrieved from https://bcnroc.ajuntament.barcelona.cat/jspui/bitstream/11703/115442/1/Informe_qualitat-aire-2018.pdf

from 7% (Nou Barris district) to 100% (Eixample district). NO2 varies from 7% (Nou Barris) to 100% (Eixample). While population exposure to higher-than-normal levels of PM10 is estimated at 77% in Horta-Guinardó, 85% in Nou Barris, 96% in Sant Andreu and 97% in Sarrià-Sant Gervasi. The same trend is recorded for exposure to higher levels of PM2.5. Thus, according to the data, one in four schools is exposed to an excess of NO2, 35% of the total population is exposed to an excess of NO2 and 100% to PM2.5, and the Eixample district is the most polluted.

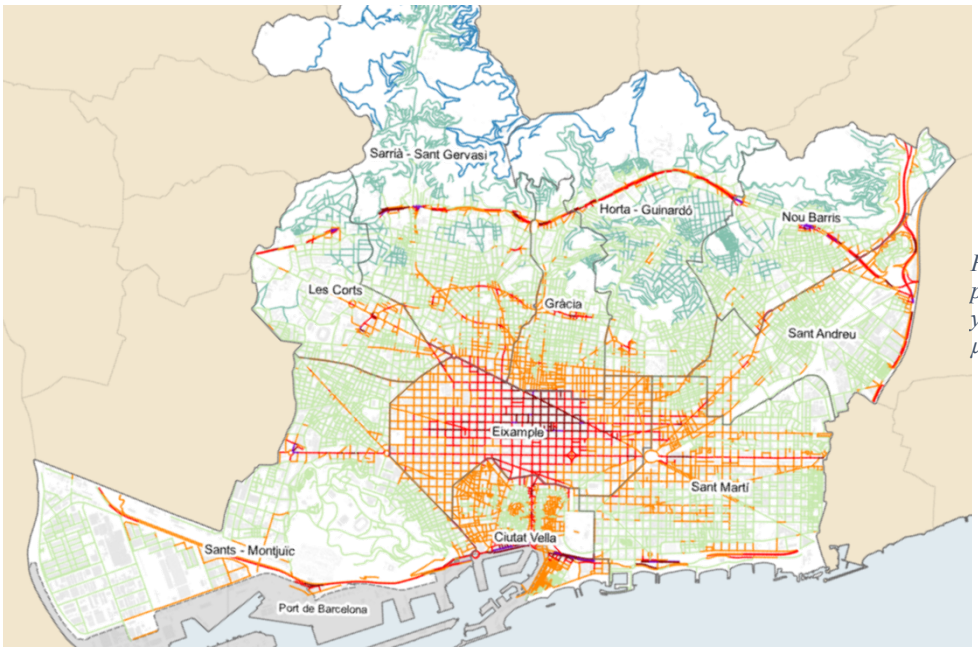

Figure 8: Potential exposure levels of the population to the annual average NO2 during the year 2018. Green < 40 µg/m3 ; Red/Orange > 40 µg/m. (Source: Ajuntamiento Barcelona)

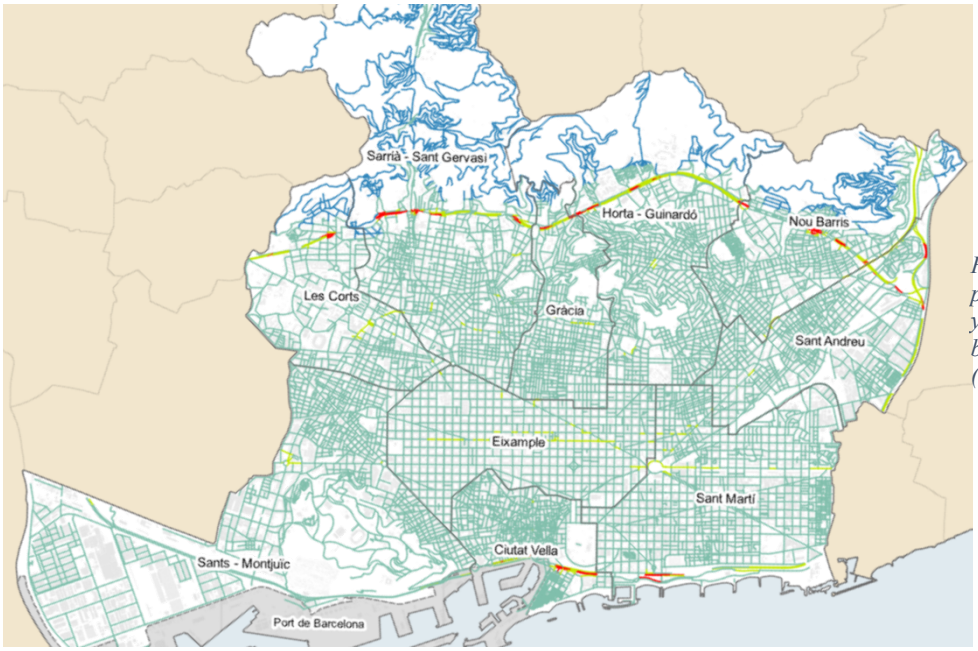

Figure 9: Potential exposure levels of the population to the annual average PM10 during the year 2018. Light blue < 15 µg/m3; Blue and Green between 15 µg/m3 - 40 µg/m3 ; Red > 40 µg/m3. (Source: Ajuntamiento Barcelona)

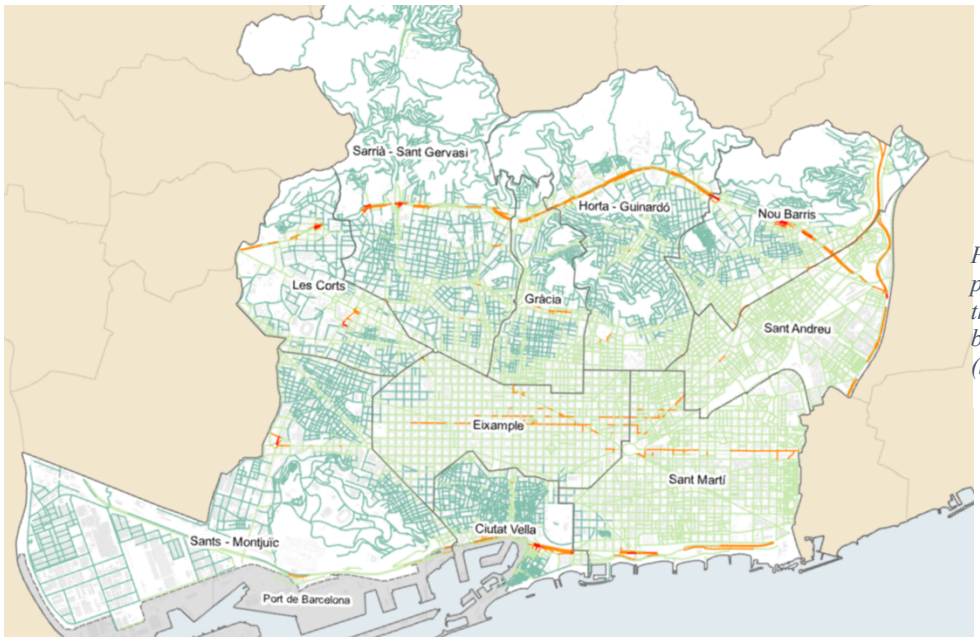

Figure 10: Potential exposure levels of the population to the annual average of PM2.5 during the year 2018. Blue < 10 µg/m3; Green and orange between 10 µg/m3 - 25 µg/m3; Red > 25 µg/m3. (Source: Ajutamiento Barcelona)

Chronic exposure to air contamination has obvious effects on public health, especially for the most vulnerable part of the population (children, adolescents, the elderly, the poor), leading to an increase in mortality and respiratory diseases. Contamination is responsible for 7% of natural deaths (approximately 1000 deaths per year); 11% of new cases of lung cancer (approximately 110 cases per year) and 33% of new cases of childhood asthma (approximately 525 cases per year)[88].

According to data from the Barcelona Public Health Agency from 2010 to 2018, the mortality attributable to excess PM2.5 in 2018 is 2% in residents aged 30 or older. This roughly represents an average of 424 deaths per year. If NO2 levels are taken as an indicator of air contamination, mortality is increasing. This is at 5% in 2018, or an average of 757 deaths per year.

[88] Agència de Salut Pública de Barcelona and Consorci Sanitari de Barcelona. (2019). Qualitat de l'aire i impacte en salut a Barcelonna 2019. Retrieved from https://www.aspb.cat/wp-content/uploads/2020/10/ASPB-INFO_qualitat_aire_2019-02.pdf

Among the recommendations made by the Agency to mitigate this situation is the increase of green areas and urban vegetation. In fact, the introduction of larger green spaces could bring significant benefits to the community. Today, in terms of **green spaces**[89], Barcelona has 3,611 hectares, which represent 35.3% of the municipal surface.

Figure 11: Barcelona green areas. (Source: Ajuntamiento Barcelona)

The overall endowment of green spaces is therefore quite good, but only 30% of them are strictly public and urban. The 1,076 hectares of public urban green areas are mainly concentrated in three districts: Sants-Montjuïc (27.8%), Sant Martí (15.4%) and Horta-Guinardó (11.3%). In contrast, there is a more modest presence of green spaces in districts with historic centres, such as Gràcia (3.6%), Sant Andreu (5.1%) and Ciutat Vella (5.9%); this is due to the compactness of the urban fabric and its smaller surface area. With the addition of Collserola, Sarrià-Sant Gervasi is the district with the largest area of green space, more than 1,266 hectares. The city's greenery also includes roadside trees. In the last 30 years, the number of trees has doubled to over 153,000 (1 tree every 8.6 m). Green roofs in height currently account for 3.5 hectares in Barcelona, although the potential area, considering public buildings close to green corridors, is 65 hectares, a figure that could be expanded with private and entrepreneurial initiative. As far as green walls are concerned, however, there are only isolated and private cases. The municipality of Barcelona is currently working on encouraging

[89]Ajuntament de Barcelona. (2020). Plan del Verde y de la Biodiversidad de Barcelona 2020. Retrieved from https://ajuntament.barcelona.cat/ecologiaurbana/sites/default/files/PlanVerde_2020.pdf

the creation of more urban green spaces in order to mitigate the effects of climate change; the city has drawn up the Barcelona Green Infrastructure and Biodiversity Plan 2020 with the aim of maximising the presence of green spaces to improve the socio-health aspect[90].

3.1.2 BCN Climate Plan 2018-2030[91]

The primary emphasis of the city of Barcelona's policy is the fight against climate change, which will benefit the environment and, more importantly, protect public health.

For this reason, Barcelona has made the decision to further its battle against climate change, which was previously strengthened in 2015 with the Climate Commitment, by approving a Climate Plan to get the city ready to abide by the Paris Agreement.

To this end, the city hall adopted the Climate Plan 2018-2030. The main spheres on which climate change has an effect and on which the Plan wants to take efficient action are:

1. ***People's health and survival:*** rising temperatures have a direct effect on mortality, particularly of the elderly and children. In addition, through the spread of new viruses, diseases increase as well as the incidence of respiratory diseases.
2. ***People's quality of life and public safety:*** climate change reduces the quality of life due to extraordinary weather events (such as heat islands).
3. ***Guarantee of basic supplies:*** one of the main consequences is a reduction in the availability of resources, e.g., water. There is also an increased demand for energy due to extreme temperatures.
4. ***Cost of living:*** the cost of food and water increases, at the same time there is an increase in poverty.
5. ***Environment:*** changes threaten existing species and landscapes and the appearance of new pests and weeds.

Hence, one of the Plan's primary objectives is to preserve the community and its health. To achieve this, the Plan's primary goals are to reduce the excessive temperature rise and enhance air quality, which will enhance thermal comfort in the city's public spaces and buildings and enable the development of a network of locations where people can seek refuge from extreme heat and receive medical attention.

[90]Ajuntament de Barcelona. The energy, climate change and air quality plan of Barcelona (PECQ 2011-2020). Retrieved from https://mycovenant.eumayors.eu/docs/seap/381_1331047596.pdf
[91]Barcelona City Council. (2018). Barcelona Climate Plan 2018-2030. Retrieved from https://cdn.locomotive.works/sites/5ab410c8a2f42204838f797e/content_entry5ae2f905a2f4220ae645f026/5afc10d27478206be9209e60/files/Bcn_Climate_Plan.pdf?1526468818

With the combined goals of reducing the consequences of climate change and integrating the community in adaptation, the Climate Plan seeks to encourage the use of roofs, walls, and partition walls as productive areas where new urban spaces may be created for thermal activities and varied applications. These surfaces turn into possible settings for delivering socio-environmental services and generating favorable effects on public health.

The expansion of green areas and locations is another significant step the city of Barcelona wishes to implement. This is vital both to prevent the adverse effects of environmental change and to enhance inhabitants' health. By 2030, the Barcelona Climate Commitment wants to increase green space by 1.6 km^2. A 5% increase in tree cover is anticipated by 2037 according to the Trees Master Plan, which also specifies criteria for tree selection and encourages a range of species that are appropriate to the urban ecology and climate.

3.1.3 Trees for Life

The Master Plan for Barcelona's Trees 2017-2037[92], Trees for Life, is the plan introduced by the city of Barcelona to ensure the development of an equitable, sustainable and inclusive city, improving the comfort and health of the population, through the improvement of features such as environmental quality, urban land balance and public services for all neighbourhoods in the municipality. To ensure this, the city's green infrastructure, particularly trees, plays a key role. Indeed, if properly planned, developed, managed and maintained, it contributes to the human and ecological development of the city, to the point of becoming a life-supporting system.

The density and extension of the city meant that the inclusion of nature through parks, gardens and trees was difficult due to the lack of space, road layout and location of buildings. Currently, according to the study “Ecological Services of Barcelona's Urban Green Areas” there are 1.4 million trees in the city area, covering 25.20 per cent of the territory. For this reason, the urban agenda has set the goal of reviewing and upgrading the trees and other green infrastructure present, in order to positively impact citizens in a healthy way. Fundamental, however, is to select tree species that are more appropriate for the city, able to withstand the particular characteristics of the Mediterranean climate, with mild winters and hot, dry summers, with plenty of sunshine and irregular rainfall throughout the year.

Considering the ecological, environmental, social and landscape services and benefits that trees bring to the city as living beings, the Plan refers to trees in the city as the tree population or urban canopy. Urban trees define the urban fabric of cities, improve the health and well-being of people and determine the standard of

[92]Barcelona City Council. (2019). Trees for Life: Master Plan for the Urban Forest of Barcelona 2019-2030. (https://ajuntament.barcelona.cat/ecologiaurbana/sites/default/files/Pla-director-arbrat-barcelona-ENG.pdf)

public places, with positive social and environmental effects. In particular, the following beneficial characteristics are emphasised:

- ***Positive effects on people's health:*** due to the psychological and physical benefits of physical and social activities performed by people in contact with the environment, green infrastructure has a favourable influence on life expectancy and the elimination of health inequalities, thus improving mental health.
- ***Building emotional bonds:*** for many people, following the life cycle of trees is also their closest connection with nature, to the point that an emotional bond is often established (biophilia).
- ***Creation of meeting places:*** the shade provided by trees encourages human activity and creates a place for conviviality and social cohesion. It is particularly appreciated by groups that spend more time outdoors, such as children, young people, the elderly and newcomers.

In general, the Master Plan for Barcelona's Trees 2017- 2037 establishes five objectives to guide the planning, management, and future conservation of Barcelona's trees:

1. To have a tree stock that forms a true green infrastructure, achieving maximum connection with the surrounding urban and natural environment.
2. Obtaining the greatest number of environmental, social and economic services from trees.
3. To have a tree stock that is biodiverse and in good condition and gives identity to the city.
4. Having a tree stock as a tool for adaptation to climate change.
5. To achieve good coexistence between the public and trees and to encourage society to value trees more.

Quantitatively, Barcelona hopes to have 30 per cent of the city covered with trees by 2037, 40 per cent of which are adapted to climate change. Creating a species-rich tree population so that no single tree species exceeds 15% of the total urban population. Finally, the city aims to ensure that all information on the properties and services offered by each tree is made available to residents and visitors through interactive technology that fosters citizen knowledge and collaboration.

3.1.4 Results

Morbidity, Mortality and Years of Life Lost due to poor air quality					
When?			Annually		
How?			Epidemiological data		
Year	**Deaths**	**Population**	**Respiratory patients**	**Mortality rate (Deaths/Population)**	**Morbidity rate (Respiratory patients/Population)**
2013	14.855	1.611.822	22.193	0,009	0,014
2014	14.835	1.602.386	23.657	0,009	0,015
2015	15.478	1.604.555	24.152	0,010	0,015

2016	15.183	1.608.746	24.771	0,009	0,015
2017	15.574	1.620.809	25.451	0,010	0,016
2018	15.238	1.620.343	19.962	0,009	0,012
2019	14.401	1.636.762	20.686	0,009	0,013

Age/Years	**2015**			**2019**		
	Deaths	**Life Expectancy**	**Years of life lost**	**Deaths**	**Life Expectancy**	**Years of life lost**
0-4	34	81,91	2.784,94	29	82,78	2.400,62
5-14	17	75,08	1.276,36	7	75,95	531,65
15-24	30	65,15	1.954,5	17	66,01	1.122,17
25-34	60	55,3	3.318	51	56,14	2.863,14
35-44	168	45,49	7.642,32	120	46,31	5.557,2
45-54	468	35,89	16.796,52	420	36,65	15.393
55-64	945	26,82	25.344,9	891	27,51	24.511,41
65-74	1.773	18,36	32.552,28	1.726	19,04	32.863,04
75 >	11.983	9,23	110.603,09	11.140	9,74	108.503,6

Hospital admission due to high temperature during extreme heat events (hospital admissions for specific disease categories such as diseases of the circulatory system and diseases of the respiratory system)							
When?				Before and after the implementation			
How?				Epidemiological data			
Disease of the circulatory system							
2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
13,55%	13,70%	13,64%	13,73%	N/A	N/A	11,36%	N/A
Disease of the respiratory system							
2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
9,76%	10%	10,10%	10,10%	N/A	N/A	10,22%	N/A

Pollution Index								
When?				Before and after the NBS implementation				
How?				Data collected				
2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
75.9	70.9	73.2	71.0	69.4	69.8	65.8	64.2	64.8

Quality of life Index								
When?				Before and after the NBS implementation.				
How?				Response of population and data collected				
2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
81.5	83.3	93.3	159.0	147.6	135.2	141.9	141.1	134.3

Health Care Index								
When?				Before and after the NBS implementation.				
How?				Data collected				
2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**

58.5	69.8	69.5	70.8	73.0	72.0	75.4	77.5	77.7

In addition to the above data, a written interview was conducted with the head of the Barcelona Natura Plan, and the head of the Trees for Life Project. The main objective was to validate the data found and at the same time obtain more information regarding the status of the project and how it is benefiting the citizenship, in particular the state of health.

3.2 Turin (TRN) - proGIreg: the "metropolisation" of the city and climate change

In the north-east of Italy, bordered by the rivers Stura di Lanzo, Sangone and Po and facing some of Italy's most important mountains, lies the city of Turin, known as "the city of four rivers[93]" because, in addition to the three watercourses just mentioned, it is also crossed from west to east by the river Dora Riparia. Turin occupies an area of 130 km^2 and with 2,247,780 inhabitants of which 890,000 are residents, it is the fourth largest Italian municipality by population. The capital of Piemonte is Italy's third largest economic-productive complex, in the years of the post-war economic miracle it was one of the components of the industrial triangle, and is one of the country's major university, tourist, scientific and cultural centres.

Throughout the 20th century, Turin was the *ville industrielle* par excellence: the factory city. Until, with the arrival of the system crisis at the end of the 1970s, Turin took the opportunity to radically transform itself in terms of production and morphology. The city's first Master Plan was published in 1995, focusing on the implementation of public transport, the redevelopment of the industrial fabric and the redevelopment of the city centre. In this phase, the public sector plays a role in guiding and supporting change. Major events were organised, from the Winter Olympics to the 150th anniversary of the Unification of Italy, which supported Turin's transformation. In addition to the

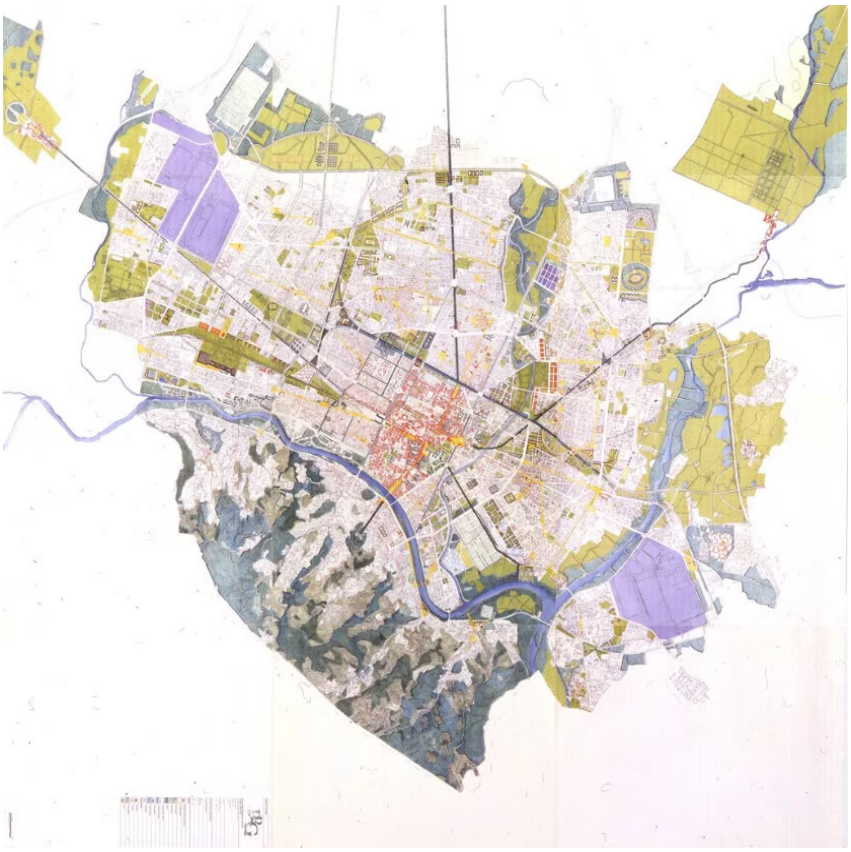

Figure 12: Turin Municipal General Regulatory Plan (1995), structure diagram. (Source: Museo Torino)

[93] Dario Lanzardo. (2011). La città dei quattro fiumi. Torino lungo le sponde di Po, Dora, Stura, Sangone. Con una passeggiata letteraria in compagnia di Giovanni Tesio. Edizioni del Capricorno.

physical mutation of the city, there is also a change in society, with a strong increase in the foreign population. A process of urbanisation, also referred to as "metropolisation", thus began[94].

Turin's ambitious urban revolution returned a city in the vanguard. This was based on three main physical and symbolic axes of the city: the Po axis, the Corso Marche axis and the Viale della Spina Centrale axis. The first focuses on the environmental, landscape and historical part of the city. The second axis concerns instead the Turin conurbation, oriented to accommodate the relocation of productive activities and services. The third and last instead represents the location of a railway and metro system that has made access to Turin easy from all directions. The transformation was designed for the citizens and therefore in function of making the city more liveable and usable. Turin's future perspective is to incorporate the entire metropolitan area into the urbanisation process, thus including the plain, the hills and the Alps.

This frenetic development, simultaneously with climate change, is having particular consequences for Turin, including the phenomenon of heat islands. According to a CNR study, in Turin a 10 % increase in the central core of areas with high land use and low tree cover is associated with an increase in the intensity of the average summer heat island of 4 °C[95] . Major events of rising temperatures and subsequent heat island formation were recorded in 2003, 2006, 2015 and 2017[96]. Recently, between May and June 2022 have been recorded three heat waves. The May wave lasted for about 22 days, at the same time the average number of deaths observed among the over-65 population was 22.1. This was statistically higher than the expected number of 20.6 deaths per day for the same period[97].

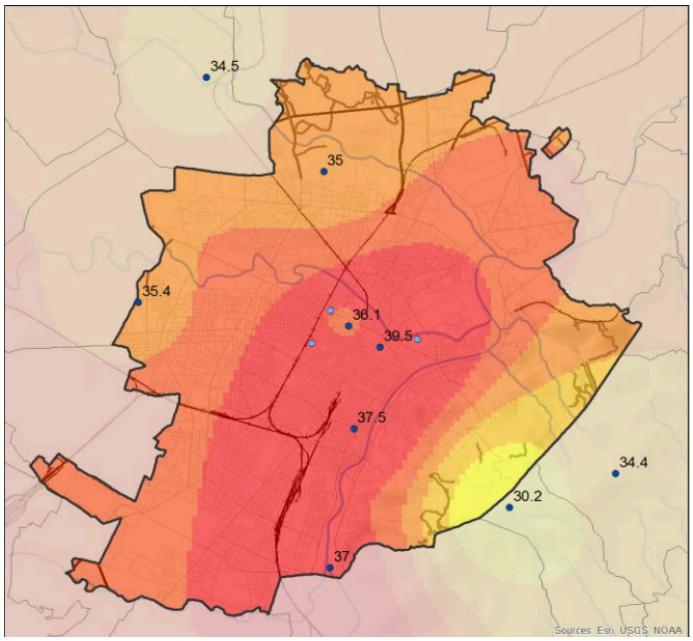

Figure 13: Maximum temperatures in 2015. (Source: Comune di Torino)

Satellite analysis results from Arpa Piemonte recorded warmer areas in industrial zones and cooler areas in areas with open water and vegetation[98]. Overall, according to Arpa's study, 27% of Turin's territory falls in an area with a low heat island risk, 44% in an area with a medium risk and 2% in an area with a high risk. For this reason, Turin has decided to draw up plans through which to mitigate this phenomenon and at the same

[94] Martini, F.M. and Pirulli, N. (2011). Torino: storia di una città. Museo Torino Rivista. https://www.museotorino.it/resources/pdf/magazine/rivista_mt_01.pdf

[95] Morabito, M., Crisci, A., Guerri, G., Messeri, A., Congedo, L., Munadò, M. (2021). Surface urban heat islands in Italian metropolitan cities: Tree cover and impervious surface influences. Science of the Total Environment, Volume 751. (https://doi.org/10.1016/j.scitotenv.2020.142334)

[96] Città di Torino. Department for Environmental Policies with the coordination of the Environment Area. Climate Resilience Plan. Turino 2030 Sustainable | Resilient. Retrieved from http://www.comune.torino.it/ambiente/bm~doc/resilienza-climatica_en.pdf

[97] Arpa Piemonte. (2022). Effetti sulla salute delle ondate di calore: valutazione dell'andamento della mortalità nei mesi di maggio e giugno 2022 a Torino. Retrieved from http://www.arpa.piemonte.it/news/effetti-sulla-salute-delle-ondate-di-calore-valutazione-dell2019andamento-della-mortalita-nei-mesi-di-maggio-e-giugno-2022-a-torino

[98] DERRIS. Analisi multi-pericoli nella città di Torino e nei distretti industriali. Pericolosità ed esposizione. Retrieved from http://www.comune.torino.it/ambiente/bm~doc/02---derris_analisi_ponte_sept14.pdf

time combat the consequences of climate change. In addition to the phenomena of heat islands and rising temperatures, Turin has also had to deal with major flooding episodes. In 1994, 2000 and 2016, the city suffered extensive damage from river flooding.

As part of the "Europe 2020" strategy, Torino has joined the European Covenant of Mayors and Smart Cities initiatives, pledging to reduce CO2 emissions. Turin has also developed strategies and actions to adapt to the impacts of climate change. In this context, the city joined the "Mayors Adapt" initiative, deciding to contribute to the overall objective of the EU adaptation strategy and to create a more climate resilient Europe. Furthermore, through the LIFE DERRIS (DisastEr Risk Reduction InSurance) project, it will implement a first methodological experimentation of the overall local adaptation strategy to prepare for the unavoidable effects of climate change and to improve resilience against them[99].

3.2.1 Current environmental and health situation in TRN

Turin's socio-health situation has been affected by urban transformation and the impacts of climate change. This is confirmed by a recent study published in the scientific journal Environmental Research, conducted by Marta Ellena, researcher at the Euro-Mediterranean Centre on Climate Change (CMCC) and Giuseppe Costa, epidemiologist at the Piedmont Regional Epidemiology Unit. Through a quantitative analysis, the researchers analysed the trends in cold and heat attributable mortality risk for the period 1982-2018[100]. The results suggest an increase in mortality linked to temperature variation, denoting a maladaptation of citizens to extreme weather events. An analysis by Arpa Piemonte also underlines among the socio-health impacts of temperature increase and heat island formation an increase in mortality, morbidity and a worse quality of life[101].

In this regard, according to the latest Sole24Ore survey, published last December, Turin ranks 40th out of 107 Italian provinces for quality of life. The Piedmontese capital has lost nine positions since 2021, and the causes are mainly attributable to poor air quality. An indicator for which Turin is almost at the bottom of the ranking, 105 out of 107, with a PM10 index of 86 out of an average of 51[102].

Data that could get worse, if we take into consideration the assessment of possible future trends conducted by ARPA Piemonte. As far as heat waves are concerned, the three main parameters that characterise them are expected to increase, namely the number of summer days in a heat wave, the number of heat waves and the

[99] Città di Torino. InformAmbiente. (2018). Cambiamenti Climatici. Retrieved from http://www.comune.torino.it/ambiente/cambiamenti_climatici/index.shtml

[100] Ellena, M., Ballester, J., Costa, G., Achebak, H. (2022). Evolution of temperature-attributable mortality trends looking at social inequalities: An observational case study of urban maladaptation to cold and heat. Environmental Research, Volume 214, Part 3. (https://doi.org/10.1016/j.envres.2022.114082)

[101] Città di Torino. Department for Environmental Policies with the coordination of the Environment Area. Climate Resilience Plan. Turino 2030 Sustainable | Resilient. Retrieved from http://www.comune.torino.it/ambiente/bm~doc/resilienza-climatica_en.pdf

[102] Lab24, Il Sole 24 Ore. Qualità della vita, Torino. Retrieved from https://lab24.ilsole24ore.com/qualita-della-vita/torino

maximum duration of the waves. The impacts will be even more pronounced if we consider that atmospheric CO2 concentrations will also triple or even quadruple compared to pre-industrial levels[103].

However, this evidence contrasts with the presence of greenery in the city. A presence that on the one hand should mitigate environmental impacts and at the same time bring improvements to public health. Urban transformation has left around 10 million square metres of industrial space, which has then favoured the development of green infrastructure. As of today, Turin is one of the greenest cities in Italy, with a green area of about 48 km^2 corresponding to 55 square metres of green space per resident. Of these 48 km^2 of green area, 36% is classified as recreational green space for recreational, social and sports activities and more than 90% of the population can reach one within a 5-minute walk from their homes[104].

Currently, the city administration has decided to prepare a Climate Change Adaptation Plan in order to reduce the vulnerability of its territory and citizens, focusing on increasing the presence of green infrastructure. In this way, the city aims to promote the physical and social well-being of the population and maximise ecosystem services effective in counteracting the effects of climate change, including the heat island phenomenon.

3.2.2 Climate Resilience Plan – Turin 2030[105]

The city of Turin has developed and published its Climate Resilience Plan with the aim of reducing the vulnerability of the region and its people, guaranteeing their health and well-being and ensuring the liveability of the city and the continuity of services, putting the most vulnerable people at the centre of climate policy. There are several specific environmental and social goals set by the plan:

- Trying to reduce the occurrence of a critical phenomenon (i.e., heat islands);
- Adapt the urban environment and services to reduce exposure and manage possible emergencies;
- Adapting the built environment to improve the quality of life and reduce energy demand;
- Manage the evolution of urban ecosystems and urban transformation;
- Developing a climate risk culture in the design of public works (sizing and innovation);
- Preparing citizens to face the new conditions.

The actions identified by the Plan are organised in two main axes:

[103] DERRIS. (2018). Piano di adattamento del pilota "Torino chi protegge". Retrieved from http://www.comune.torino.it/ambiente/bm~doc/idap_28maggio2018-c1b1207-c.pdf
[104] Città di Torino, Assessorato per le Politiche Ambientali e Verde Pubblico con il coordinamento dell'Area Verde. Torino 2030 Sostenibile | Resiliente. Piano strategico dell'infrastruttura verde. Dicembre 2020. Retrieved from http://www.comune.torino.it/torinosostenibile/documenti/piano_strategico_infrastuttura_verde_2021.pdf
[105] Città di Torino. Department for Environmental Policies with the coordination of the Environment Area. Climate Resilience Plan. Turino 2030 Sustainable | Resilient. Retrieved from http://www.comune.torino.it/ambiente/bm~doc/resilienza-climatica_en.pdf

1. ***How to prepare***: actions aimed at creating a resilient administration that manages emergencies, communicates and raises awareness among its citizens;
2. ***How to adapt the city***: actions to reduce the occurrence of a phenomenon and to cope with critical situations.

With regard to the "how to prepare" strand, the administration has implemented two main strands of actions. Actions to enable the city to respond, react and adapt quickly and innovatively to extreme events, including heat islands, to reduce impacts on the population. This is done, for example, by planning the monitoring of the evolution of phenomena and their effects over time or by introducing urban planning regulations for a more resilient city. Moreover, actions that enable proper communication and management of emergencies. For example, through the dissemination of alerts and awareness-raising activities. Or even the activation of the Heat Emergency Plan with the adoption of actions to reduce the vulnerability of fragile subjects and measures to limit the population's conditions of discomfort.

On "how to adapt the city", on the other hand, the administration has implemented actions to counter the impacts caused by extreme phenomena, through specific solutions. For example, by introducing green solutions, such as increasing the number of trees in the city, which, in addition to having positive environmental impacts, manage to improve public health aspects. But also, actions to make the various moments of community life comfortable. This is ensured by fresh and comfortable public transport or the implementation of NbS.

3.2.3 ProGIreg: the "Living Lab" – Mirafiori Sud

ProGIreg, "Productive Green Infrastructure for post-industrial urban regeneration", is a European project, funded by the Horizon 2020 programme, with the aim of developing inclusive urban regeneration actions based on environmental solutions. The project started in June 2018 and, with a duration of 60 months, ends in April 2023. Turin, together with Dortmund (Germany), Zagreb (Croatia) and Ningbo (China), was one of the front-runners of the project.

The reference district to be transformed is Mirafiori Sud in Turin, a post-industrial and peripheral area of the city characterised by poor environmental quality and socio-health problems. The area has a high potential for urban regeneration, with its active local associations, strong cultural heritage and abandoned industrial buildings available for new community initiatives. In addition, there is a high incidence of various cardio-respiratory and chronic diseases and mental stress, with in addition a significant presence of lonely elderly people with mental disorders.

The project strategy is based on the implementation of green infrastructure, which can solve or mitigate some socio-environmental problems. These are some of the activities organised:

- Creation of an “urban forestation” area of two thousand square metres along the banks of the Sangone stream, using regenerated soil;
- Experimentation of innovative gardening and collective farming techniques, such as “green” roofs and walls or “aquaponics”
- Promotion of the social value of the activity, through collaboration with associations, educational institutions, local farmers' groups and residents;
- Development and shared management of 'green' areas and infrastructures for sharing and socialising;
- Social accompaniment activities and support paths for citizens to develop entrepreneurial or employable skills.

As shown in the image below, all types of NbS have been implemented in the district[106].

Figure 14: Living Lab Turin, Map of NbS. (Source: ProGIreg)

3.2.4 Results

Cardiovascular diseases (mortality rate)						
When?			Before and after the implementation			
How?			Epidemiological data			
	Circulatory system disease	**Heart Stroke**	**Respiratory system disease**	**Chronic respiratory system disease**	**Asthma**	**Total Medical reasons**

[106] Città di Torino. proGIreg. Living Lab Turin. Retrieved from https://progireg.eu/fileadmin/user_upload/Turin/ProGIreg-Living_Lab-Turin.pdf

2002-2008	715,7	198,6	161,9	22,56	1,88	1.807,9
2009-2013	579,7	162,5	137,6	14,51	1,31	1.673,6

Pollution Index							
When?				Before and after the NBS implementation			
How?				Data collected			
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
78.8	75.7	74.5	71.4	69.6	71.3	70.1	68.2

Quality of life Index							
When?				Before and after the NBS implementation.			
How?				Response of population and data collected			
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
140.5	133.8	133.5	129.7	129.8	125.8	132.0	132.7

Health Care Index							
When?				Before and after the NBS implementation.			
How?				Data collected			
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
68.5	66.5	69.9	67.2	69.3	67.2	66.9	67.0

Years of Life Lost (YLL)						
When?			Before and after NBS implementation			
How?			Epidemiological data			
Age/Years	**2015**			**2019**		
	Deaths	**Life Expectancy**	**Years of life lost**	**Deaths**	**Life Expectancy**	**Years of life lost**
0-4	24	82,46	1.979,04	22	83,28	1.832,16
5-14	6	75,19	451,14	7	76,05	532,35
15-24	15	65,26	978,9	19	66,13	1.256,47
25-34	37	55,41	2.050,17	27	56,3	1.520,1
35-44	94	45,63	4.289,22	57	46,49	2.649,93
45-54	301	36,05	10.851,05	266	36,86	9.804,76
55-64	560	26,89	15.058,4	562	27,59	15.505,58
65-74	1.356	18,38	24.923,28	1.206	19	22.914
75 >	8.172	4,36	35.629,92	8.185	4,64	37.978,4

In addition to the above data, an interview was conducted with Dr. Roberta Molinar, the Mirafiori Foundation's contact person for social inclusion and active citizen participation. The Mirafiori Onlus Community Foundation was established in 2008 on the initiative of a group of third sector realities. Among the various projects that the Foundation is carrying out for the area, it is also a partner in the proGIreg project, together with the City of Turin and with the collaboration of the Mirafiori Community Association Miravolante,

Politecnico and University, Environmental Park, Dual, Orti Alti and Associazione Clorofilla. Attraverso l'intervista sono stati raccolti ulteriori dati, principalmente qualitativi, inerenti la percezione che i cittadini hanno delle NBS implementate nell'area e come queste stanno impattando sul benessere dei cittadini.

CHAPTER THREE – DISCUSSION

4.1 Interpretation and discussion of findings

In this section, the objective is to discuss the data collected for each city in chapter two, analysing how and how much the implementation of NbS has benefited community health. As anticipated in the methodology, data was acquired through online databases. Interviews were also conducted, with two experts for the Trees for Life project in Barcelona and with Dr. Roberta Molinar[107] for the ongoing proGIreg project in Turin. The benchmarks are those mentioned in paragraph 2.6, Impact Assessment Method, and subsequently adapted and modified for cities on the basis of data availability.

4.1.1 Barcellona

The following data were collected for the Trees for Life project (2017-2037): morbidity, mortality and years of life lost due to poor air quality; hospital admission due to high temperature during extreme heat events; pollution index; health care index and quality of life index. Afterwards, through the opinion of the interviewed experts, the reported indicators were supplemented with other values and information provided by them.

- ***Morbidity, mortality and years of life lost (YLL) due to poor air quality***

For morbidity and mortality, data were obtained on an annual basis, from 2013 to 2019, through epidemiological analysis. While for life years lost, two years, 2015 and 2019, pre- and post-implementation of NbS, were taken into account.

Specifically, mortality and morbidity were calculated for respiratory diseases, as these are among the main consequences of climate change for which there is a known correlation between asthma and climatic factors such as weather variables, allergens and air pollutants. Morbidity refers to the frequency of diseases of the respiratory system in a given population, usually measured as the number of cases of disease over a given period of time or the proportion of people in the population who have been affected by a given respiratory disease. While mortality refers to the number of people who die from a disease affecting the respiratory system, such as pneumonia, influenza, tuberculosis or lung cancer. Respiratory disease mortality is expressed as the death rate, i.e., the number of deaths for a given population and the total population during a specific time period, usually one year. In contrast, the indicator for life years lost is an estimate of the number of life years lost due to diseases or premature deaths attributable to air pollution. This indicator considers both premature mortality and the impact on quality of life due to respiratory and cardiovascular diseases caused by air pollution. It is a way of measuring the long-term impact of air pollution on people's health. The calculation was made by taking into account the deaths and life expectancy of a specific age group.

[107] The person interviewed gave the consent in order to be cite in the work.

Analysing the data in more detail, it can be seen that mortality and morbidity have had a significant impact on public health in recent years. In the upper table, the number of deaths has remained relatively constant, ranging between 14,401 and 15,574 between 2013 and 2017, with a slight decrease in 2018 and 2019. However, the mortality rate has remained fairly constant over the years, hovering between 0.009 and 0.010. The same trend was seen for the number of respiratory patients, which increased in 2015 and continued to increase until 2017, with a slight decrease in 2018 and 2019. The morbidity rate, i.e. the proportion of respiratory patients to the total population, has remained relatively constant, rising from 0.014 in 2013 to 0.013 in 2019 and peaking in 2017 at 0.016.

In the table concerning years of life lost, it can be seen that deaths are more frequent in the older age groups, with a higher incidence among the over-80s, where years of life lost are very high. It is therefore assumed that poorer air quality has a higher incidence, in terms of deaths, among the elderly. However, younger age groups are also significantly impacted, with significant years of life lost. Overall, these data suggest that poor air quality could be a threat to public health in all age groups and that efforts to improve quality through the implementation of NbS could have a significant impact on the health and longevity of the population.

However, due to the lack of certain data and, above all, the generality of these data, it is not possible to effectively calculate these indicators in relation to the environment and air quality. Therefore, conclusions can be drawn from them as to how mortality, morbidity and years of life lost have varied over these years.

In order to actually calculate whether and what health benefits NbS has brought, other indicators should be taken into account. For example, some specific data on how much air pollution is contributing to the increase in deaths can be derived from the 2021 WHO air quality guidelines. Considering the new reference values (5 μg/m3 for PM2.5 and 10 μg/m3 for NO2), the health impact of air pollution in cities increases considerably, so much so that it is responsible for **13%** of all natural deaths (around **1,900 deaths per year**), **17%** of new cases of lung cancer (around **170 cases per year**) and 51% of new cases of childhood asthma (around **1,100 cases per year**)[108].

Starting from these data, one should then analyse whether the adoption of policies to improve air quality at a European and national level and, more specifically, in the city of Barcelona, is neutralising this deterioration.

Related to other spheres of health that may be affected by climate change is mental health. Exposure to extreme events or rising temperatures can cause mental problems. Despite the cross-cutting nature of the effects of climate change on mental health, they are the least known and often ignored. This lack of knowledge is mainly

[108] Marí-Dell'Olmo M, Oliveras L, Arechavala T, Ariza C, Borrell C, Font-Ribera L, Gómez-Gutiérrez A, González-Marín P, Grau E, Mercuriali L, Montalvo T, Olabarría M, Pérez C, Portaña S, Realp E, Rico M, Sánchez-Martínez F, Valero N, Villalbí JR. (2022). Canvi climàtic i salut a la ciutat de Barcelona. Barcelona: Agència de Salut Pública de Barcelona.

due to the difficulty of monitoring, assessing and predicting the implications of climate change on mental health, but also to the general lack of attention and stigmatisation of mental health as a fundamental part of health[109].

Despite this broad impact, there is little scientific evidence of the current and future consequences of climate change on mental health. Recent studies conducted in similar contexts in Barcelona highlight citizens' concerns about climate change and associated emotional responses, such as eco-anxiety, especially in younger people. In Barcelona, 86.4% of girls and 78.8% of boys believe that climate change has a negative effect on their lives[110].

- ***Hospital admission due to high temperature during extreme heat events (hospital admissions for specific disease categories such as diseases of the circulatory system and diseases of the respiratory system)***

These data concern hospitalisations due to illnesses that could arise due to the formation of heat islands, i.e. high temperatures. The data are annual and refer to the years 2013 to 2020.

The data are divided into two disease categories: diseases of the circulatory system and diseases of the respiratory system. For the first category, the values show that the percentage of hospitalisations remained essentially stable from 2013 to 2016, with a subsequent decrease of 2% in 2019. However, it is not possible to see whether there was actually a decrease post-implementation NbS, as data for 2017, 2018 and 2020 are not available. This may be due to possible changes in hospital admission criteria or patient registration. Regarding hospitalisations related to respiratory system diseases, the data show a steady increase from 2013 to 2015, rising from a rate of 9.76% to 10.10%. However, data for 2017, 2018 and 2020 are not available, so the only reference data for post-implementation is for the year 2019, where the percentage of 10.22% is higher than in 2016, the year before the project started.

In general, these data suggest that the planting of trees may have brought a benefit in terms of hospitalisations for circulatory diseases, but not for respiratory diseases, but it is not possible to establish with certainty, due to the lack of data, whether this trend is constant. However, in order to consider the validity of the indicators in relation to NbS, it is necessary to consider other factors that may have influenced and will influence hospital admissions, such as access to medical care and the effectiveness of preventive measures.

[109] Hayes, K.; Poland, B. (2018). Addressing mental health in a changing climate: incorporating mental health indicators into climate change and health vulnerability and adaptation assessments. International Journal of Environmental Research and Public Health, 15(9). (https://doi.org/10.3390/ijerph15091806)

[110] Marí-Dell'Olmo M, Oliveras L, Arechavala T, Ariza C, Borrell C, Font-Ribera L, Gómez-Gutiérrez A, González-Marín P, Grau E, Mercuriali L, Montalvo T, Olabarría M, Pérez C, Portaña S, Realp E, Rico M, Sánchez-Martínez F, Valero N, Villalbí JR. (2022). Canvi climàtic i salut a la ciutat de Barcelona. Barcelona: Agència de Salut Pública de Barcelona.

- ***Pollution Index, Quality of life Index, Health Care Index***

In order to gain a better understanding of how the implementation of NbS can benefit the health status of citizens, three annual indicators were considered for the years 2013 to 2021: pollution, health care and quality of life.

The Pollution index is an indicator measuring several factors, where the greatest weight is given to air pollution compared to water pollution/accessibility, the two main pollution factors. Less weight is given to other types of pollution. Through this we can understand the extent to which pollution has changed over the years. In particular, in the specific case of Barcelona, we can see a steady improvement from 2013 to 2021, from a percentage of 75.9% to 64.8%, which however remains moderate. This indicates that the implementation of NbS has had a positive impact on air quality and the urban environment.

The Health Care index is an indicator that measures the accessibility and quality of health care services in a specific area. In this specific case, the indicators were collected before and after the implementation of the NBS intervention and show a steady increase in the Health Care Index since 2013, from a value of 58.5% to 77.7% in 2021. This suggests a general improvement of health services in the area under analysis.

Finally, the Quality-of-Life index is an indicator that measures the perception of well-being of residents in a specific area, so it takes into account both the previous indicators (pollution and health care) as well as others that affect the well-being of the population. This index shows a positive trend after the implementation of NBS. The indicator shows a significant increase in quality of life from 2013 to 2016, interrupted by a decline in 2017, before rising again and then stabilising around 2019. Thus, the index shows a positive trend after the implementation of NBS, with a positive impact on both the health and well-being of residents.

Overall, the data collected suggests that the implementation of NBS has had a positive impact on air pollution, quality of life, health care, heat-related hospital admissions and years of life lost. However, it is important to note that these data are not exclusively related to the implementation of NbS, but there are other factors that may have influenced their increase/decrease over the years.

4.1.2 Torino

The following data were collected for the proGIreg project (2018-2023): cardiovascular diseases (mortality rate); years of life lost; pollution index; health care index and quality of life index. In addition, in order to validate the data and to have more evidence of how the implementation of NbS in Turin is progressing and how it is impacting the health status of citizens, an interview was conducted with Dr. Roberta Molinar, contact person for social inclusion and active citizen participation interventions for the project.

- ***Cardiovascular diseases (mortality rate)***

This data refers to the mortality rate for various cardiovascular diseases in the city of Turin, such as circulatory diseases, heart attacks, respiratory diseases, chronic respiratory diseases and asthma. In order to establish whether the NBS actually had an impact on a lowering of the rate, pre- and post-implementation data should be taken into account. However, in this case, the data collected refer to two six-year periods, the first from 2002 to 2008 and the second from 2009 to 2013. Therefore, it cannot be established with certainty whether there has been any improvement in this regard. One can only note a reduction in mortality rates from all causes in the second period compared to the first. In particular, mortality rates for cardiovascular diseases decreased by 19%, from 715.7 to 579.7 per 100,000 inhabitants. Similarly, the mortality rate for stroke decreased by 18%, from 198.6 to 162.5 per 100,000 inhabitants. However, it is not possible to confirm that this trend also holds true for the years after 2018.

- ***Years of Life Lost (YLL)***

As in Barcelona, the years of life lost due to an illness or adverse event were also calculated for Turin. The data is collected through epidemiological studies conducted before and after the implementation of an intervention of NbS.

The data cover the years 2015 and 2019 and show that, in general, the number of deaths and life years lost due to diseases decreased after the implementation of green solutions in the city of Turin. However, the effect of green solutions seems to be more pronounced in younger age groups, where there was a greater reduction in life years lost than in older age groups. In particular, for the over 75 age group there was an increase compared to 2015.

It is important to note that while these data suggest a positive impact of NbS on public health, other factors may have contributed to the decrease in YLL, such as improvements in healthcare or changes in lifestyle. Moreover, the increase in death among older age groups is also due to the incidence of other factors, such as old age and the occurrence of more chronic diseases than among younger age groups. Therefore, it is necessary to interpret these data with caution and to consider other factors that might have influenced the results, not only the implementation of NbS.

- ***Pollution Index, Quality of life Index, Health Care Index***

Pollution, quality of life and health care indicators were collected from the same database as Barcelona, for the years 2016 to 2023.

As in the Spanish city, Turin shows an improving trend for pollution, from 78.8% in 2016 to 68.2% in 2023. This indicates that the implementation of NbS has contributed to a positive impact on pollution levels in the Piedmontese capital.

The Health Care index showed some fluctuations, but the general trend shows an improvement from 2016 to 2018, followed by a slight decrease in 2019 and 2020, before increasing again in 2021 and decreasing slightly between 2022 and 2023. This could indicate that the implementation of the NBS has had a positive impact on the healthcare system, but other factors could also be at play.

Finally, regarding the Quality-of-Life index, this also shows some fluctuations, with a decrease in 2020 and 2021, but an overall increase from 2016 to 2023. This might suggest that other factors may have affected the population's quality of life, such as economic factors or social changes. However, the overall trend shows a positive impact on quality of life after the implementation of the NBS.

The Quality-of-Life index and the health care index can be seen as complementary data sets, as the quality of health care services contributes significantly to the overall quality of life. In this case, we can observe a slight decrease in both indices after the implementation of the intervention, which might indicate that there is still room for improvement.

Overall, the data suggest that the implementation of NbS had a positive impact on the health status and well-being of citizens. This conclusion was also drawn during the interview with Dr. Molinar. In fact, the latter emphasised several times how green infrastructure is benefiting citizens' health, both physical and, above all, mental. This is also because the newly introduced green spaces are mainly managed by voluntary citizens and associations dealing with environmental sustainability with the help of a group of people with intellectual disabilities; namely who have mild to moderate mental retardation or are psychiatric patients. Based on the feedback received, she confirmed how spending time outside in green spaces is of great help to them, particularly for their mental health. As, by taking care of NbS they are able to feel fully integrated into the community and, by having responsibilities, they can “test their skills, interact with normally endowed citizens and make the community recognise that even a person with a disability is able to take care of a public good”.

In addition, soft gymnastics courses for the elderly population have also been initiated and are held annually, once a week. In addition, scout groups also frequently organise their meetings and motor activities in these spaces. Thus, as can be deduced and as also confirmed by the doctor, “the relationship between physical/social activity and green spaces is very strong”. This means that an increase in green infrastructure could lead to more people being physically active and thus, in the long run, this could reduce the obesity rate in the city and benefit the physical health of citizens.

Citizens' perception of these new green solutions seems to be positive. But, during the interview, she explained that in order to get positive feedback from the community and for these spaces to actually benefit their health,

a lot of work needs to be done by those responsible for taking care of these NbS. For example, when for environmental reasons or because volunteers are less present and involved in maintenance, the green spaces are less well cared for. This, in the eyes of citizens, is perceived as a lowering of the level of care, almost to a state of neglect. In this way, “they begin to despise these spaces, no longer spending time in them, no longer exercising, more forced to spend more time indoors”.

Therefore, according to Dr. Molinar, in order to have a beneficial return on society also in terms of health, we should, first of all, work on and with citizens. This means including them as much as possible in the maintenance and design of these spaces and educating them and making them aware of environmental sustainability and biodiversity issues.

4.2 Comparison of cities: current situation and gaps in the analysis

Comparing the two cities, we note similarities as well as differences. First, at the level of data availability, the city of Barcelona has a more comprehensive database available to citizens than Turin, although not enough to effectively assess whether NbS plays a role in improving citizens' health.

Looking at the data, we see how the two cities are currently progressing along the same lines. In fact, looking at deaths in 2015 and 2019 the values are nearly the same. While for the years of life lost, the values obtained are very different between the two cities, but this is mainly due to the different life expectancy. However, in order to effectively assess whether NbS has improved the situation since it was implemented, other factors would also have to be included, such as changes in air quality or temperature and deaths related to this factor. In this way, it would be possible to gain a more precise understanding of how many years of life have been lost for the specific reason of pollution and heat islands.

On the other hand, regarding the indicators of pollution, health care and quality of life, the years taken into account between Turin and Barcelona are different, as for Turin the years from 2016 to 2023 were analysed, while for Barcelona from 2013 to 2021. For this reason, it is not possible to make a direct comparison. However, it can be seen that for pollution, both cities have improved in recent years, but with a different trend. Turin seems to have had a constant improvement, going from an index of 78.8 in 2016 to 68.2 in 2023, while Barcelona has had more significant fluctuations, with a maximum peak of 75.9 in 2013 and a minimum of 64.2 in 2020.

Concerning the Quality-of-Life index, the Spanish city had a significant improvement from 2015, reaching a peak of 159.0 in 2016, while the Piedmontese capital had less significant fluctuations and increased from 2020, reaching a value of 132.7 in 2023. Regarding the health care index, both cities seem to have had steady

improvements in recent years, with Barcelona growing faster than Turin. In 2021, Barcelona's health care index was 77.7, while Turin's was 67.2.

In order to make a complete analysis, in both cities, data was collected, where available, for the pre- and post-implementation period, so that the change could be seen concretely. Unfortunately, however, many indicators that would have been useful to analyse the impact of NBS even more in depth are not available.

In general, although the health benefits of NBS are among the main ones mentioned in numerous scientific research works and studies; in reality, by examining the data and information collected through the interviews, the health impact cannot always be assessed quantitatively. This is either due to the lack of databases or due to the difficulty of interpreting certain data. For example, in the case of both Barcelona and Turin, the values for years lost, and deaths are not directly related to the implementation of NbS. Therefore, additional factors should be included in the data collection in order to be able to say with certainty whether, indeed, green solutions may have directly benefited the health status of citizens.

This lack was also confirmed by the people interviewed and directly involved in the two projects. In fact, as far as Turin is concerned, Dr. Molinar, proGIreg's contact person, confirmed to us that the NbS project does not have a research dimension, in other words they are not collecting quantitative data. This is because the main objective is first to improve the aesthetics of the city and attract as many citizens as possible to those spaces, and only secondly to assess the possible impacts that these solutions have on the environment, as well as on the state of health. Thus, to date, the only source of evidence from which we can draw conclusions for our research question is the point of view of those who are directly involved in the maintenance and care of these spaces and the citizens who frequent them.

Instead, in the case of Barcelona, the two respondents stated that one of the main challenges and objectives of the project is to improve the health and livability of citizens, and at the same time the plant and animal communities. However, the study of the relationship between vegetation, nature in general, and public health is still a work in progress and will take a long time. This is because, in order to collect the required data and analyses, it is necessary to bring together the competences of different actors and departments in the city (e.g., the Energy and Air Quality Department, the Urban Planning and Strategic Projects Area, the Sustainability and Climate Change Office, etc.). In addition to the City Council, there are other entities and administrations such as universities and research centres (e.g., CREAF, ISGLOBAL, CREAL) that represent reference points for carrying out environmental studies that relate vegetation and health.

Currently, the study concerning the elaboration and evaluation of the global impact of nature on citizens' health, which considers services such as mental health and well-being, improvement of air quality, noise

reduction, heat reduction, etc., and services such as allergies or the emission of volatile organic compounds (VOCs) is underway and is working transversally with the Barcelona Public Health Agency (ASPB), CREAF and in the future it is planned to collaborate with ISGLOBAL. However, as already mentioned and highlighted by the experts, the complexity is very great, the results depend on many factors and the stakeholders do not yet have the final results.

To conclude, we can therefore state that theoretically and also on the basis of the data collected here, the answer to the research question; therefore, if the NbS in the two cities under consideration are having a positive effect on the health and well-being of citizens, it is positive. However, other factors may also have influenced these variables. Therefore, further studies, data collection and comparisons with the citizens of the cities involved would be necessary to assess the long-term effects of the intervention on the population.

Conclusions

In an era of increasing urbanisation, climate change, environmental degradation and the emergence of health problems related to these causes, the issue of urban nature, and thus the implementation of green solutions, is becoming central to healthy, more resilient and sustainable urban planning. The aim of this research is precisely to assess whether green solutions, by succeeding in decreasing the effect of heat islands, are able to bring benefits to the health of citizens. This means leading to a reduction in cardiovascular diseases closely linked to air pollution and rising temperatures; to an increase in mental wellbeing, which is often affected by these problems, and at the same time to greater general wellbeing; or even to a reduction in diseases that are sometimes linked to the lack of green spaces, such as obesity.

Specifically, the two cities to be analysed selected in the work were Barcelona and Turin, as both are Mediterranean cities and, for this reason, are more affected by the heat island phenomenon, which leads to negative health consequences both in the short and long term. To address this problem, mitigating climate change and responding to public health challenges, both have initiated nature-based green solutions projects. The latter, as highlighted in the first chapter and recognised by public health professionals and landscape architects, are a resource with enormous potential to improve health and well-being by reducing air pollution, ensuring better air quality, enhancing physical activity, reducing stress levels and promoting social cohesion. Effects of which numerous studies speak and for which NbS are among the main solutions implemented.

However, by collecting data and listening to the opinions of the experts interviewed, to date it is not possible to truly establish, on the basis of quantitative data, whether these solutions are bringing benefits to the overall health and well-being of society. This is mainly due to the lack of data and the fact that, in order to evaluate this complex area, a large number of actors need to be involved, which entails more interdisciplinary and transdisciplinary work. This requires collaboration between different fields such as public health, sociology, urban ecology, environmental policy and human geography to comprehensively capture the multitude of interconnected factors. Hence, an interdisciplinary approach is fundamental in order to emphasize the connection between green infrastructures in urban environments and their potential impact on the health and well-being of urban populations. Therefore, further research is needed, especially to understand *how collaboration between different disciplines would yield concrete results*. However, the set of indicators developed and used in this work provides a good starting point for the planning of further strategies in the implementation of nature-based solutions and may allow over time to have answers on a larger scale of how these solutions are or are not benefiting the health of citizens. In addition, the hope is also to be able to engage and educate citizens on these new issues of environmental sustainability and biodiversity, so that they understand how these tools can benefit their health and the health of our planet at the same time.

RQ: *How can Nature-based Solutions mitigate the negative effects of climate change, while having a positive impact on society in terms of healthy well-being?*
Positive outcomes of the study:
1. Useful set of indicators to understand the current general health situation of citizens in the cities in question
Outcomes of the study for future research hints:
1. In the two NbS-type projects analysed, the implementation of the health sphere is still not very mature
2. Need for interdisciplinary approach
3. Necessity for further research in the health sphere associated with NbS

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Figure Index

Annex

A. Morbidity, Mortality and Years of Life Lost due to poor air quality

Morbidity refers to the long-term annual incidence of respiratory diseases due to poor air quality. Mortality refers to the annual long-term incidence of mortality due to respiratory diseases. The data taken into account to calculate the two indicators are deaths, total population and respiratory patients. These were taken from the website of the Ajuntamiento de Barcelona. While, to calculate the years of life lost, life expectancy was taken from the WHO website.

B. Hospital admission due to high temperature during extreme heat events (hospital admissions for specific disease categories such as diseases of the circulatory system and diseases of the respiratory system)

Data on hospital admissions for diseases due to high temperatures, i.e., diseases of the circulatory and respiratory system, were collected from the Ajuntamiento de Barcelona website.

C. Pollution Index, Health Care Index, Quality of Life Index

The pollution, health care and quality of life index were taken from the Numbeo website. Numbeo is the world's largest cost-of-living database. Numbeo is also a global crowd-sourced database of quality-of-life data: housing indicators, perceived crime rates, health care quality, transport quality and other statistics. The indices considered for Barcelona refer to the years 2013 to 2021, and for Turin from 2016 to 2023.

D. Cardiovascular diseases (mortality rate)

The data were taken from the ARPA Piemonte website. The mortality rate was taken into account with regard to diseases that can be related to heat island formation, i.e. cardiovascular diseases. The data taken into consideration refer to the years 2002-2008 and 2009-2013.

E. Years of Life Lost (YLL)

As stipulated by the World Health Organisation, the indicator years of life lost is calculated by taking into account deaths occurring in a given year and in a given age group multiplied by life expectancy. The data on the number of deaths and life expectancy was taken from the city of Turin website.

F. Interview with dr. Roberta Molinar, contact person for social inclusion and active citizen participation interventions

The interview took place on Wednesday 9 May 2023 via the Teams platform. The interviewee is Dr Roberta Molinar (RM) and the interviewer is myself, Ercoli Elisa (EE). The transcript of the interview is reproduced below.

EE: Good morning doctor, thank you for giving me this opportunity to discuss the proGIreg project with you.

RM: Thank you for contacting me.

EE: Before I start with the questions, let me give you a brief recap. I am currently writing my dissertation focusing on the topic of nature-based solutions. In particular, my aim is to understand whether or not these solutions have a positive impact on the health of citizens, for example by leading to a decrease in the level of cardiovascular diseases or by increasing the practice of sports activities due to the availability of more green areas. *Before we start with more specific questions, could you give me a general overview of the project?*

RM: Sure. ProGIreg began as a project aimed at implementing nature-based solutions in the Mirafiori district of Turin. Mirafiori was chosen as the neighbourhood because it is a post-industrial area of Turin where the former Fiat car factory is located. Some of the implemented solutions involve interaction with citizenship, while others do not. As the Mirafiori foundation, we take care of NBSs that involve interaction with the community, such as the shared gardens. These were created primarily with the aim of improving the aesthetic quality of the neighbourhood; thus, bringing greenery to concrete, former industrial areas. Bringing benefits to the health status of citizens is not a direct objective of these implemented solutions, but by automatically collecting citizens' perceptions, we realised that there are numerous benefits both for physical health but also, and above all, for mental health. Furthermore, the creation of these solutions has led to the emergence of new social gathering points. In particular, there are three points created:

1. The “wow space”, namely a former abandoned factory owned by the City of Turin, unfit for use internally, but externally consisting of a large fenced green area. Two NbS were built inside the green area: the pollinator garden and the urban apiary. The garden consists of 16 ground boxes containing plants and flowers that attract pollinating insects and butterflies to feed them. While the urban apiary consists of 5 arns that produce an urban millefiori honey. In addition to these two, a third NbS, the green roof, has been created on the roof. This is an oasis for pollinating insects and butterflies. The roof is not accessible to the public and is not visible from the street. Instead, the garden and apiary are accessible to the public.
2. Public open space where there are five boxes containing flowers and herbs. The objective of this space is to improve the aesthetic quality, to create a meeting point and to raise awareness on issues related to nature. An additional NbS, the green butterfly corridor, was implemented near this point. The corridor is a path where flower beds have been created with plants that attract butterflies.
3. Box garden in an open and always accessible area.

Thus, in general, the primary objective is to make an improvement on a purely aesthetic level. For this reason, specific data regarding the state of health is not directly measured. Reference can only be made to the operators' or citizens' point of view.

EE: *Based on the feedback you have had from citizens and from your point of view, have these spaces brought/are they bringing benefits on the health of citizens or, anyway, on a social level?*

RM: Yes, these spaces have a great impact on a social level. First, all these spaces are cared for by volunteer citizens with, in addition, people with intellectual disabilities; that is, who have mild-moderate mental retardation or are psychiatric patients, and with the help of organisations that are active on issues of environmental sustainability. This already contributes strongly to the theme of social inclusion and, at the same time, improves the mental wellbeing of citizens, especially minorities, so in this case people with disabilities. Citizens have expressed to us how happy they are to spend time outside in the green and have stated that they feel much better. In addition to this, ordinary citizens can enter these spaces at special events that are organised. For example, with a view to implementing physical activity, a gentle exercise class is organised once a week for the elderly. Or even the neighbourhood scout groups hold their meetings and activities in this garden. Urban green workshops are organised every year to raise awareness of issues related to biodiversity and environmental sustainability. So, the relationship between physical/social activity and green spaces is very strong. Or young people with disabilities who attend a neighbourhood vocational training course within a training agency to get closer to work, then do an internship in turn in one of these NbS. This is a very important goal for them and in this way, they test their skills, interact with normally endowed citizens and make the community recognise that even a person with a disability is able to take care of a public good.

EE: So, from what you are telling me, there is a very strong theme of social inclusion and mental wellbeing of the people who attend and work within these NbS. *But, speaking of perception, in your opinion, also based on the feedback you have received, what do citizens think? In their opinion, are these new infrastructures useful?*

RM: The perception of citizens to date is positive. However, it should be emphasised that the perception is positive when there is community work and those responsible for taking care of these NbS behind it. When, for environmental reasons or because volunteers are less involved in maintenance, the green areas are less well cared for, the demanding citizen perceives the lowered level of care as a state of neglect. But, in this case, it is necessary to explain to the citizen that these NbS are also cared for through ecological gardening practices, so if, for example, there is a drought, water-saving practices are adopted. This may result in a slightly more yellow lawn, but not because nobody takes care of it. So, there is a need to accompany the citizen in this cultural change, to maintain their positive perception of the infrastructure and at the same time their mental well-being. Because, if citizens see these places treated with little care, they automatically despise them, they do not spend time there, they do not engage in physical activity and they would be more likely to spend more time in enclosed places, perhaps without the possibility of going to green spaces often. So, in general, the

presence of green infrastructures allows the improvement of aesthetic quality, can function as a point of aggregation, a point that facilitates relationships, allows outdoor activities and allows citizens to experience concepts that they may not have (e.g., concepts of biodiversity, sustainability).

EE: So, in your opinion, the right mechanism for ensuring a beneficial return on society, including in terms of health, is *to work on the community as well.*

RM: Exactly. The citizen must be accompanied and incentivised to use these green spaces. Awareness-raising campaigns must be organised, so that there is then a positive spin-off. All this work is up to the skill of the operators. For example, the apiary is not open to the public, but is managed by certified beekeepers and on some occasions, there are guided tours. Guided tours are done very frequently and have an educational purpose, which is to make people understand that the apiary is used to bring benefits to people's daily lives. Trivially, by then producing honey, this honey can be sold, thus also benefiting the citizens economically.

EE: Thank you, Dr. Your explanation was straightforward and thorough. Even though I do not have any specific quantitative data on the state of health, I notice from your explanation that there has been an improvement, even a minimal one, related to the state of health.

RM: Exactly. Even though we do not have specific data, we do notice a great improvement, especially in mental health, as in the case of people with disabilities. That is why it is good to continue to take care of these NbS and implement more of them. It was a pleasure to be able to help you!

G. Interview with the responsible of Barcelona Natura Plan and the responsible of Trees Master Plan

In conjunction with the interview conducted for the city of Turin, contact persons were also contacted for the city of Barcelona. As an oral interview was not possible, the answers to the questions below were sent by e-mail.

Questions:

1. In the implementation of various green infrastructures, in particular with the planting of trees, have you seen improvements in public health? In this regard, do you feel that the quality of life has improved?
2. How do citizens perceive these new spaces? Are they satisfied with them? Are they used frequently?
3. In terms of air quality, also based on scientific data, has there been an improvement related to the implementation of these solutions?
4. Considering the following indicators:
    a. Reduction of life years due to premature mortality compared to standard life expectancy.

b. Morbidity: Long-term (annual) incidence of chronic bronchitis due to poor air quality, calculated using atmospheric data of NO2 and PM10.
c. Mortality: Long-term (annual) incidence of mortality due to poor air quality, calculated using atmospheric data of PM2.5, PM10, O3 and NO2.

Have you experienced a decrease in these parameters? Or have they remained static?

5. Considering that rising temperatures also lead to an increase in chronic stress and mental illness, has there been an improvement in this respect with more exposure to green spaces?
6. Regarding illnesses and hospitalisations closely linked to poor air quality and exposure to sunlight in general, has there been any improvement?

Summary

Introduction

Climate change is the single biggest health threat facing humanity, according to the World Health Organisation's 2021 report. The IPCC claims that from the middle of the 20th century, the observed warming has been mostly caused by human activity, namely greenhouse gas emissions. Cities are major contributors to CO2 emissions, but they are also the most vulnerable to climate change risks. Heat waves are more strongly felt in urbanised areas due to urban heat island effects (UHI), which occur due to high vertical densities and textiles structured on a dense street network. The average annual temperature difference between urban and rural areas ranges from 3.5 to 4.5 °C and is expected to increase by 1 °C per decade. Urban populations are particularly at risk from global warming and rising temperatures, which are predicted to become more frequent and severe. Extreme heat waves (UHIs) have a negative impact on society, especially on community health, causing heat-related deaths and illnesses such as general malaise, cardiovascular and respiratory problems, heat cramps, chronic stress and heat stroke. The United Nations has designated the Mediterranean basin as a "hot-spot" because it is one of the areas most vulnerable to urbanisation and climate change. Due to their hot, dry summers and moderate, rainy winters, Mediterranean towns are particularly vulnerable to UHI, which can enhance their risk. Until 2100, some predictions indicate that the Mediterranean region's yearly temperature will rise by 1 to 5° C.

At national and European level, efforts have begun to implement efficient solutions to cope with and adapt to climate change, which will reduce the prevalence of heat island phenomena and improve human health. Nature-based Solutions (NBS) are described as “solutions to societal challenges that are inspired and supported by nature, that are cost-effective and that simultaneously provide environmental, social and economic benefits to help create resilience”. These solutions can include design components that mimic, enhance, maintain or support nature, such as reflective or cool infrastructure, or increasing surface vegetation, such as green roofs, urban forests and vegetated vertical surfaces. The benefits of NBS include reducing energy consumption, moderating the microclimate and benefiting the health of citizens. This study will investigate how Nature-based Solutions can mitigate the negative effects of climate change while having a positive impact on society in terms of healthy well-being. The main RQ is: ***How can Nature-based Solutions mitigate the negative effects of climate change, while having a positive impact on society in terms of healthy well-being?***

In the first chapter, the problem will be introduced, explaining the concepts of urban heat islands and Nature-based Solutions and highlighting the positive benefits they can bring to society. European and national policies implemented with the aim of increasing the application of green solutions will be explored, and parameters used in the analysis of NbS impacts will be presented. In the second chapter, case studies will be presented, namely two selected Mediterranean cities: Barcelona and Turin, with an initial general overview and plans introduced by the cities to mitigate/combat the effects of climate change. Finally, specific implemented NbS

projects will be discussed in detail for each of them. Conclusions will be drawn, discussing the data collected in the previous chapter and through interviews.

The methodology used in the word is empirical. Empirical research is a type of scientific investigation that involves the collection and analysis of data from direct observation or experimentation. It is based on the principles of the scientific method, which involves formulating a hypothesis, designing a study to test the hypothesis, collecting and analysing data and drawing conclusions based on the results. The thesis is divided into three parts: literature review, case studies analysis, and results and discussion. Hence, a mixed qualitative and quantitative method is used, with theoretical insights gathered through an in-depth reading of various academic and scientific papers. These articles were consulted through the main databases of scientific publications.

The most important details in this text are that numerical data were collected from statistical databases related to the main indicators to be analysed on the cities under study, tables were created in which data for specific years were entered, and external opinions were heard. Interviews were conducted with experts currently working on the projects, asking them various questions. For the city of Barcelona, the responsible for the Barcelona Natural Plan and the Trees for Life Project were interviewed. For the city of Turin, Dr. Roberta Molinar, the contact person for social inclusion and active citizen participation interventions, was interviewed. The method used for the interviews was the semi-structured interview, which combines a series of open questions with the chance for the interviewer to go deeper into certain topics or replies.

Thus, the main tools used are scientific evidence, research on various databases and contributions from various experts. The study was chosen to analyze green infrastructure on one scale, namely the areal scale, within three cities: Barcelona (Spain) and Turin (Italy). Reference parameters for the analysis include the quality of life of citizens, indicators concerning diseases related to environmental factors, and environmental parameters such as the pollution index in the areas of interest. This will help to understand the consequences of the application of NBS in the two case studies.

First Chapter: State of the art analysis

The geological time scale is a hierarchical list of shorter time periods that represents Earth's history. These units are categorized in accordance with the fossils discovered in the geological layers of the Earth. Officially, the Holocene period, which started around 11,700 years ago after the last major ice age, is the one we are currently living in. However, around 1950 with the Great Acceleration began the Anthropocene period, which refers to the most recent period in Earth's history when human activity began to have a significant influence on the planet's climate and ecosystems. Until it is reversed, this acceleration and the Anthropocene epoch are expected to persist.

Strong global urbanization, one of the primary drivers and accelerators of the deterioration of our planet, has further intensified the effects of human activities on the climate and ecosystems of the globe. Furthermore, the population is anticipated to grow by 2 billion from the present 7.7 billion to 9.7 billion in 2050, according to the Revision of World Population Prospects 2022, which would cause metropolitan areas to continue to flourish. The continuous climate change brought on by the growing CO2 concentration in the atmosphere exacerbates these shifts. When it comes to urbanization, the Mediterranean area has seen a tendency that is quickly expanding in recent years, with major urbanization occurring in cities like Rome, Barcelona, Athens, Tel Aviv, and Madrid. This has led to the construction of new infrastructure, such as skyscrapers and modern transport systems, as well as the influx of people seeking better job opportunities and a higher standard of living.

In order to understand how important is to take an effort to prevent and resolve these problems, it is vital to analyze the tremendous influence that rising anthropisation has had on human civilization over time. More and more individuals are being impacted by urbanization's worldwide effects. The climate is being heavily impacted by these developments. Urban heat islands (UHI) can develop, which are marked by a real microclimate that is created within built-up areas and results in temperature increases of up to five degrees.

The Urban Heat Island effect (UHI) is a heat accumulation phenomenon caused by human activities such as cooling, heating, transport, and air pollution, as well as the materials and density of urban infrastructure. It has a close relationship with urban heat release, the properties and structure of the underlying surface, vegetation cover, population density, and meteorological conditions. Urbanisation has the greatest impact on the formation of urban heat islands. Different types of urban heat islands can be defined based on differences in urban and rural surface cooling and heating rates, such as surface heat islands (UHISurf), sub-surface urban heat islands (UHISub), canopy layer urban heat islands (UHIUCL), and boundary layer urban heat islands (UHIUBL). Urban heat islands are caused by the thermal differential of closely connected components that vary depending on the unique characteristics of each urban center.

The scale of the city, its functions, geometry, construction materials, and vegetation covering, as well as urban growth, should all be taken into account. Physical location, temporal timing, and weather conditions all have an impact on how intense the event is. Studies have shown powerful negative effects of urban heat islands, with increased exposure to extreme heat threatening urban settlements and their rapidly growing populations worldwide. Globally, urban exposure has increased by almost 200%, affecting about 1.7 billion people. To reduce social damage from exposure to extreme heat, local adaptation and early warning systems should be introduced.

Exposure to dangerously high temperatures can endanger health and urban development, causing decreases in economic productivity and increasing morbidity and mortality. However, the damage caused is highly unequal and inequitable, as vulnerability to heat is not the same for all urban dwellers. Evidence of this is the 22,000 people, half of whom elderly, taken to hospital with symptoms of heatstroke during the 2018 heat wave in Japan or 90 per cent of the people who died during the 2003 heat wave in Paris. UHIs also lead to an increase in deaths from cardiovascular and respiratory diseases and are also associated with more suicides. Providing healthcare is complicated as the demand for care increases and not all hospitals are designed to cope with heat.

To combat this, cities should increase green space, reduce vehicular traffic, and initiate a campaign of urban planning interventions to replace materials that retain less heat and reflect more sunlight. These strategies can help reduce the spread of chronic diseases such as cancer, diabetes, and heart disease.

In this context, nature-based Solutions (NbS) are initiatives to safeguard, sustainably manage, or rehabilitate natural ecosystems that effectively and adaptively address societal issues like climate change, human health, food and water security, and disaster risk reduction while enhancing both human well-being and biodiversity. In the early 2000s, the Nature Conservancy and the International Union for Conservation of Nature were the first scientific communities to give a clear definition of NbS. The World Bank helped to secure investments of around USD 6 billion in projects that supported nature-based solutions for the increased conservation and sustainable use of natural capital. The European Union has recently embraced the use of NbS, as a way to foster biodiversity and make Europe more climate resilient. NbS are defined as solutions that are inspired and supported by nature, which are cost-effective, provide environmental, social and economic benefits and help build resilience.

The EU must provide evidence for nature-based solutions, improve the policy-level framework, develop a European Research and Innovation community, advance the development, adoption and dissemination of innovative nature-based solutions, and integrate nature-based solutions into international research and innovation. To achieve these objectives, NBS is currently implemented through two elements: Horizon 2020 and BiodivERsA ERA-Net.

There are different types of NbS:

- Type 1: minimal or no intervention in ecosystems;
- Type 2: some intervention in ecosystems and landscapes;
- Type 3: management of ecosystems in extended ways;
- Hybrid solutions combine natural features with green infrastructure in a way that is better for the environment and people.

This study examines the implementation of Type 3 NBS in urban areas in the Mediterranean. Examples of Type 3 NBS include extensive and intensive green roofs, urban parks, and groups of trees. Greening roofs improve air quality and mimic CO2 emissions, while urban parks have positive effects on the urban climate, social recreation, and biodiversity. Finally, urban tree clusters offer many advantages, such as better water management and, from a social point of view, help mitigate urban heat stress and reduce deaths.

The implementation of NBS can lead to a wide range of Ecosystem Services (ES) that contribute to the health of people and communities, such as improving air and water quality, reducing local temperatures, providing a natural environment for exercise and reducing stress. Additionally, NBSs can help prevent diseases transmitted by insects and other animals, as the natural habitat of their predators helps control their population. The relationship between NBS and ES is important for the well-being of communities and the creation of a more sustainable and resilient future.

Contact with nature can affect human health through multiple pathways, such as air quality, physical activity, social cohesion and stress reduction. Trees and shrubs can reduce the levels of gaseous air pollutants and particulate matter (PM) through absorption systems in leaf stomata, while indoor plants can also affect indoor air quality. Vegetation also indirectly improves air quality by providing shade and cooling urban environments by reducing energy needs. However, there may be negative impacts on health, such as hydrocarbons and pollen production, which can be mitigated by choosing plants with low pollen production. Careful selection of flooding species, planting design and vegetation maintenance can optimise the beneficial effects on air quality.

The outdoor environment influences the degree to which an individual engages in physical activity. Green space promotes increased physical activity, but at the same time may hinder it depending on the type of activity in question. In the work environment, green space is unimportant for the amount of physical activity. For active transport, green spaces make it more attractive to use modes of transport other than the car, bus and metro, such as walking or cycling. For leisure, large amounts of green space tend to go hand in hand with greater societal involvement.

In general, there is a positive association between physical activity and green spaces, and a positive relationship is also evident for social cohesion. Social cohesion refers to shared norms and values, positive relationships and feelings of acceptance and belonging. To date, few studies available in this regard suggest a positive relationship between social cohesion and natural environments. Nature can reduce the risk of diseases involving chronic stress and promote a number of intermediate outcomes such as increased subjective well-being. There are two theories on how nature can promote faster and more complete restoration than other environments: the psycho-evolutionary theory and the attention restoration theory.

At the environmental level, green areas are excellent climate mitigation factors that can contain Urban Heat Islands, which can prevent climate change, improve air quality, and contribute to the maintenance of biodiversity. At the economic level, the introduction of urban gardens may lead to the creation of employment centres for the integration of citizens and their environmental and food education. These solutions would also generate increased cash flow from new investments, tourism flows, and new jobs.

Law and policy have a significant role to play in addressing the risks and dangers of climate change and environmental and social calamities. They can reduce social and environmental vulnerabilities and bring multiple co-benefits such as mitigating climate change, improving human health and well-being, and providing jobs and business opportunities. A desk-based review was conducted to identify the EU and International policy instruments of the highest relevance for enhancing the use of NbS. These instruments include directives, strategies, programmes, and funding instruments. The study from the International Federation Red Cross and WWF highlights the benefits of NBS and how law and policy can be used to enable it through establishing policies, government mandates, roles and responsibilities of groups involved in conservation, coordination mechanisms, and imposing legal duties on relevant actors.

In recent years, global and EU policies on sustainable development, disaster risk, climate and environmental issues have increasingly embedded NBS. However, there are still numerous knowledge gaps that hinder the adoption and implementation of NBSs. These include a lack of standards, technical and operational competence, knowledge, and financing for NBS implementation, a significant problem that needs to be solved is quantifying the effects, advantages, and cost-effectiveness of NBS, limited availability and poor quality of information regarding the carbon storage and sequestration potential of different habitats, lack of accessibility to best practices and knowledge, and accessing investment funding for NBS. To assess the impact of NBS, it is difficult to quantify intangible effects (like aesthetic pleasure) and spillovers (the effects of an NBS intervention may extend beyond the treated area or group), as well as account for trade-offs. The citizen monitoring experience of NBS is restricted, and information acquired about the effects is not made public or presented in a user-friendly way.

Additionally, there are several societal challenges that may impede the successful implementation of NBS, such as community involvement, conflicts of interest among stakeholders, difficulty in access to financing, and climate change. These challenges can be mitigated through transparent communication and active participation of communities from the beginning of the planning process. Additionally, climate change influences the effectiveness of NBS through changing precipitation patterns or increasing the frequency of extreme events such as floods and droughts, which may necessitate the modification of existing projects to adapt to new environmental and climatic conditions.

In order to understand the strengths and the weakness of Nature-based Solutions (NBSs), it is important to use an impact assessment method looking at real case studies. To answer the research question of this study several parameters will be considered. The indicators considered belong to two categories, health and well-being and green management, and they are inferred from the monitoring and evaluation plans of several projects financed by the EU's Horizon 2020 Research and Innovation Programme. Impacts are evaluated using quantitative and qualitative criteria to examine particular and specific qualities and provide exact answers. The choice was made on the basis of the principle of simplification, namely choosing a limited number of meaningful, relevant and feasible indicators to collect in order to provide useful information for the achievement of objectives.

Second chapter: Barcelona and Turin

Barcelona is a city in the north-eastern corner of the Iberian Peninsula, in the Spanish Levant. It is the capital of Catalonia and is the second largest city in Spain in terms of population. It has undergone rapid growth and urbanisation over the last two decades due to two major events: the 2004 Olympic Games and the 2004 Universal Forum of Cultures. New infrastructure was built with significant investments, and urban revitalization was guided by culture, producing high-caliber architecture. This has resulted in a significant gentrification phenomenon, with impoverished neighborhoods like El Raval being revitalized by the construction of museums, clubs, and hotels; but, in other areas, sizable populations of less affluent individuals and/or immigrant communities have taken over the apartments that Spaniards no longer want to live in.

Barcelona's urban revolution has been driven by economic growth, leading to increased prices, gentrification, noise, air pollution and congestion, and the formation of urban heat islands. As part of the Urban-CLIMPLAN project, the Centre for Land Use Policies (CPSV UPC) studied urban heat islands in the Barcelona metropolitan area and the main factors that cause them. The results of the project included the identification of nocturnal urban heat islands, which are particularly relevant to health due to the increased vulnerability of the population. 1.6% of midsummer fatalities are related to heat, and mortality rates in extremely hot weather have increased by 15% for individuals between the ages of 60 and 70, 17% for those between the ages of 70 and 80, and 26% for those between the ages of 80 and 90. Mortality rates for people over 90 years of age can reach 36%. Infants younger than one year old are quite susceptible.

The most important idea is to bring about a new change in an inclusive and sustainable way, designed around people and public spaces, to reduce social inequalities and improve public health. However, firstly is fundamental to analyse the current environmental and health situation in Barcelona. In terms of quality of life, Barcelona ranks fourth, after New York, London and Los Angeles, among the 50 cities ranked in the Raking of Sports Cities 2021. In terms of air quality, the Barcelona Public Health Agency assesses it and the results for 2018 show that levels are still above the WHO recommendations for NO2, particulate matter (PM10 and PM2.5), benzene, ozone and benzo(a)pyrene, and that the population potentially exposed to levels above the

WHO recommendations is 48% for NO2 and 95% for PM10. The potential exposure of the population to higher-than-normal levels of NO2 varies between 7% (Nou Barris district) and 100% (Eixample district). Population exposure to higher-than-normal levels of PM10 is estimated at 77% in Horta-Guinardó, 85% in Nou Barris, 96% in Sant Andreu and 97% in Sarrià-Sant Gervasi. Exposure to higher levels of PM2.5 is estimated at 77% in Horta-Guinardó, 85% in Nou Barris, 96% in Sant Andreu and 97% in Sarrià-Sant Gervasi.

Public health is clearly impacted by repeated exposure to air pollution, which increases mortality and respiratory illnesses. Natural fatalities, new occurrences of lung cancer, and 33% of new episodes of pediatric asthma are all caused by contamination. The mortality rate related to excess PM2.5 in 2018 is 2% among people aged 30 or older, which equates to an average of 424 fatalities each year, according to data from the Barcelona Public Health Agency from 2010 to 2018. If NO2 concentrations are used as a measure of air pollution, mortality is rising. The Barcelona Public Health Agency has suggested expanding green spaces and urban plants as a way to alleviate this condition. Today, Barcelona has 3,611 hectares of green spaces, which represent 35.3% of the municipal surface. The 1,076 hectares of public urban green areas are mainly concentrated in three districts: Sants-Montjuc (27.8%), Sant Mart (15.4%) and Horta-Guinardó (11.3%). There is a more modest presence of green spaces in districts with historic centres, such as Gràcia (3.6%), Sant Andreu (5.1%) and Ciutat Vella (5.9%). With the addition of Collserola, Sarrià-Sant Gervasi is the district with the largest area of green space, more than 1,266 hectares.

The first plan introduced by the city to tackle these problems was the Climate Plan 2018-2030. The key areas of focus are the environment, cost of living, basic supply assurance, quality of life and public safety, and people's health and survival. All of these objectives are sought after by the Plan. Through lowering the excessive temperature rise and improving air quality, the Barcelona Climate Commitment seeks to protect the neighborhood and its residents' health. In order to do this, the Plan aims to promote the use of partition walls, walls, and roofs as productive areas for a variety of thermal activities. One further key action the city wants to take is to increase the number of green spaces. The Barcelona Climate Commitment aims to provide 1.6 km^2 more green space by 2030, and by 2037, it expects a 5% increase in tree cover according to the Trees Master Plan.

The Master Plan for Barcelona's Trees 2017-2037 aims to assure the growth of a just, sustainable, and inclusive city while enhancing public comfort and health. The city's green infrastructure, especially its trees, is crucial in ensuring this. The urban plan has made it a priority to assess and upgrade the trees and other green infrastructure in order to have a good influence on the residents.

Urban trees contribute to positive social and environmental impacts, improving people's health and wellbeing, defining the urban fabric of cities and assessing the quality of public spaces. The Master Plan for Barcelona's

Trees 2017- 2037 establishes five objectives to guide the planning, management, and future conservation of Barcelona's trees. These objectives include having a tree stock that forms a true green infrastructure, obtaining the greatest number of environmental, social and economic services from trees, having a tree stock that is biodiverse and in good condition, having a tree stock as a tool for adaptation to climate change, and achieving good coexistence between the public and trees. By 2037, Barcelona aims to have 30% of the city covered in trees, 40% of which will have climate change adaptations, and a diverse tree population. The city also hopes to use interactive technology to provide residents and tourists with all the knowledge they need about the traits and benefits each tree has to offer.

The city of Turin is located in the north-east of Italy, bordered by the rivers Stura di Lanzo, Sangone and Po and facing some of Italy's most important mountains. It has an area of 130 km^2 and has 2,247,780 inhabitants, of which 890,000 are residents. It is the fourth largest Italian municipality by population and is one of the country's major university, tourist, scientific and cultural centres. Throughout the 20th century, Turin was the ville industrielle par excellence, but with the arrival of the system crisis at the end of the 1970s, it took the opportunity to transform itself in terms of production and morphology. The city's first Master Plan was published in 1995, focusing on the implementation of public transport, the redevelopment of the industrial fabric and the redevelopment of the city centre.

Turin's transformation was made possible by occasions like the Winter Olympics and the 150th anniversary of Italy's unification. Thus, the "metropolisation" process of urbanization was started. The Po axis, the Corso Marche axis, and the Viale della Spina Centrale axis served as the foundation for Turin's urban transformation. The Turin conurbation, the site of a railway and a metro system, and the environmental, landscape, and historical aspects of the city were the emphasis of these axes. This transformation was designed for the citizens and made the city more liveable and usable.

Concurrent with climate change, this development is having specific repercussions for Turin, notably the heat island phenomenon. The average summer heat island intensity increases by 4 °C for every 10% increase in the central core of areas with heavy land use and poor tree cover. Major instances of temperature increases and the accompanying development of heat islands were noted in 2003, 2006, 2015, and 2017. Three heat waves have recently been observed between May and June 2022. The over-65 population saw 22.1 fatalities on average throughout the 22 days of the May wave.

Arpa's satellite analysis findings Piemonte noted warmer regions near commercial centres and colder regions near open water and greenery. Overall, 27% of Turin's area is in a low-risk heat island area, 44% is in a medium-risk area, and 2% is in a high-risk area. Torino has joined the European Covenant of Mayors and Smart Cities projects as part of the "Europe 2020" agenda, vowing to cut CO2 emissions and create plans and

efforts to cope with the effects of climate change. It will implement a first methodological trial of the entire local adaptation strategy through the LIFE DERRIS (DisastEr Risk Reduction InSurance) project to get ready for the inevitable consequences of climate change and boost resilience.

Turin's present environmental and health conditions are influenced by urbanization and the effects of climate change. According to new research in the academic journal Environmental Research, a rise in temperature-related deaths indicates that people are not coping well with extreme weather occurrences. The effects of increasing temperatures and the development of heat islands on society and public health are also highlighted in an analysis by Arpa Piemonte. With a PM10 index of 86 out of an average of 51, Turin has the 40th-lowest quality of life rating among the 107 Italian provinces, according to the most recent Sole24Ore poll. To lessen the vulnerability of the area and its residents, the city of Turin has created and made public a Climate Change Adaptation Plan that focuses on expanding the amount of green space.

This plan aims to promote the physical and social well-being of the population and maximise ecosystem services effective in counteracting the effects of climate change, including the heat island phenomenon. The actions identified by the Plan are organised in two main axes: How to prepare: actions aimed at creating a resilient administration that manages emergencies, communicates and raises awareness among its citizens; How to adapt the city: actions to reduce the occurrence of a phenomenon and to cope with critical situations. The actions identified by the Plan are organised in two main axes: How to prepare: actions aimed at creating a resilient administration that manages emergencies, communicates and raises awareness among its citizens; How to adapt the city: actions to reduce the occurrence of a phenomenon and to cope with critical situations.

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Specifically, with a view to implementing NbS, the ProGIreg Project was launched. The European project ProGIreg, which is supported by the Horizon 2020 program, aims to create inclusive urban regeneration efforts based on environmental solutions. The Mirafiori Sud neighborhood in Turin, a post-industrial outlying region of the city plagued by low environmental quality, social issues, and health issues, is the target area to be renovated. The foundation of the project approach is the development of green infrastructures, which can resolve or lessen various socio-environmental issues. Activities include creating an “urban forestation” area,

experimentation of innovative gardening and collective farming techniques, promotion of the social value of the activity, development and shared management of 'green' areas and infrastructures for sharing and socialising, and social accompaniment activities and support paths for citizens to develop entrepreneurial or employable skills. All types of NbS have been implemented in the district.

Third Chapter: Discussion

The last chapter analyses the data collected for each city in the second chapter, analysing how and how much the implementation of NbS has benefited community health.

For the city of Barcelona, some data was collected and an interview was also conducted with two experts, the manager of the Barcelona Natura Plan and the manager of the Trees for Life Project. The morbidity, mortality and life years lost due to poor air quality were collected on an annual basis, from 2013 to 2019, through an epidemiological analysis. The life years lost were taken into account for two years, 2015 and 2019, before and after the implementation of the NbS.

Mortality and morbidity were calculated for respiratory diseases, as these are among the main consequences of climate change. Morbidity refers to the frequency of diseases of the respiratory system in a given population, while mortality refers to the number of people who die from a disease affecting the respiratory system. The indicator of life years lost is an estimate of the number of years lost due to diseases or premature deaths attributable to air pollution. Data analysis shows that mortality and morbidity have had a significant impact on public health in recent years, with the number of deaths ranging from 14,401 to 15,574 between 2013 and 2017, with a slight decrease in 2018 and 2019. The mortality rate has remained fairly constant over the years, ranging between 0.009 and 0.010.

The morbidity rate has remained relatively constant, rising from 0.014 in 2013 to 0.013 in 2019 and peaking in 2017 at 0.016. The table of years of life lost shows that deaths are more frequent in older age groups, with a higher incidence among the over-80s. However, younger age groups are also significantly impacted, with a significant loss of life years. This suggests that poor air quality could be a threat to public health in all age groups and that efforts to improve quality through the implementation of NbS could have a significant impact on the health and longevity of the population. However, due to the lack of data and their generality, it is not possible to draw conclusions on how mortality, morbidity and years of life lost have varied over the years.

To actually calculate whether and what health benefits NbS has brought, other data must be considered. For example, the fact that the health impact of air pollution in cities is increasing significantly, with 13% of all natural deaths, 17% of new cases of lung cancer and 51% of new cases of childhood asthma. Despite the cross-cutting nature of the effects of climate change on mental health, there is little scientific evidence of current

and future consequences. Recent studies conducted in similar contexts in Barcelona highlight citizens' concerns about climate change and associated emotional responses, such as eco-anxiety, especially in younger people. In Barcelona, 86.4% of girls and 78.8% of boys believe that climate change has a negative effect on their lives.

The data on hospital admissions due to high temperatures during extreme heat events (hospital admissions for specific disease categories such as circulatory system diseases and respiratory system diseases) are annual and refer to the years 2013 to 2020. The data show that the proportion of hospitalisations remained essentially stable from 2013 to 2016, with a subsequent decrease of 2% in 2019. With regard to admissions related to respiratory system diseases, the data show a steady increase from 2013 to 2015, from a rate of 9.76% to 10.10%. However, data for the years 2017, 2018 and 2020 are not available, so the only post-implementation reference data is for the year 2019, where the rate of 10.22% is higher than in 2016. To better understand how the implementation of NbS can benefit the health status of citizens, three other annual indicators were considered for the years 2013 to 2021: pollution, quality of life and health care.

From 2013 to 2021, the pollution level decreased steadily, from 75.9% to 64.8%, which is still a moderate level. This suggests that the installation of NbS has improved the urban environment and air quality. After the adoption of NBS, the Quality-of-Life index indicates a rising trend. Life quality rises from 2013 to 2016, is interrupted by a fall in 2017, then rises once more until stabilizing in 2019. The health care index also reveals that from 2013, when it stood at 58.5%, it has steadily increased, reaching 77.7% in 2021. This shows that health services in the study region have generally improved.

Overall, the data gathered indicates that the adoption of NBS has improved air quality, health care, hospital admissions due to heat-related illness, and years of life lost. It is crucial to keep in mind that these statistics are not only connected to the deployment of NbS; rather, other variables may have impacted their growth or decline over time.

For the proGIreg project in Turin, data was collected on cardiovascular diseases (mortality rate), years of life lost, pollution index, health care index and quality of life index. An interview was conducted with Dr. Roberta Molinar, project contact person for social inclusion and active citizen participation interventions. The mortality rate for various cardiovascular diseases in the city of Turin decreased by 19%, from 715.7 to 579.7 per 100,000 inhabitants. The years of life lost due to an illness or adverse event were also calculated for Turin. The data cover the years 2015 and 2019 and show that the number of deaths and life years lost due to illness decreased after the implementation of green solutions in the city of Turin. However, the effect of green solutions seems to be more pronounced in younger age groups, where there was a greater reduction in years of life lost than in older age groups. Data from the same Barcelona database for the years 2016 to 2023 suggest that NBS

implementation has had a positive impact on public health, but other factors may have contributed to the decrease in life years lost.

Turin saw an improvement in pollution levels, from 78.8% in 2016 to 68.2% in 2023. The health care index showed an improvement from 2016 to 2018, followed by a slight decrease in 2019 and 2020, then increased again in 2021 and decreased slightly between 2022 and 2023. The Quality-of-Life index also showed some fluctuations, with a decrease in 2020 and 2021, but an overall increase from 2016 to 2023. However, the overall trend shows a positive impact on the quality of life after the implementation of the NBS, with a slight decrease in both indices after implementation.

According to Dr Molinar, the implementation of the NBS has had a positive impact on the health and well-being of citizens. Green infrastructure is benefiting citizens' physical and mental health, as it is managed by voluntary citizens and associations with the help of people with intellectual disabilities. Soft gymnastics courses for the elderly population have also been initiated, and scout groups regularly organise their meetings and motor activities in these spaces. Hence, the relationship between physical/social activity and green spaces seems to be strong, meaning that an increase in green infrastructure could lead to more people being physically active and benefit the physical health of citizens.

However, in order to obtain positive feedback from the community and for these spaces to actually benefit the health of citizens, it is necessary for those who take care of these NbS to do a lot of work. For example, when for environmental reasons or because volunteers are less present and involved in maintenance, green spaces are less well cared for and this leads citizens to despise these spaces. In order to have a beneficial return on society in terms of health, it is important to work on and with citizens, including them as much as possible in the maintenance and design of these spaces and educating them on issues of environmental sustainability and biodiversity.

There are several parallels and contrasts between the two cities. First, in terms of data accessibility, Barcelona has a larger database available to residents, but not enough to fully evaluate if NbS contributes to enhancing residents' health. While the figures for fatalities in the two cities in 2015 and 2019 are about the same, the values for years of life lost are significantly different because of the disparity in life expectancy. The years considered between Turin and Barcelona in terms of indices of pollution, healthcare, and quality of life are different; for Turin, the years from 2016 to 2023 were examined, whereas for Barcelona, the years from 2013 to 2021 were considered. It is clear that both cities have made progress in terms of pollution in recent years, but with differing trends. The Piedmontese capital saw fewer notable variations and climbed from 2020, whilst the Spanish city experienced a considerable improvement from 2015, reaching a peak of 159.0 in 2016.

Both cities appear to have seen continuous advances in the health care index in recent years, with Barcelona expanding more quickly than Turin. The most crucial piece of evidence is the collection of data for the pre- and post-implementation periods in both cities, but the absence of numerous indicators that would have been helpful in analyzing the effects of NBS. This is a result of the dearth of databases or the complexity of some data's interpretation. In order to be able to declare with certainty if green solutions may have positively impacted residents' health condition, additional elements should be included in the data collection as the figures for years lost and fatalities are not directly tied to the implementation of NBS. Dr. Molinar, proGIreg's contact person, confirmed that the NbS project does not have a research dimension, in other words they are not collecting quantitative data.

Therefore, the opinions of individuals who are directly involved in the upkeep and maintenance of these places as well as the residents who use them are the only sources of data from which we may draw conclusions for the study issue. It will take a long time to complete the investigation of the connections between vegetation, nature in general, and public health. Other organizations and agencies, such as universities and research institutes, in addition to the City Council, serve as reference points for conducting environmental studies that link vegetation and health. Currently, for the city of Barcelona, the study concerning the elaboration and evaluation of the global impact of nature on citizens' health is underway and is working transversally with the Barcelona Public Health Agency (ASPB), CREAF and in the future it is planned to collaborate with ISGLOBAL. However, the complexity of the study is great and the results depend on many factors. Therefore, further studies, data collection and comparisons with the citizens of the cities involved would be necessary to assess the long-term effects of the intervention on the population.

Conclusion

This research aims to assess whether NbS can benefit the health of citizens. The two cities analysed are Barcelona and Turin, as they are most affected by the heat island phenomenon and have initiated nature-based green solution projects. These projects have the potential to improve health and well-being by reducing air pollution, ensuring better air quality, improving physical activity, reducing stress levels and promoting social cohesion. They also have the potential to reduce stress levels and promote social cohesion. However, the lack of quantitative data and the need for collaboration between different fields such as public health, sociology, urban ecology, environmental policy and human geography hinder a more thorough assessment of green infrastructure in cities.

Therefore, an interdisciplinary approach is necessary for research purposes. However, the set of indicators developed and used in this work provides a good starting point for planning further strategies in the implementation of nature-based solutions and may, over time, allow for answers on a broader scale on how these solutions are or are not benefiting the health of citizens. The hope is also to be able to engage and educate

citizens on these new issues of environmental sustainability and biodiversity, so that they understand how these tools can benefit their health and that of our planet.

RQ: *How can Nature-based Solutions mitigate the negative effects of climate change, while having a positive impact on society in terms of healthy well-being?*
Positive outcomes of the study:
1. Useful set of indicators to understand the current general health situation of citizens in the cities in question
Outcomes of the study for future research hints:
2. In the two NbS-type projects analysed, the implementation of the health sphere is still not very mature
3. Need for interdisciplinary approach
4. Necessity for further research in the health sphere associated with NbS