Nature-based Solutions in the Mediterranean: How can Nature Help Tackle the Growing Air Pollution Crisis?

NOTE FOR POLICY MAKERS

Air pollution in Mediterranean cities is a growing concern, driven by industrial emissions, traffic, and climate change, which exacerbates pollutant formation. With two-thirds of Mediterranean countries exceeding air quality standards set by the European Union (EU) and World Health Organisation (WHO), this issue poses significant health risks, including respiratory diseases and environmental degradation. Nature-based solutions (NbS), such as green roofs, street trees, and urban green and blue spaces and corridors, offer effective strategies for mitigating air pollution while providing additional benefits like temperature regulation, biodiversity support, and improved public health. This paper summarizes through various Plan Bleu publications and other relevant research, the potential of implementing NbS at various scales, from individual buildings to city-wide initiatives, emphasizing the need for context-specific, integrated approaches. The findings highlight the importance of design, economic considerations, and long-term maintenance in maximizing NbS impacts, ultimately contributing to enhanced urban resilience and sustainability as well as inhabitants wellbeing.

Air pollution in the Mediterranean Cities

Mediterranean cities, where 70% of the region's population lives - including one-third in coastal areas (see Figure 1) - face severe air pollution issues, especially in urban, peri-urban, and port-adjacent coastal zones (RED 2020 Infographies, 2020; RED 2020).

This is driven by industrialisation, traffic emissions, and global warming, which in turn, intensifies pollutant formation through amplifying heat, wildfires and air stagnation (Dulac et al., 2016).

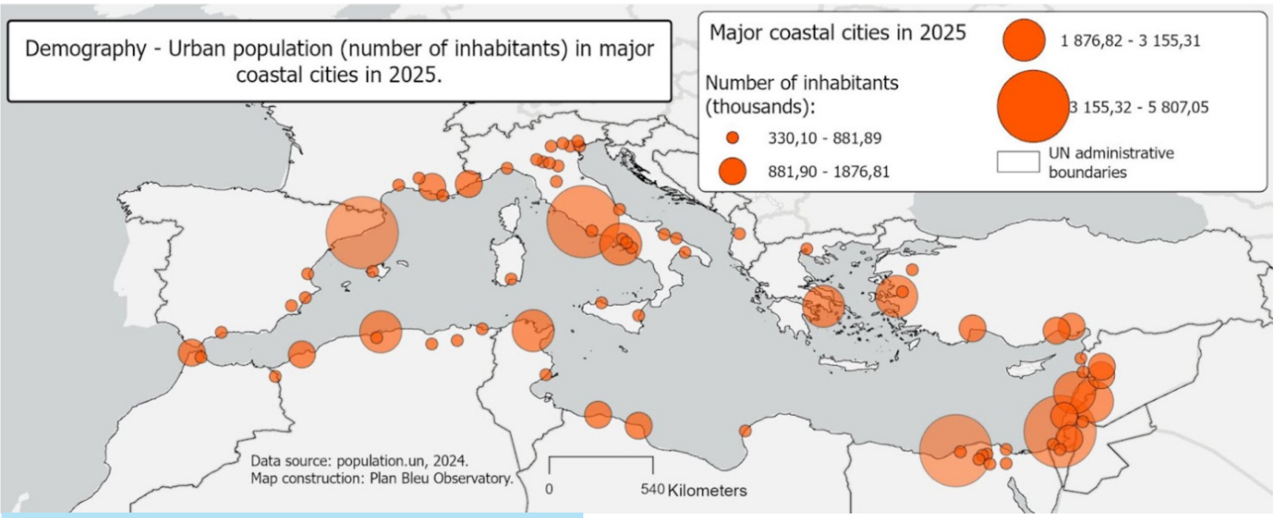

Fig.1 *Demography in major coastal cities in 2025*
Source: Plan Bleu Observatory

Poor air quality causes major health issues, including respiratory diseases, reduced life quality, and long term environmental degradation. Air pollution standards set by both EU directive[1] and WHO guidelines[2] for pollutants such as particulate matter (PM), nitrogen oxides (NOx) and ozone (O_3), are exceeded in 2/3 of Mediterranean countries (Plan Bleu MED2050, 2025). In fact, air pollution was estimated to cause up to 228 000 premature deaths per year in the Mediterranean countries as of 2016 (RED 2020). More recent figures indicate that in the Middle East and North Africa region alone, this number has reached approximately 270 000 deaths annually (World bank, 2022)[3], reflecting the significant and rising health burden across the region. WHO data show that 74-81 % of the EU population is exposed to harmful PM2,5[4] levels, and 95-98 % to ozone concentrations above health thresholds (Calfapietra, 2020 ; Air - European Commission (n.d.)).

Figure 2 illustrates the shore disparities in average annual PM2.5 concentrations across the basin, with notably high levels in Egypt (above 60 µg/m³) between 2010 and 2019. Over the 1961-2022 period, total NOx emissions varied significantly at national levels from +1697,3 % (in Libya) to -99,1 % (in Türkiye) and by approximately 73.6 % in North Mediterranean countries and striking 758 % in Southern and Eastern countries (Plan Bleu Observatory, based on Our World in Data database, 2024). These trends point to important implications for policy and planning, particularly in sectors such as transportation - which are closely linked to emissions patterns and exposure levels - and more broadly by strengthening socio-economic development. They also reflect the increasing urgency of addressing air quality challenges across the region, emphasizing the value of integrated and sustainable approaches to managing environmental and development goals.

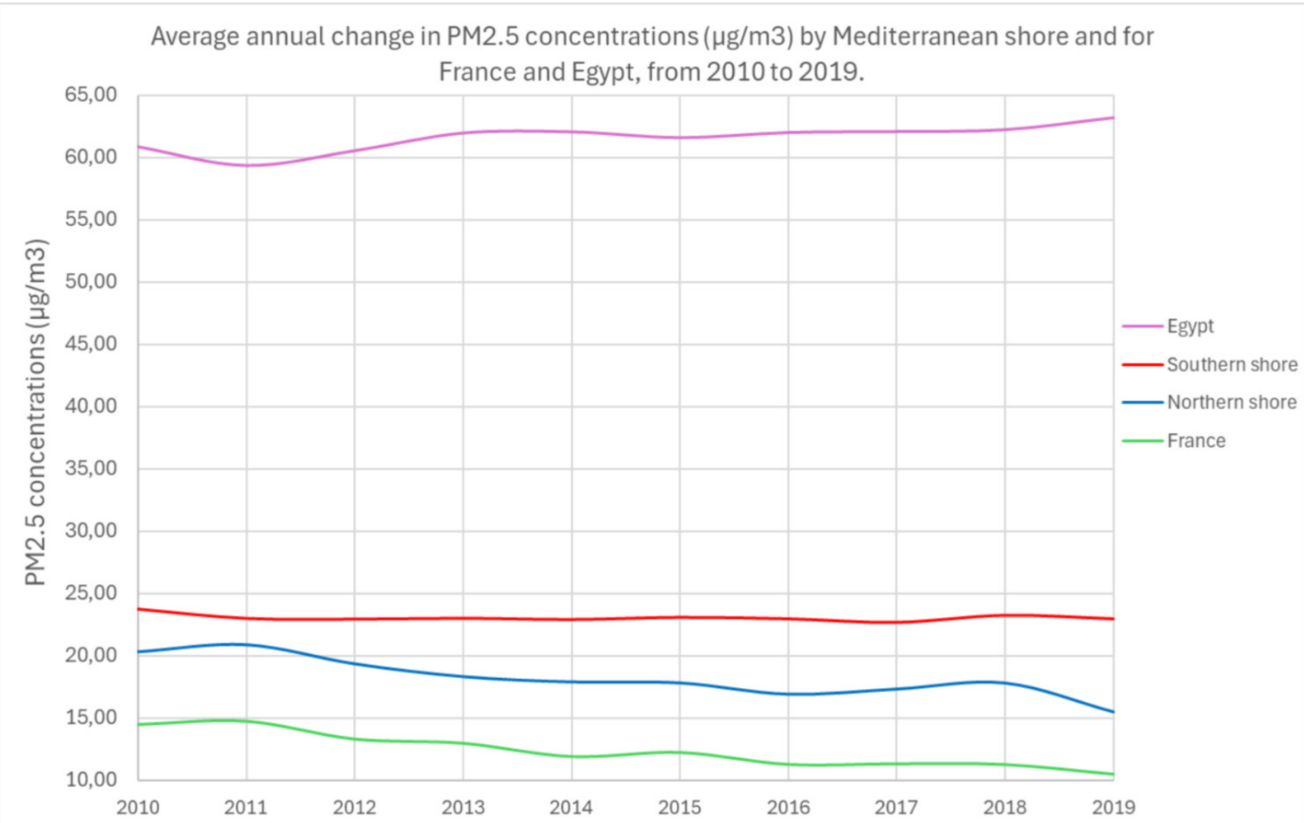

Fig.2 *Average annual change in PM2.5 concentrations (µg/m³) by Mediterranean shore, as well as for France and Egypt, from 2010 to 2019.*
Source: Plan Bleu Observatory, based on World Health Organization database 2024.

1 Directive 2008/50/EC.
2 Air quality Standards (2021)- Annual averaging time (2021) : PM2.5 µg/m³ = 5; PM10 µg/m³= 15; NO_2 µg/m³ = 10 (WHO, 2021).
3 MENA's Polluted Skies And Seas Hurt Economies, Livelihoods (2022).
4 Solid particles with a diameter <2.5 µm.

In this regard, nature-based solutions (NbS) through the process in particular of greening (see Figure 3), offer a cost effective way to address urban air pollution by protecting, managing, and restoring ecosystems. Beyond improving air quality, NbS enhance resilience, support biodiversity, and provide multiple co-benefits through sustainable, locally adapted actions (Plan Bleu, 2024). Although NbS aimed at mitigating air pollution often function through comparable mechanisms, their implementation in Mediterranean cities have to account for specific constraints such as high urbanization density, limited space, and strong demographic rates and climate pressures.

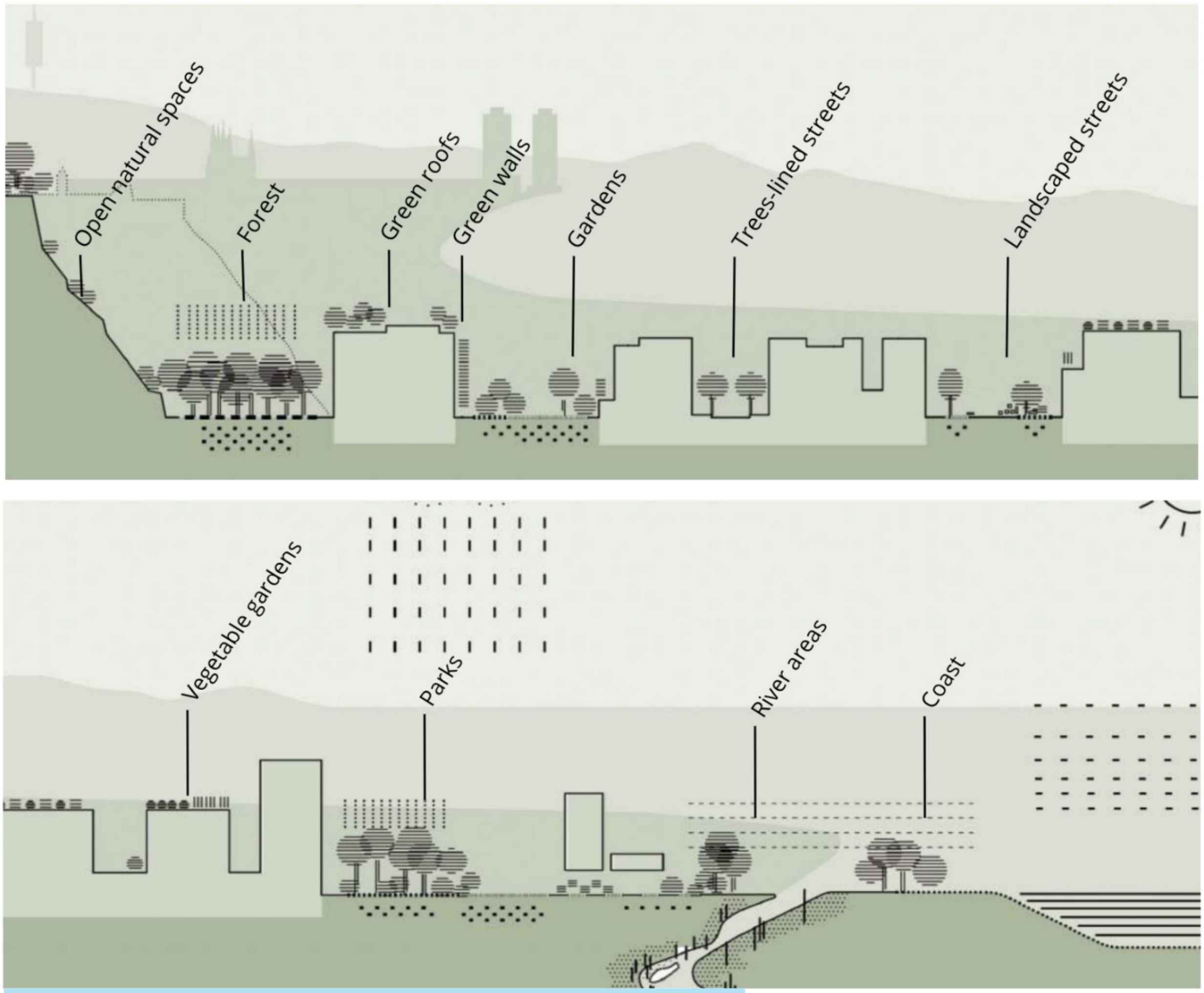

Fig.3 *Types of green urban spaces in cities.*
Source: Adapted from Barcelona Green Infrastructure and Biodiversity Plan 2020. (n.d.)

Approach

This analysis is grounded in Criterion 2 of the IUCN Global Standard for Nature-based Solutions, "Design at Scale", which highlights the importance of designing scale-sensitive, context-specific solutions that integrate economic, social, and ecological systems (IUCN Global Standard for Nature-based Solutions: first edition, 2020). In this context, as air pollution occurs at all geographical scales, from the local level of individual buildings (e.g. industries, fuels combustion to power buildings) to neighborhoods (e.g. buildings and traffic emissions), and extending to the broader city scales (cumulative impact of all emissions) (Manzueta et al., 2024), it is valuable to explore which types of NbS are more appropriate for adapted implementation at each level of the urban fabric. Indeed, NbS are not one-size-fits-all responses, but rather interventions for adaptation that must be carefully designed according to the spatial scale and specific characteristics of the urban fabric and conjointly planned with emission mitigation processes.

This paper proposes a non-exhaustive list of NbS to be implemented, categorized across three scales: the building level (local), to neighborhoods and streetscapes level (intermediate), and up to the city-wide level (global). Building on a literature review of various Plan Bleu's publications and other relevant research on NbS, it provides on one hand, some quantitative insights of their implementation and maintenance costs - mainly issued from Panduro et al. (2021) research - and on the other hand, a qualitative overview of their spatial requirements, as well as their benefits and limitations. It also offers actionable recommendations to support the effective deployment of NbS, with the aim of enhancing urban resilience to air pollution and climate change.

NbS as a solution to tackle Air Pollution issue

Natural elements act as filters by capturing air pollutants - both gases (e.g., NOx, Ozone, CO_2) and fine particles - through mechanisms like dry deposition and stomatal uptake[5]. These pollutants originate from both human (e.g. industry, transport) and natural processes (e.g., wildfires) (Singh et al., 2023). However, the effectiveness of vegetation in improving air quality by sequestrating air pollutants depends on species physiological characteristics (e.g., foliage type, leaf size, crown structure, stomatal behavior) and seasonal dynamics (Calfapietra, 2020). Moreover, urban greening strategies should prioritize plant diversity while avoiding the use of invasive exotic species, highly flammable vegetation, and species known to trigger allergic reactions.

Which NbS in the urban fabric?

From the building level: Green buildings

Green roofs and walls offer a multifunctional solution for mitigating air pollution, particularly well-suited to densely populated cities with limited space. By utilizing the horizontal and vertical surfaces of existing buildings, they make use of otherwise underused space, integrating green infrastructure without encroaching on valuable ground-level land. This spatial strategy is particularly advantageous in compact urban environments where creation of new green spaces is constrained. Also, their relatively low land-use opportunity cost enables cities to deliver socio-ecological benefits, without competing with essential urban functions (e.g., housing, transportation) (Panduro et al., 2021).

There are two types of green roofs: the extensive one, that can be added to existing buildings without the need for structure reinforcements; and the intensive one, which usually requires buildings specifically designed to support it. Costs for construction vary depending on factors such as material selection, installation techniques, and local labor prices, and a successful implementation depends on appropriate design, quality materials and skilled installation. Table 1 shows establishment and maintenance costs (L'Institut Paris Region, 2021) for extensive and intensive green roofs, but also for the priciest green wall (Tablecloth) and the cheapest one (Climbing) in France[6] (Panduro et al., 2021).

	Establishment	Maintenance
Extensive green roof	63 €/m^2	11.77 €/m^2
Intensive green roof	185 €/m^2	14.01 €/m^2
Tablecloth green wall	797 €/m^2	61 €/m^2
Climbing green wall	55 €/m^2	9.5 €/m^2

Table 1. *Establishment and maintenance cost for Green roofs and green walls in France (2021).*
Source: Panduro et al. (2021) from L'Institut Paris Region (2021)

5 A process through which pores found in the epidermis of leaves can improve air quality by capturing pollutants.
6 The exact location is not specified.

Figure 4 : *Green buildings in Paris: a semi-intensive green roof.
Source: Mairie de Paris (2024)*

Figure 5 : *Green buildings in Paris: a climbing wall.
Source: Mairie de Paris (2024)*

A relevant project was carried out in Izmir, Türkiye, as part of the Horizon 2020 URBAN GreenUp initiative, which aimed to address the urban heat island effect and reduce air pollution. Among various small-scale nature-based interventions, green roofs were implemented over car parking areas to lower temperatures, expand UGSs[7], and enhance sustainability (Plan Bleu, 2024). The intervention was expected to reduce evaporative organic gas emissions by approximately 2%, and NOx emissions by less than 1% (IZMIR (Türkiye) – RE-NATURING URBAN PLAN WITH NBS. (n.d.)).

Green roofs may appear as a cost-effective solution regarding traditional roofs. As illustrated in Figure 6, green roofs and cool roofs have similar benefits, however, green roofs, although moderately effective, stand out as a more favorable option when addressing air quality in urban environments (Panduro et al., 2021).

7 Urban green spaces.

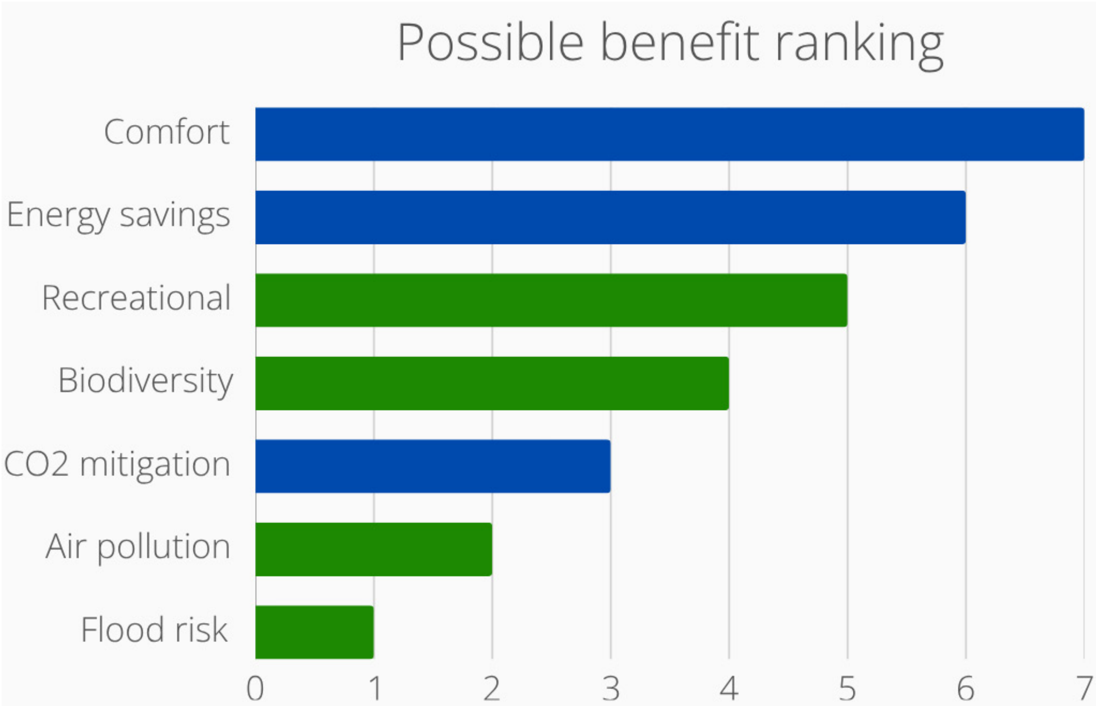

Fig.6 *Illustrative ranking of potential benefits for green roofs and cool roofs. The green column is specific to green roofs, while the blue column represents shared benefits with cool roofs.*
Source: Adapted version of Panduro et al. (2021)

From an economic perspective, while green roofs may involve higher upfront installation costs compared to conventional or cool roofs, they can become 20-25% less expensive over time when factoring in savings on heating and cooling. Overall cost savings can increase by up to 40% when including non-market benefits (e.g. stormwater retention) (United Nations Environment Programme, 2020). However, these estimates depend on local conditions, including energy prices, policy incentives, and the methods used to value environmental benefits. A study conducted by Berto et al.(2018) in Trieste (North-Eastern Italy), compared extensive roofs and cool roofs over a 40-year period for a 400 m³ volume. Despite the initial cost difference, green roofs ultimately proved slightly more cost-effective (€76,443 vs. €77,100), primarily due to their longer lifespan and lower maintenance costs, which are influencing the outcomes along with the discount rate (Berto et al., 2018). Given the marginal cost difference, a broader assessment of green roofs may be relevant, particularly when considering co-benefits beyond air pollution.

To neighborhoods and streetscapes level: the role of street trees

As a key component of the 3-30-300 green space rule[8], street trees offer an efficient use of limited space, being suitable for narrow strips, sidewalks, or underused areas and making them well-suited for dense city environments. The typical volume of planting pits range from 1 to 10 m³ per tree (Pauleit, 2002). While smaller than larger green spaces (e.g. woodlands, urban forests), they still compete for space with urban needs like parking, bike lanes, or building expansions. However, with a lifespan over 50 years, street trees not only save space but also significantly reduce air pollution, outperforming green roofs, walls, and wetlands (Panduro et al., 2021). For instance, road trees in Istanbul can reduce PM2.5 levels by 17%, and avenue trees in China can lower PM10[9] by 39% to 89%, depending on wind conditions (Ozdemir, H. 2019 ; Ren et al., 2023). Reflecting this growing recognition, cities like Lyon (France) have launched ambitious Nature Plans: the municipality aims to plant 100,000 new trees and has already transformed 7,500 m² of paved surfaces into green areas, with a €141 million budget dedicated to greening urban space and creating cooling corridors across neighborhoods.

8 Cities' residents should see 3 trees from home, have 30% tree canopy cover in the neighborhood, and be within 300 meters of a green space (Konijnendijk, 2021)
9 Solid particles with a diameter <10 µm.

In an economic perspective, costs for establishment of street trees range from approximately 100€ to 2000€ per tree in European Cities, a cost that includes acquisition of trees and site preparation (Pauleit, 2002). Street trees require ongoing maintenance, including pruning, pest management and watering which need to be integrated in the municipal budgets. Maintenance costs in Lisbon, Portugal, are estimated to be 43.51 €/unit (2011). Root interference with roads or sidewalks has been identified as a potential challenge, highlighting the importance of thoughtful design and planning in street tree implementation (Panduro et al., 2021).

In Barcelona (Spain), the Green Infrastructure and Biodiversity Plan to 2020 serves as a key example of urban greening efforts. This plan focuses on increasing both the number and diversity of street trees, expanding the soil available for their growth, and improving the overall quantity and quality of green spaces (Plan Bleu, 2024 ; Eklipse, 2017).

Fig.7 *Street trees of the Eixample district in Barcelona.*
Source: Àrea d'Ecologia et al (2017)

Up to the city-wide level: Urban green spaces & blue spaces

Urban green spaces (UGSs), such as parks, forests, and woodlands, and urban blue spaces (UBSs), including wetlands, ponds, and lakes, are both long-lasting NbS with lifespans exceeding 50 years. They provide vital ecosystem services: UGSs are particularly effective in mitigating air pollution primarily through their abundant vegetation, while UBSs contribute through both air and water purification. Both NbS are effective in flood mitigation - though UBSs tends to perform better in this regard - and contributes to recreational opportunities while enhancing the aesthetic and social values of urban environments (Panduro et al., 2021).

Fig 8. *Ichkeul Lake in Tunisia.*
Source: Garcia (2021)

Fig 9. *Camaldoli City Park in Napoli.*
Source: Camaldoli City Park - NapoliForMe. (n.d.)

As an example, it has been estimated that urban green infrastructure removes around 1,148 Mg[10] of PM10 annually, corresponding to a monetary value of 36 million €/year in the Metropolitan City of Naples - where approximately 20% of lands are covered by vegetation - and a loss of 3 million euros after a devastating wildfire where PM10 removal capacity was clearly diminished (Sebastiani et al., 2021). This underscores the relevance of preserving green infrastructure, as its degradation may be associated with significant economic consequences for cities.

On the other side of the Mediterranean basin, a relevant example can be found in Alexandria (Egypt), where a project addresses urban flooding through NbS, such as wetlands ponds to support urban microclimates, groundwater recharge, and enhance recreational spaces. These solutions are tailored to fit the diverse urban fabric of Alexandria, ensuring the most suitable environmental benefits of each area (Plan Bleu, 2024).
Despite their environmental and health benefits, both UGSs and UBSs face a common limitation: the significant amount of land they require. In densely populated urban areas, where land is scarce and expensive, this presents a major challenge. However, implementing these solutions on the outskirts of cities can help reduce establishment costs, as land is generally cheaper and land-use competition is less intense in peri-urban areas (Panduro et al., 2021). To ensure that land is set aside for natural areas, regulatory tools such as "coupures d'urbanisation" ("urbanization breaking")[11] - as required by France's Littoral Law - offer an additional opportunity to preserve or create natural spaces within urban continuums. These non-urbanized buffer zones, mandated in planning documents, can serve as ecological corridors with land reserved for future green or blue spaces. Integrating similar instruments into urban planning frameworks across Mediterranean countries could support coastal resilience while curbing urban sprawl.

Economically, establishing either green or blue spaces in urban settings involves high initial investments. For UGSs, this often includes soil treatment, landscaping, planting, and the installation of features like benches, pathways, or playgrounds. Similarly, UBSs development typically requires excavation, land clearing, landscaping, and sometimes additional infrastructure. Costs for both types of spaces vary depending on size, design complexity, and included amenities, but larger projects often benefit from economies of scale. Labor costs significantly influence the initial expense, making projects more feasible in areas with lower wages.

Examples illustrate these costs: in Getxo (Spain), creating a new UGS was estimated at 23.29 €/m² (2019), while in Gonesse, Paris (France) the mean establishment cost for wetlands was 1.6 €/ m².
Cost-effectiveness ratios have been estimated in Gonesse for the establishment and maintenance of a wetland (and small ponds) of 38 €/m³ and 838 €/m³ for installing concrete open basins. This suggests that NbS such as wetlands, especially when restored and protected, can be more cost-effective strategies (Panduro et al., 2021).

Maintenance is another economic aspect to account for both UGSs and UBSs. UGSs require regular landscaping, litter removal, and security, with park maintenance. For example, in the Veneto Region (Italy) in 2012, maintenance costs were on average €1.10 per m² (Tempesta, 2016). UBSs maintenance includes habitat restoration, water quality monitoring, and debris removal, with maintenance costs for wetlands in Gonesse of 0.5 €/m². Without proper upkeep, both green and blue spaces risk degradation, leading to environmental, social and safety concerns (Panduro et al., 2021).

Major co-benefits of NbS

The NbS discussed in this paper, not only contribute to improving air quality, but also provide multiple additional benefits across various sectors (Figure 10), such as reducing urban temperatures and energy demands - essential in Mediterranean cities exposed to extreme weather conditions like heatwaves and droughts - by providing shade and enhancing air cooling and humidity through evapotranspiration. This becomes crucial given projections of increasing warm temperature and heat waves intensification in duration and peak temperatures (MAR1 - MedECC, 2020). Reduced heat also leads to lower air conditioning needs, energy savings, and overall reductions in cities' carbon footprint (Calfapietra, 2020).

These NbS can also help absorb rainfall, reduce runoff, and relieve pressure on drainage systems playing a key role in flood risks, and in parallel, enhance quality of life by improving both physical and mental health. They support biodiversity, foster urban regeneration, and reconnect residents with nature, which promotes relaxation and well-being. Proximity to green spaces has been associated with reduced risks of cardiovascular and obesity-related diseases (Calfapietra, 2020). In addition, urban nature also supports, if well-implemented, social cohesion and sustainable community development, contributing to a healthier, more inclusive environment (Plan Bleu, 2024).

10 Megagram (tonnes)
11 For more information: link.

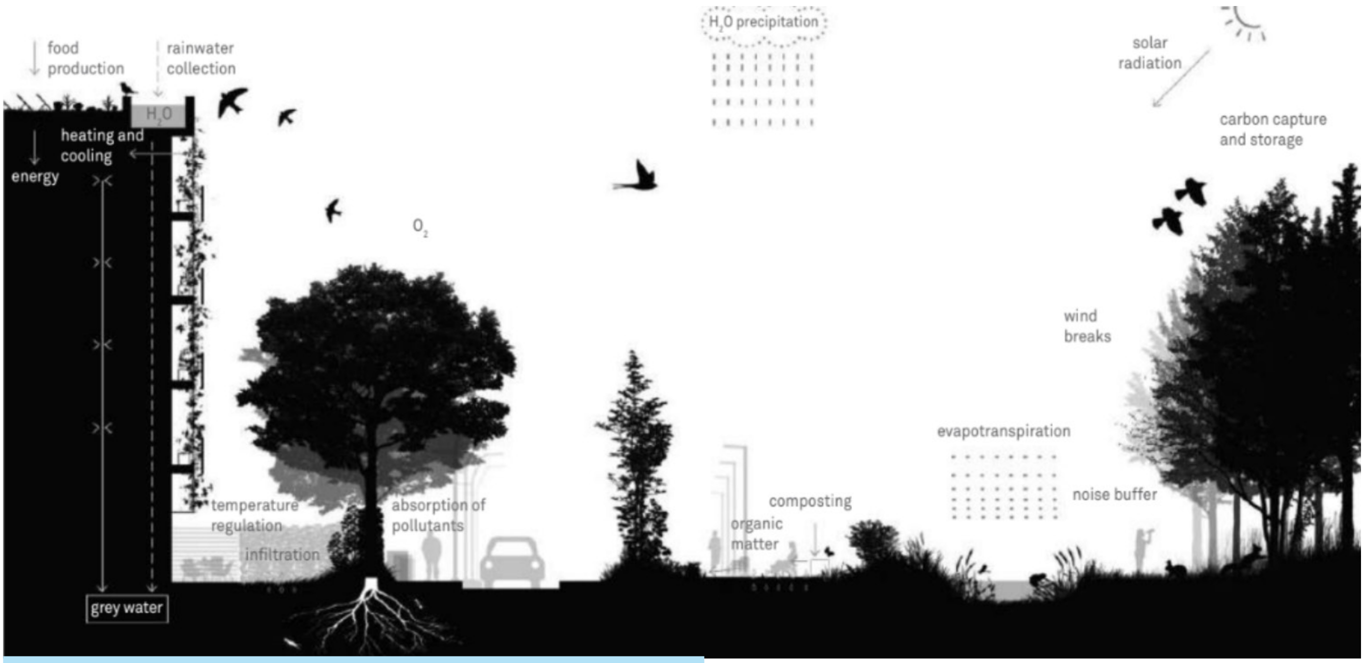

Fig.8 *Major co-benefits of greening urban spaces.*
Source:Barcelona Green Infrastructure and Biodiversity Plan 2020. (n.d.)

Finally, they offer cost effective alternatives to traditional infrastructure, while generating long-term savings in energy, public health, and stormwater management. They also boost local economies by attracting tourism and increasing foot traffic in commercial areas (Plan Bleu, 2024).

Conclusion & Recommendations

When considering scale, different NbS can be designed, from local-scale and low-space options like green roofs to cities-scale urban parks and wetlands, all contributing to air pollution mitigation. To maximize their impact, urban planning must prioritize integrated, context-specific interventions - favoring compact solutions in dense areas while preserving space for larger ones where feasible. Ensuring a just transition, promoting social cohesion, and combining multiple small-scale interventions to offer a holistic approach can enhance outcomes.

To support large-scale and sustained investment in NbS, considering pathways for better integration of financing mechanisms is valuable. Instruments such as green bonds or blended finance schemes represent potential tools to attract both public and private capital, lower investment risks, and enhance the long-term viability of NbS. Understanding how such mechanisms align with existing urban planning frameworks could inform future strategies for scaling NbS implementation.

In parallel, hybrid approaches that combine NbS regulatory air pollution control measures (e.g., low-emission zones) can generate stronger, longer-term impacts. NbS alone cannot sufficiently address urban air pollution and must be supported by robust emission reduction policies. In the Mediterranean, the Barcelona Convention promotes this complementarity: the Mediterranean Strategy for Sustainable Development (MSSD) identifies urban greening as a key indicator[12], while recent regulatory steps - such as the entry into force of the Sulphur Emission Control Area (SECA) and the ongoing efforts toward a Nitrogen Emission Control Area (NECA)[13] - illustrate concrete action to curb emissions and reinforce the role of NbS.

12 Indicator under the Objective 3.1 of the MSSD, promoting a holistic and integrated territorial planning processes, alongside improved compliance with relevant regulations, to enhance economic, social, and territorial cohesion while reducing environmental pressures (link).
13 For more information: (1) ECAMED: a Technical Feasibility Study for the Implementation of an Emission Control Area (ECA) in the Mediterranean Sea (2019, link); (2) Market responses and distribution of costs related to the possible designation of the Mediterranean Sea, as a whole, as an Emission ControlArea for Sulphur Oxides (Med SOX ECA) (2022, link).

Summary Table

The summary table is informed by both qualitative and quantitative data presented in the paper. However, it is important to note that the results related to air pollution mitigation efficiency are primarily drawn from Panduro et al (2021) and should be interpreted with caution.

Mitigation outcomes are highly specific to types of pollution, the NbS considered, and the city-context, making it difficult to extract precise, generalizable data from the literature. Additionally, the cost level legend was developed based on the range of examples discussed throughout the paper.

Urban Frabric Scales	Types of NbS	Spatial Features	Air pollution mitigation efficiency	Cost level	Cost Depends On
Building level	Green roofs	Space-efficient		Moderate to High	Materials, labor, techniques, structural capacity (extensive/intensive)
	Green walls	Space-efficient		Moderate to High	Materials, labor, techniques, wall type and species used, irrigation
Street/District level	Street trees	Narrow fit		Moderate to High	Tree species, preparation work, labor, long-term care
City-wide/Peri-urban level	Green spaces (Woodlands, Urban Parks)	Large-scale		Low to Moderate	Land prices, scale, labor, design complexity, species used, site conditions
	Blue spaces (Wetlands)	Large-scale		Low to Moderate	Excavation, scale, labor, infrastructure, site conditions

	Low
	Moderate
	High

Cost level:

Low	≤ 25 €/m² or ≤ 100 €/unit
Moderate	≥ 26 €/m² or ≥ 101 €/unit
High	≥ 150 €/m² or ≥ 1000 €/unit

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ADEME AGENCE DE LA TRANSITION ÉCOLOGIQUE

PLAN BLEU
Regional Activity Centre of UN Environment/MAP
Marseille, France
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Graphic Design : **Christelle El Selfani**
Legal deposit : **N° ISSN 2606 61 06**

UN environment programme | Mediterranean Action Plan Barcelona Convention | Plan Bleu