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Building evidence regarding nature-based solutions indicators and their implications for policy – the case of air quality

Corina Basnou [a,*], Geovana Mercado [b], Åsa Ode Sang [b], Thomas B. Randrup [b], Verónica Fabio [c], Adrián Cabezas [d], Arnau Lluch [d], Marc Montlleó [d], Juan Miguel Kanai [e], Riccardo Saraco [f], Olivia Bina [g], Tom Wild [h]

[a] CREAF, Cerdanyola del Vallès, Spain
[b] Department of Landscape Architecture, Planning and Management, Swedish University of Agricultural Sciences, Box 190, 234 22, Lomma, Sweden
[c] Faculty of Architecture, Design and Urbanism, University of Buenos Aires, Intendente Güiraldes 2160, Buenos Aires C1428EGA, Argentina
[d] Barcelona Regional Agència de Desenvolupament Urbà, Carrer 60, 25-27. Edifici Z, 2a planta. Sector A, Carrer 60, 25, 08040 Barcelona, Spain
[e] Department of Geography, Faculty of Social Sciences, University of Sheffield, Sheffield S10 2TN, UK
[f] Divisione Innovazione e Fondi Europei, Ufficio Smart City, Progettazione Europea, Innovazione, Corso Ferrucci 122, 10141 Torino, Italy
[g] Instituto de Ciências Sociais, Universidade de Lisboa, Lisbon, Portugal
[h] Department of Landscape Architecture, Faculty of Social Sciences, University of Sheffield, Sheffield, UK

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ABSTRACT

Air pollution is one of world's largest planetary health risk factors. Nature-based solutions (NBS) have been key in integrating air quality indicators into the urban green planning and public health discourse. Despite important contributions, approaches that include multidimensional indicators into research, planning and policies are still limited. National standards for some types of air pollutants are missing, with little evidence for a threshold for health effects. To respond to these gaps, we provide an overview and guidance for air pollution indicators, using three case studies in Europe and Latin America. We discuss the importance of context, specific pollutants and vulnerable groups and suggest new approaches at finer scales. Our findings also point out that knowledge of pollutants uptake in edible plants can give a hint to potential exposure risks for humans. Our lessons learned target specific policies and are organized into three main ideas: (a) multidimensional indicators and their implications for NBS and policy; (b) plants as biological indicators and as schools' subjects and (c) the integration of the co-benefits to manage air quality.

Introduction

Air pollution is a major threat to the environment and to human health worldwide [1], being responsible for approximately 9 million deaths per year, corresponding to one in six deaths worldwide [2]. Certain demographic groups, such as children and the elderly, are more sensitive to the health issues associated with urbanization and urban living, including exposures to air pollution, particularly in combination with climate change [3].

Traffic is a significant source of air pollution. Research revealed that particulate matter (PM), CO, NO_2, O_3, SO_2 and heavy metals were all positively and significantly associated with all-cause mortality [4]. Other studies found that both $PM_{2.5}$ and PM_{10} were associated with increased mortality for cardiovascular disease, pulmonary/respiratory disease, and lung cancer [5,6]. PM and NO_2 have also been shown to be associated with a higher likeliness to develop type 2 diabetes, as well as patients with type 2 diabetes to be more vulnerable to those pollutants [7,8]. Recent studies also document negative impacts on neurological and reproductive health [9,10].

PM, which includes heavy metals, is highly mobile in the atmosphere and can deposit to soils and water, where the metals can accumulate in drinking water and in various plants and animals that are ingested by humans. The concentration levels of heavy metals in the European Union (EU) are regulated by European legislation, which sets target and limit values as annual means, and by the World Health Organization (WHO) that defines guidelines and reference values for those metal elements for food consumption. With regard to heavy metal pollutants (part of the complex mixt of PM), various studies reported their harmful

* Corresponding author.
E-mail address: c.basnou@creaf.uab.es (C. Basnou).

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Box 1
Summary of pollutants effects on human health.

Cd: Nephrotoxicity; Long-term exposure to lower levels leads to accumulation in the kidneys and kidney disease, lung damage and brittle bones, hypertension, arthritis, diabetes, anemia, cancer, cardiovascular disease, stroke, etc. [13,14]; Itai-Itai disease, bone disorders in Asian countries [15]; it is eliminated very slowly, with a biological half-life of 16 to 33 years [16]
Co: Physical properties similar to Ni; it is part of vitamin B12; in high concentrations, it can cause vomiting, vision problems, asthma, cardiovascular, thyroid problems
Cr: Nephrotoxicity, respiratory problems
Cu: Wilson's disease, liver diseases
Mn: Manganism (similar to Parkinsonism); neurodegenerative alterations (possibly at the level of the *substantia nigra*) (Harischandra 2019)
Ni: Eczema, allergies, asthma, chronic bronchitis, carcinogen
Pb: Neurotoxicity; It accumulates mainly in long bones, but also in the liver or kidney; children and the elderly with osteoporosis are among the population at risk. It can have an average life of 25 days in adults, 10 months in children or over 20 years (bones) [16]
V: Gastrointestinal disorders, green staining of mucous membranes, haematological disturbances and reduced concentrations of cysteine in hair and nails [17,18]
Zn: Interferes with Cu in the body; it is an important nutrient, it helps the immune system and metabolism; in general, low doses to the body are of more concern
NO_2: Asthma symptom episodes in children (depends on the time of exposure); other respiratory diseases [19,20]. Motor traffic has been associated with increased heat-related mortality (Nieuwenhuijsen and Khreis, 2017). Is associated with dysregulation of glucose metabolism increasing likelihood to develop type 2 diabetes [7]
Other traffic-related air pollutants (CO, SO_2, VOCs polycyclic aromatic hydrocarbons - PAHs): hypoxia, respiratory diseases; among traffic related VOCs, aromatic compounds, including benzene, toluene, ethylbenzene, and isomers of xylene (BTEX), have public health importance; they have high toxicity, especially to central nervous system; benzene is a human carcinogen [21]
Some health problems, such as heart and lung conditions, can make a person more vulnerable to harm from air pollution. Exposure to traffic-related air pollution has been associated with increased mortality from COVID-19 and exposure to cadmium has been associated with increased mortality from influenza [2].

effects on crop quality, affecting both food security and human health [11]. Despite evidence of the damage these pollutants cause for humans, there are no uniform and appropriate indicators and sampling protocols to collect evidence on exposure to hazardous chemicals such as lead, cadmium or chromium around the world [2]. These metals are not vital for living organisms and can cause serious health problems even at low concentrations (see Box 1 to explore the effects of air pollution for human health). However, recent updates of the WHO air quality guidelines (a set of evidence-based recommendations for limit values of specific air pollutants), provided clear evidence of the damage that air pollution inflicts on human health, at even lower concentrations than previously recognized [12].

In response to these challenges, EU legislation set air quality standards (Directive 2008/50/EU) and recommended additional indicators. Recent ambitious policies in EU develop the framework for reducing air, water and soil pollution, as part of the Zero Pollution Action Plan (a pillar of the European Green Deal), and the EU's strategy to reach climate-neutrality by 2050 [22]. Other strategic policies, such as the 2030 Agenda for Sustainable Development, list a wide range of relevant indicators across societal challenge areas [23–25] of which several relate to air pollution. The UN Sustainable Development Goals (SDGs) with its 17 thematic goals and 231 indicators are a key part of the EU policymaking, across all sectors, including the cross-cutting strategy to protect citizens' health from environmental degradation and pollution. The following goals specifically target air pollution:

- SDG target 3.9.1, which calls for a substantial reduction in deaths and illnesses from air pollution
- SDG target 7.1.2, which aims to ensure access to clean energy in homes
- SDG target 11.6.2, which aims to reduce the environmental impact of cities by improving air quality

Europe has developed various strategies to implement the SDGs and to bring tangible progress in various areas. Especially relevant is the European Green Deal, which conserves and enhances the EU's natural capital, and protects the health and well-being of citizens from environment-related risks. The EU Global Health Strategy offers a holistic view and seeks to reach the universal health-related targets in the 2030 SDGs. The strategy stresses the importance of addressing important drivers of ill health, such as environmental degradation.

In Latin American countries, the appropriation of the 2030 Agenda presents important differences among countries. To date, the most comprehensive initiative on the localisation of the SDGs is the Forum of Countries of Latin America and the Caribbean on Sustainable Development, instituted by the United Nations Economic Commission for Latin America and the Caribbean [26].

The concept of nature-based solutions (NBS) was designed to address a range of environmental, social and economic challenges (European Commission 2016) and their benefits for urban planning have been well-documented [27–30]. NBS (i.e., the use of green infrastructure, ecosystem restoration etc) deliver health and wellbeing outcomes, as they play a relevant role in mitigating air pollution (i.e. foliar deposition, phytoremediation), among others. Apart from their multiple benefits and their integration as a vital component of the cities, ecosystem services and NBS, plants are the primary receptors for both gaseous and particulate pollutants of the atmosphere. In terrestrial plant species, the foliar surface area acts as a natural sink for pollutants [31]. Depending on the context, urban green can help to reduce and mitigate air pollution levels [32], but also to be used as bioindicators of air pollution [33]. As such, knowledge of the uptake in edible plants can give a hint to potential exposure risks for humans [34].

Even if important contributions to the concept of NBS in relation to urban green and public health is acknowledged by various studies [3, 35], the skills, methodologies, resources and policies to include and evaluate multidimensional air quality indicators are still limited. Moreover, despites some NBS frameworks include indicators related to air quality (i.e. REGREEN or EKLIPSE frameworks, Banzah et al. 2024), there is no specific methodology addressing or guiding the selection or place-based data collection related to air quality indicators (i.e. some assessments only develop proxies for air quality indicators and address remote sensing methodologies). There is also little evidence about the integration of indicators [36] into urban planning and related public health policies. At the same time, knowing which NBS are effective is critical for decisions about the implementation itself, and whether an NBS can be up-scaled and/or replicated. Furthermore, these data should integrate and target all population groups and deploy indicators adapted for vulnerable groups. Therefore, there is an urgent need to document empirical evidence on the green spaces multi-dimensional effectiveness in relation to air quality and enable cities to conduct more evaluation and monitoring studies on NBS efficiency and effectiveness.

The aim of this study is to provide guidance for selecting appropriate indicators to pinpoint those impacts that are attributable to the NBS implemented and contribute to a solid evidence base to inform further nature-based interventions and policy decisions. As there is no standardized methodology for reporting on the local contributions of NBS to the SDGs in general and to the challenge area of air quality especially, finding indicators that can be more operational at finer scales is important.

However, the process of selecting indicators related to NBS uptake in different contexts is challenging. Especially in relation to air quality, rather than using a one-size-fits-all solution and the business-as-usual

Table 1
Overview of methodologies and approaches to measure indicators related to air quality in each city.

City	Indicator	Pollutants	NBS type	Main methodology	Target public
Barcelona	Heavy metals content in edible plants/soils in urban municipal gardens	V, Cr, Mn, Co, Ni, Cu, Zn, Cd and Pb	Urban gardens	Field sampling/Laboratory measurements	Elderly
	Dietary intake of heavy metals	V, Cr, Mn, Co, Ni, Cu, Zn, Cd and Pb	Urban gardens	Data analysis	Elderly
Buenos Aires	Concentration of NO_2	NO_2	Green fences	Field sampling/Laboratory measurements	Children
	Air quality	PM_x, NO_2	Green fences Green schoolyards	Nature-based learning	Children
Torino	Leaf area index (LAI)	NO_2, PM_{10}	Trees	Scenarios for pollutant removal Mapping (QGIS plugin “Ecosystem Services Turin”)	All citizen
	Promotion of more sustainable mobility	NO_2, PM_{10}	Green areas	Mapping (QGIS plugin “Ecosystem Services Turin”) Participatory approach	All citizen, with some specific activities targeting children

indicators, a more integrated approach and frameworks are needed, to address the multiple local constrains [37]. As NBS can also embrace a great range of typologies, shapes and functions, a multidimensional approach is needed to integrate various scales, actors, fields or participation approaches, to build meaningful and realistic indicators.

Existing indicators related to air quality fail to address local scales and they are mostly based on certain types of pollutants (there is no specific indicator related to heavy metals) and they are mostly derived from traffic volume modelling. Moreover, there is still unclear how the designed NBS (i.e. urban gardens, green fences) can be integrated into a framework of fine-scale assessment of air pollution in cities. Moreover, as NBS still struggle to be integrated with education, health and communication plans, this highlights the importance of dissemination and local understanding of the concept so that it can be accessible to all [38]. Therefore, the complex relationship between nature and cities cannot be properly addressed without incorporating awareness raising and education, as part of any NBS related framework.

To respond to these research and policy gaps, our study provides an overview of the *air pollution indicators* picked by a selection of European and Latin American city-academia living labs, as part of the science-policy process of evaluating and monitoring NBS contribution to improved air quality and health, in close relation to SDG goals. This research is based on the framework developed by the EU funded H2020 project CONEXUS. The process for indicators selection was previously documented by van der Jagt and Buijs [39] and Risi et al. [26]. This project adopted a context-based framework for the indicators to support implementing NBS actions and pilots across seven cities in Europe and Latin America (Barcelona, Bogotà, Buenos Aires, Santiago, Sao Paolo, Lisbon and Torino). In all these Living Labs (understood as part a system, an arena, a methodology, or an approach), indicators selection was framed around the categories of societal challenges defined by the NBS Evaluation Handbook [36]. Each city was encouraged to develop their own place-based indicators and select, when necessary, micro-scale indicators, related to experimental sites.

The process showed considerable challenges regarding the NbS concept, indicators and lack of evidence for NbS uptake were especially relevant in relation to air quality frameworks [38]. Therefore, based on project́s methodology (i.e. co-creation process, [40]) and through expert judgement, the selected indicators on air quality followed the cities ‘selection of prioritized challenges and training needs. As each city developed different approaches for different indicators, the approach on air quality indicators at various scales was considered especially relevant in Barcelona, Buenos Aires and Torino.

Therefore, we focussed our research on these three cities, where the interventions specifically aimed to improve air quality and therefore human health and well-being. We developed a conceptual study, to bolster cities capabilities to better integrate NBS and related indicators on air quality into planning and policy, through the following objectives:

- Understand how air quality is integrated and measured in selected cities from Europe and Latin America, under different contexts and targeting various vulnerable groups
- Identify relationships of the proposed indicators with local and global air quality policies and with regards to health benefits
- Suggest new approaches and future research to quantify and integrate various proxies and vegetation typologies into the assessment of air quality indicators to support efficient evidence-based mitigation policies for optimal health and climate benefits

The global context: case studies

Barcelona

Air quality in Barcelona has been one of the main environmental problems of the city, as is the case for most large urban agglomerations worldwide.

Biomonitoring was the pillar of studying air quality for Barcelona Living Lab. Research was conducted across municipal gardens, belonging to the network of Urban Gardens of Barcelona. The inclusive view was enforced by the fact that the users of these specific urban gardens are elderly persons.

The indicators monitored (Table 1) were integrated into a more complex informational system (“The Observatory of Urban Agriculture”, https://hortsurbans.bcnregional.com/), which comprises data on biodiversity, ecosystem services or productivity, to help managers to find new planning and action strategies. Indicators selection has been closely related to the main cities’ strategies, such as Nature Plan 2030 (https://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity/nature-plan), Urban Agriculture Strategy and Barcelona Healthy and Sustainable Food Strategy for 2030, which promote urban biodiversity and ecosystem services, but also healthy, sustainable food for all.

Other SDG goals, transversally related to health and air quality (i.e. related to sustainable transport, mobility or climate change), are also targeted in the Citizen Commitment to a Barcelona + Sustainable **or the City Climate Agreement, which incorporates the Barcelona Commitment towards climate neutrality by 2030.**

Torino

The air quality in the city of Torino has been strongly influenced by the particular orographic and climatic conditions of the Po Valley Basin, which contributed to the formation of particularly widespread pollution situations that do not allow the dispersion of emitted pollutants. In order to meet this need, the New Programme Agreement for a coordinated and joint adoption of measures to improve air quality in the Po Valley Basin was signed by the Emilia Romagna, Lombardy, Piedmont and Veneto regions in 2017, which defined remediation measures to be applied in a

Box 2
Summary of the methodologies.

Field sampling and laboratory measurements

Barcelona

Field sampling for both edible vegetables (*Beta vulgaris* leaves) and soils was developed in May 2023 along 6 urban gardens, spread along a pollution gradient (traffic related). Heavy metals content in edible plants/soils in urban municipal gardens were assessed using a stratified field sampling; samples of leaves and soil were dried and analysed for V, Cr, Mn, Co, Ni, Cu, Zn, Cd and Pb (spectrometry and digestion). This data fed the dietary intake of heavy metals, assessed for adults and children [44]. The reference levels were established according to [45–47].

Other air pollution indicators available for the city of Barcelona have not been the objective of this study.

Buenos Aires

To measure massive diffusion of NO_2, passive tubes were installed in various schools. For example, for the study at the Medone School, 26 tubes were installed to quantify NO_2. These were installed in 4 points of interest (in the schoolyard, corresponding to the inner green fence and outside the school) during 3 measurement campaigns, corresponding to 27 days, 21 days and 28 days respectively (April/July 2021).

Mapping and modelling

Torino

NO_2 was estimated considering two main parameters: the dry deposition rate of NO_2 on vegetation and the amount of NO_2 removed by vegetation. The downward flux of pollutant (calculated as the multiplication between deposition and the average PM_{10} concentration and is provided by environmental data of air quality monitoring stations of the City of Torino. The amount of PM_{10} removed from vegetation in one year was set as the multiplication among Leaf Area Index (LAI) and resuspension value. For the Promotion of more sustainable mobility (the creation of Pedestrian and Cycling Paths), the surface and/or length of new pedestrian and cycling paths created in the NBS scenario was calculated [48].

Participatory processes and learning

Torino

The Torino Urban Lab (https://urbanlabtorino.it/) established an open and friendly forum in the Valdocco Vivibile pilot, where local stakeholders met for discussions and build a learning community to help developing a multifunctional greenery and a sustainable mobility (2023). This participatory process envisaged multiple goals: informing citizens about the works and the strategic framework adopted by the city to counteract global change risks; fostering awareness about climate change and air pollution risks; boosting dialogue between stakeholders and the local administration; involving residents and other stakeholders in public debate etc.

Some activities were also co-designed with teachers to match the students' engagement with ongoing learning courses during the school year (in 2023, followed by a communication campaign in 2024). The participatory process accompanying the pilot focused mainly on involving students and teachers from schools within the working area of the pilot. The process combined training and awareness-raising initiatives with practical activities to provide scholars with a sense and the concrete functioning of NBS in general. To assure the inclusive view, the number of children involved in educational activities was set as one of the monitoring of indicators for the evaluation of the benefits generated by the nature-based solutions (NBS) implemented within the 'Valdocco Vivibile' pilot project carried out by the City of Turin.

Buenos Aires

Design students participated in studying the context and site, and then developing a design for one of the schools in Buenos Aires. In parallel, multiple school-based workshops with children and teachers were held to develop activities using art, music and games. The green fences were installed as part of a larger vegetation assemblage, which were called "living yards", and mobilised in support of a long-term agenda to raise environmental awareness and increase societal understanding of air pollution and its detrimental effects on human health and development. This agenda required a complex approach, including: qualitative assessments of children's and their teachers use of the site for both curricular and recreational activities; observational counts of pollinators, other insects and birds on site; and monitoring of air quality (using passive tubes) with methods that could be easily implemented and explained to stakeholders.

coordinated and joint manner in the Po Valley territory. On the territory of the City of Torino, the measures set forth in the Agreement were fully implemented by adopting, in a coordinated manner with the Municipalities of the Torino Metropolitan area, the measures to improve air quality and by making some restrictive changes with regard to temporary limitations, especially those related to traffic.

Within this policy framework, Valdocco Vivibile Living Lab (Torino) integrated micro-scale NBS interventions, working closely with stakeholders and citizens to improve air quality, liveability and increase biodiversity. Valdocco Vivibile is part of a more comprehensive city strategy named "Resilient districts." Specifically, it intends to reduce asphalt and impervious surfaces, converting them into green infrastructure and sustainable drainage systems. The introduced greenery and tree plantings also aimed at slowing the traffic flow. Additional measures, such as the narrowing of roadways and chicanes, further reduced the velocity of motor vehicles, while allowing cars, bicycles, and pedestrians to coexist. Torino included indicators of air quality by measuring NO_2 deposition and removal by plants.

The approach also supported the promotion and diffusion of the strategies and policies defined in the Climate Resilience Plan and the Green Infrastructure Plan, approved by the City of Torino.

Buenos Aires

Buenos Aires Living Lab engaged the issue of NBS contributions to air quality management through the Breathe/Respirar Project (BRP). The BRP originally aimed to plant vegetation fences around school yards to mitigate the exposure of children and the wider school community to urban air pollution originating from local vehicular traffic, including $PM_{2.5/10}$ and NO_2. Early on, the team realised that project's goals had to be redefined if they were to obtain community buy-in and more than nominal governmental support. Furthermore, the lack of official city-wide figures regarding these pollutants and complications for on-site monitoring using specialized equipment (including low-cost and portable sensors) created barriers for the evaluation of effectiveness using such air quality indicators.

The BRP team hence decided to implement a more multi-functional NBS approach focusing on human health and well-being as well as urban biodiversity, and nature-based learning. A transversal approach, including landscape architecture and education, was applied to promote learning and raise awareness.

Five years on, the BRP has two functioning sites that are also used as sites for further experimentation and innovation with NBS. The project is currently developing methods to test effectiveness in reducing exposure to air pollutants by using portable black carbon sensors together with tests to assess surface and ambiance temperatures on vegetation-enhanced schoolyards, given the high concern among school communities with the heat waves that affect the city, and qualitative assessments on long-term maintenance needs and prospects for the living schoolyards.

The transformative integration of indicators for air quality monitoring

An indicator is defined as a measure or metric that help track and communicate how ecosystems support the physical, economic, and socio-cultural well-being of people [41]. With the help of indicators, the complexity can be condensed to a manageable level that can inform decisions and actions [42], based on scientific evidence. Indicators also help identify and prioritise measures, track progress toward targets, and effectively communicate the value of NBS [43].

To enable a better integration of indicators in cities plans and policies, the following criteria were settled for the selection on NBS indicators related to air quality:

- Respond to existing skills, demand and resources
- Provide long-term data collection that can be easily integrated into health studies and policies
- Inclusive

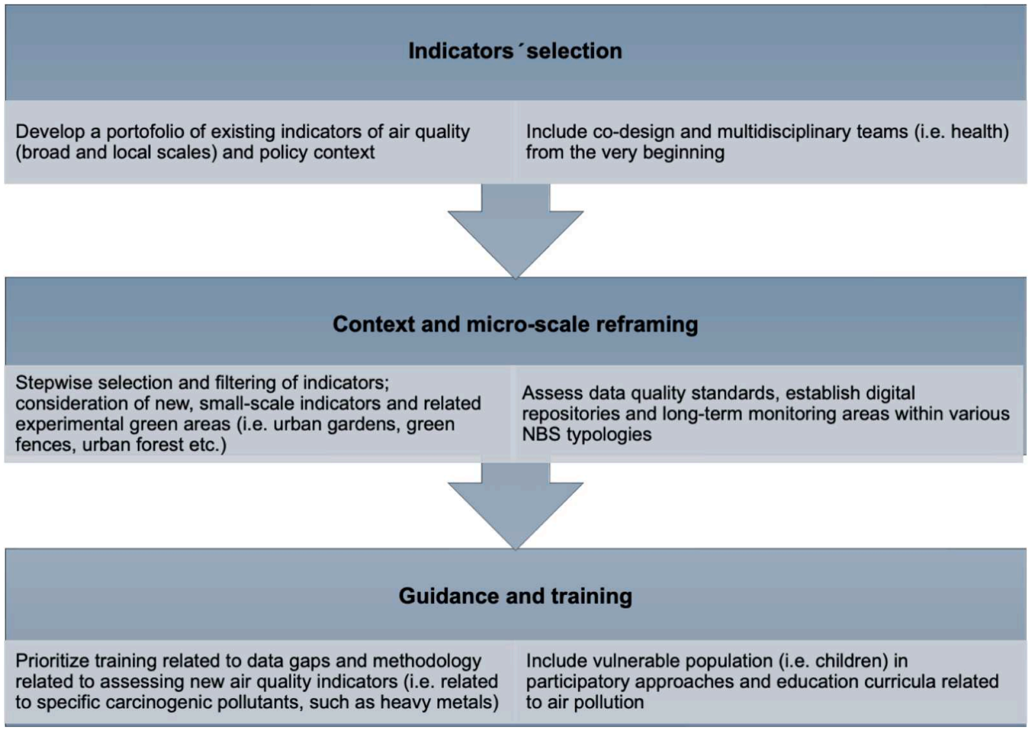

Fig. 1. A comprehensive framework for indicators on air quality.

- Provide meaningful data for all
- Adapted to socio-environmental and decision-making context
- Transversal
- Creative (cities were free to propose and develop new indicators, if needed)

The whole process was flexible: in case of barriers for indicators sampling and monitoring, a step back was taken and the methodology was reframed and better adapted to the city context.

Out of the seven cities where the process was taken, Barcelona, Buenos Aires and Torino have chosen indicators related to air quality monitoring. However, each of these three cities have chosen very different indicators and methodologies (Table 1) to address the SDGs and evaluate NBS. All cities specifically included vulnerable population in the framework of monitoring indicators and raising awareness of air quality.

Each city used different methodologies to assess indicators related to air quality, which can be clustered into 3 groups (Box 2): (1) field sampling and lab measurements (Barcelona and Buenos Aires); (2) mapping and modelling (Torino) and (3) participatory processes and learning (Buenos Aires and Torino).

Lessons learned and the way forward

1. Implications for NBS and Policy: the integrative dimension

National intentions to fight against air pollution and incorporate NBS indicators for air quality and global change adaptation vary by region and have yet to be fully translated into measurable evidence-based targets and action on the ground.

Therefore, cities need to examine multiple dimensions of urban sustainability simultaneously with new urban metrics to generate quantitative assessments of progress toward sustainable urban development. This implies both the necessity to identify new indicators and metrics that more effectively represent the multidimensionality of human–environmental systems and apply them across multiple urban regions. Previous studies highlighted the need to examine multiple dimensions of urban sustainability simultaneously and a need to generate new urban metrics for quantitative assessments of progress toward sustainable urban development [49]. Moreover, recent findings showed that current WHO guidelines (for air, water, agricultural soil and food) should be revised and air pollution concentrations should be reduced further to achieve greater protection of health in cities [50]. This suggests the need to be “creative” and to identify the right fine-tuned indicators that provide better information for action and key evidence for citizens, research, planners and decision-makers.

To answer these challenges, we proposed a science-policy framework to integrate **multidimensional** indicators related to air quality, allowing better integration of NBS and health into various policy targets (Fig. 1 and Table 2). This framework complements air quality data (indicators) usually monitored in cities (i.e. European Air Quality Index, annual average of NO_2, traffic volume, statistics on motor vehicles, monthly or annual average of PM values etc.), which are insufficient to integrate the NBS concept, urban green and health. This proves to be useful, especially when some of these measurements are lacking or when national standards for some pollutants (PM2,5 for instance) are missing. Moreover, there is no clear evidence for a threshold below which health effects do not occur in case of most pollutants.

Table 2 presents the selected NBS indicators, their relation with policy targets and transversal disciplines. Apart of the clear matches with air quality policies and requirements, these multidimensional NBS indicators have the following strengths:

- Serve as fine-tuned and high-quality data (based on field sampling) and proxies for estimating air pollution exposure at city level
- Can be integrated into an information system (i.e. The Observatory of Urban Agriculture in Barcelona), to provide a proper digital infrastructure supporting the storage and analysis of data and to foster data usability and accessibility (i.e. data needed for plans and policies, but also for raising awareness or education)
- By integrating vulnerable population (specifically targeting elderly in Barcelona or children in Buenos Aires), allows for achieving an inclusive view

- Can be easily integrated in education (Torino or Buenos Aires experience in schools and related nature-based learning on green fences) and raise awareness on place-making initiatives through NBS (i.e. greening the schoolyards in Buenos Aires), which can help foster social meaning and attachment to these solutions
- Represent cheaper alternatives (i.e. biomonitoring in Barcelona) to expensive air quality monitoring protocols, covering many locations and repeated measurements in cities
- Can be replicated
- Proved adequate for air quality monitoring at the same time as being comparable and simple enough to be intuitive and easily communicated (matching with characteristics outlined in other studies, [43])

However, the cities also may have limitations for calculating indicators, such as: data availability, lack of skills and capacity to integrate transversal disciplines or insufficient funding. Therefore, building multisectoral partnerships for pollution control and encouraging collaboration of actors that usually do not interact (see the transversal disciplines in Table 2), can also help cities to boost policies related to air pollution and health.

Last, but not least, air pollution is also affected by other policies that influence key activities and sectors in areas such as transport, industry, energy and climate, and agriculture. That is why, the management of air quality cannot be effective, without a cross-sectorial view and related indicators [51]. The city of Torino integrated indicators related to pollutants removal with policies related to sustainable mobility (reducing the traffic flow). Barcelona integrated other policies and strategies to reduce air pollution (superblocks, where traffic is restricted and priority is given to walking or cycling), while raising awareness and education have been key enables for other communities (schools in Buenos Aires)

Table 2
Multidimensional indicators to assess NBS and air quality, and their integration into policies.

MULTIDIMENSIONAL INDICATOR	POLICY MATCH	RELATION TO TRANSVERSAL DISCIPLINES AND SKILLS
Heavy metals content in edible plants (Biomonitoring) Dietary intake of heavy metals (edible plants, local food consumption)	**Zero Pollution Action Plan**	• Biomonitoring • Plants physiology • Toxicology • Public health • Biomonitoring • Healthy food • Medicine
	The 1998 Aarhus Protocol on Heavy Metals	
	EU Global Health Strategy: Better Health for All in a Changing World	
	From Farm to Fork	
	SDG Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Target 2.4. By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.	
	SDG Goal 3: Ensure healthy lives and promote well-being for all at all ages. Target 3.9. By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.	
	SDG Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable. Indicator 11.6.2. Concentrations of fine particulate matter (PM2.5).	
	Heavy metals emission in Europe (EEA)	
	Emissions of the main air pollutants in Europe (EEA)	
	Emissions of air pollutants from transport in Europe (EEA)	

(continued on next page)

Table 2 (*continued*)

MULTIDIMENSIONAL INDICATOR	POLICY MATCH	RELATION TO TRANSVERSAL DISCIPLINES AND SKILLS
Passive diffusion of NO2 in green fences	**Zero Pollution Action Plan** **SDG Goal 13** **Target 13.3.** Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.	• Horticulture • Phytoremediation • Plant morphology • Landscape architecture • Co-design • Education
Leaf area index (LAI)	**Zero Pollution Action Plan** **SDG Goal 11:** Make cities and human settlements inclusive, safe, resilient and sustainable. **Indicator 11.6.2.** Concentrations of fine particulate matter (PM2.5).	• Mapping and Remote Sensing • Environmental science
Promotion of more sustainable mobility	**Zero Pollution Action Plan** **Sustainable transport – new urban mobility framework** **SDG Goal 11:** Make cities and human settlements inclusive, safe, resilient and sustainable. **Target 11.2.** By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons. **Target 11.3.** By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries. **Target 11.6.** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. **Indicator 11.6.2.** Concentrations of fine particulate matter (PM2.5). **Target 11.7.** By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities. **Emissions of the main air pollutants in Europe (EEA)** **Emissions of air pollutants from transport in Europe (EEA)**	• Participation and co-design • Urban geography • Architecture • Transport • Sociology

to understand and fight against pollution, when clearly related air quality indicators or standards were missing.

Moreover, urban design (e.g. accessibility, connectivity, green space) influence population behaviour (i.e. towards more sustainable mobility) and contribute to mitigate air pollution and achieve more liveable cities. Nevertheless, a change to more sustainable and affordable transport solutions requires effective communication strategy for all ages and economic tools to encourage behaviour change. Van den Bosch and

Impacts on NBS policies (also as a separate section in the manuscript)

Recent ambitious EU policies developed a framework for reducing air, water and soil pollution, as part of the Zero Pollution Action Plan (a pillar of the European Green Deal), and the EU's strategy to reach climate-neutrality by 2050 [22]. Other strategic policies, such as the 2030 Agenda for Sustainable Development, list a wide range of relevant indicators across societal challenge areas [23–25] of which several relate to air pollution.

The following goals are also specifically targeted by our research (air pollution):

- SDG target 3.9.1, which calls for a substantial reduction in deaths and illnesses from air pollution
- SDG target 7.1.2, which aims to ensure access to clean energy in homes
- SDG target 11.6.2, which aims to reduce the environmental impact of cities by improving air quality

Nieuwenhuijsen [52] mentioned "Science-policy-practice gap" and "cognitive bias" in health and environmental topics, among the factors that can also hinder efficient policies related to air quality. Therefore, new scientific methods may require new ways of communicating [52], such as participation or co-design (used in Torino to complement the indicators approach), but also the integration of new disciplines (as highlighted in Table 2).

2. Taking advantage of plants to replicate NBS indicators on air quality and as school subjects

Previous studies extensively documented the utility of both trees and herbaceous plants to biomonitor trace elements [53]. Plants can also reflect the harmful effects of air pollution. As such, physiological alterations in plants (i.e. foliar injury) can indicate the level of pollution in the respective areas [54]. Therefore, more integration of plants as "sensors" for air quality monitoring is needed.

In our study, each city integrated vegetation in their approaches to indicators related to air quality. Barcelona used edible vegetables, while Buenos Aires focussed on green fences. Torino mainly focused the indicators monitoring on street trees. The use of Leaf Area Index (LAI) rely on the fact that vegetation, especially trees, could play a role in improving air quality in urban areas through increased deposition rates of particulate matter and/or absorption of gaseous pollutants. Furthermore, this multidimensional indicator also informs about other ecosystem services and challenges (i.e. temperature regulation, measuring the shading effect provided by trees). Our approach also showed that cultivated vegetables (as in the case of Barcelona), or various layers and plants assemblages (i.e. climbing plants, [55]) can be both particularly relevant for biomonitoring studies, as biological indicators. All these plants have large foliar collecting areas and can be widely planted across the cities, covering a broad pollution gradient. However, considering that metal uptake in plants takes place through roots and leaves, it is difficult to distinguish whether the accumulated elements originate from the soil or from the air. Therefore, ideally, soil analyses should complement biomonitoring (Basnou and Àvila 2023).

Integrating plants and representative field sampling into air quality monitoring has also another benefit: it provides robust data vs. models and approximations. This approach is especially needed, as most of the available modelling tools that incorporate plants (i.e. trees) fail to consider traits and the biogeographically diverse flora in cities.

Last, but not least, the management of healthy ecosystems can't be efficient without plans to increase the amount and quality of green areas. The "plant green, not grey" message should complement at every stage the air quality and health related policies.

In Buenos Aires and Torino, green infrastructure was closely integrated into school community and brought additional benefits, such as more biodiverse playgrounds, nature connectivity and an outdoor learning platform.

3. More than air quality: integrating vulnerable population and health

Managing air quality means also integrating the so-called co-benefits (Calfapietra 2017), such as microclimate regulation, urban biodiversity, education and human health. Our findings also reflect that air quality approach cannot be limited to a single air quality indicator. In order to increase their capacity to contribute to a transformative urban agenda, multidimensional indicators on air quality and health should be developed, integrating more disciplines (such as education) and a more inclusive view (i.e. developing air quality indicators targeting vulnerable population and diverse socio-demographic groups). The concept of vulnerability indicates that increases in exposure to pollution may have substantial effects on a vulnerable portion of the population, even if the change in risk for the whole population is small; and, conversely, that reductions in pollution levels leads to health benefits in population groups with the highest vulnerability [56–58]. Gestation, infancy and early childhood are vulnerable times because the young body is growing and developing rapidly. A recent study found that the adverse effects of air pollution begin in the prenatal phase and suggested that pregnant women should be considered a priority group for public health policies [59]. Older people, and adults with long-term conditions, are also vulnerable to the effects of air pollution [60]. However, little is known about indicators that measure the different health consequences of air pollution on different vulnerable groups [3], while there are there are no recommendations, nor clear data on indicators related to exposure to pollutant mixtures, which correspond to the "real data" in cities. This is also especially challenging in dense cities with heavy traffic and specific local topography (such as street canyons) and meteorological conditions that increase air pollution (i.e. drought can increase the resuspension of by road traffic).

The assessment of indicators related to heavy metals should be compulsory and be integrated in cities' public health agenda. As some of these pollutants are carcinogenic (Cd, Pb and Ni), their monitoring (or biomonitoring) should be included as part of the strategy of global health prevention (such as Europe's Beating Cancer Plan).

Therefore, we suggest that cities need both courage and creativity, in order to deploy and integrate novel air quality data and indicators at finer scales, as well as the development of clear conceptualizations of impacts across diverse environmental types and socio-demographic groups. For instance, the multidimensional indicator "Dietary intake of heavy metals" assessed in the edible vegetables in urban gardens for Barcelona, allows measuring the potential food toxicity (heavy metal exposure), but also monitoring heavy metal toxicity in air and soil. It can be easily adapted for adults or children and used as a proxy for health-related studies, when no other data is available or it's scarce.

These principles are also in line with the Planetary Health concept and various initiatives (i.e. European Health Data Space) that seek to enable the multifunctional NBS deployment [61].

Conclusions

Integrating NBS and place-based indicators which can led to effective mitigation and adaptation actions in relation to air pollution are urgently needed. This also includes a better integration of novel multidisciplinary perspectives to assess the appropriate impact of NBS and to provide credible evidence for policies. Science-policy collaboration (i.e. cities-research partnerships) is key in making NBS part of the urban regime and public health discourse. Institutional long-term commitment to NBS [40] and indicators monitoring related skills and knowledge, are critical in generating support and guiding the planning and implementation of NBS.

New transformative framework models to integrate air quality assessments are necessary to consider in cities, to help "recognizing patterns and understanding from a few indicators" [42], but also to identify the major pathways of human exposure to pollutants. The development of multidimensional and fine-tuned indicators (i.e. beyond the "business-as-usual" measurements of air quality) which integrate ecology, plant physiology, toxicology and epidemiology, can offer tangible impacts on both green space performance and human health for all. Including indicators that sum complex information on the political agenda would benefit achieving the goals of the transformative policies.

CRediT authorship contribution statement

Corina Basnou: Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Data curation, Conceptualization. **Geovana Mercado:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization. **Åsa Ode Sang:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization. **Thomas B. Randrup:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization. **Verónica Fabio:** Writing – review & editing, Methodology, Data curation. **Adrián Cabezas:** Writing – review & editing, Methodology. **Arnau Lluch:** Writing – review & editing, Methodology. **Marc Montlleó:** Writing – review & editing, Resources, Methodology. **Juan Miguel Kanai:** Writing – review & editing, Methodology. **Riccardo Saraco:** Writing – review & editing, Resources, Methodology. **Olivia Bina:** Writing – review & editing, Methodology. **Tom Wild:** Writing – review & editing, Resources, Project administration, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

References

[1] ... & M. Brauer, G.A. Roth, A.Y. Aravkin, P. Zheng, K.H. Abate, Y.H. Abate, R. Amani, Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021, Lancet 403 (10440) (2024) 2162–2203.

[2] ... & R. Fuller, P.J. Landrigan, K. Balakrishnan, G. Bathan, S. Bose-O'Reilly, M. Brauer, C. Yan, Pollution and health: a progress update, Lancet Planet. Health 6 (6) (2022) e535–e547.

[3] N. Kabisch, M. van den Bosch, R. Lafortezza, The health benefits of nature-based solutions to urbanization challenges for children and the elderly–A systematic review, Environ. Res. 159 (2017) 362–373.

[4] ... & H. Boogaard, A.P. Patton, R.W. Atkinson, J.R. Brook, H.H. Chang, D.L. Crouse, F. Forastiere, Long-term exposure to traffic-related air pollution and selected health outcomes: A systematic review and meta-analysis, Environ. Int. 164 (2022) 107262.

[5] J. Chen, G. Hoek, Long-term exposure to PM and all-cause and cause-specific mortality: a systematic review and meta-analysis, Environ. Int. 143 (2020) 105974.

[6] D. Swan, R. Turner, M. Franchini, P.M. Mannucci, J. Thachil, Air pollution and venous thromboembolism: current knowledge and future perspectives, Lancet Haematol. 12 (2024) e68–e82.

[7] B.Y. Yang, S. Fan, E. Thiering, J. Seissler, D. Nowak, G.H. Dong, J. Heinrich, Ambient air pollution and diabetes: a systematic review and meta-analysis, Environ. Res. 180 (2020) 108817.

[8] ... & M. Sørensen, A.H. Poulsen, U.A. Hvidtfeldt, J. Brandt, L.M. Frohn, M. Ketzel, O. Raaschou-Nielsen, Air pollution, road traffic noise and lack of greenness and risk of type 2 diabetes: a multi-exposure prospective study covering Denmark, Environ. Int. 170 (2022) 107570.

[9] ... & L. Pérez-Crespo, M.S. Kusters, M. López-Vicente, M.J. Lubczyńska, M. Foraster, T. White, M. Guxens, Exposure to traffic-related air pollution and noise during pregnancy and childhood, and functional brain connectivity in preadolescents, Environ. Int. 164 (2022) 107275.

[10] W. Yuchi, M. Brauer, A. Czekajlo, H.W. Davies, Z. Davis, M. Guhn, I. Jarvis, M. Jerrett, L. Nesbitt, T. Oberlander, H. Sbihi, J. Su, M. van den Bosch, Neighborhood environmental exposures and incidence of attention deficit/hyperactivity disorder: A population-based cohort study, Environ. Int. 161 (2022) 107120.

[11] ... & N. Munir, M. Jahangeer, A. Bouyahya, N. El Omari, R. Ghchime, A. Balahbib, M.A. Shariati, Heavy metal contamination of natural foods is a serious health issue: A review, Sustainability 14 (1) (2021) 161.

[12] WHO, WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide. Executive summary, World Health Organization, Geneva, 2021.

[13] J. Godt, F. Scheidig, C. Grosse-Siestrup, V. Esche, P. Brandenburg, A. Reich, D. A. Groneberg, The toxicity of cadmium and resulting hazards for human health, J. Occup. Med. Toxicol 10 (1) (2006) 22.

[14] Y.N. Jolly, A. Islam, S. Akbar, Transfer of metals from soil to vegetables and possible health risk assessment, SpringerPlus 2 (2013) 1–8.

[15] Y. Huang, C. He, C. Shen, J. Guo, S. Mubeen, J. Yuan, Z. Yang, Toxicity of cadmium and its health risks from leafy vegetable consumption, Food Funct. 8 (4) (2017) 1373–1401.

[16] A. Ferrer, Intoxicación por metales, Met. Poisoning vol.26 (suppl.1) (2003) 141–153. Anales Sis San Navarra [online]ISSN 1137-6627.

[17] M. Anke, Vanadium-an element both essential and toxic to plants, animals and humans, Anal Real Acad. Nac. Farm 70 (2004) 961–999.

[18] N.C. Fan, H.Y. Huang, S.L. Wang, Y.L. Tseng, J. Chang-Chien, H.J. Tsai, T.C. Yao, Association of exposure to environmental vanadium and manganese with lung function among young children: A population-based study, Ecotoxicol. Environ. Saf. 264 (2023) 115430.

[19] G. Weinmayr, E. Romeo, M. De Sario, S.K. Weiland, F. Forastiere, Short-term effects of PM10 and NO2 on respiratory health among children with asthma or asthma-like symptoms: a systematic review and meta-analysis, Environ. Health Perspect. 118 (4) (2010) 449–457.

[20] ... & S. Lee, D. Tian, R. He, J.J. Cragg, C. Carlsten, A. Giang, E. Brigham, Ambient air pollution exposure and adult asthma incidence: a systematic review and meta-analysis, Lancet Planet. Health 8 (12) (2024) e1065–e1078.

[21] R.J. Laumbach, H.M. Kipen, Respiratory health effects of air pollution: update on biomass smoke and traffic pollution, J. Allergy Clin. Immunol. 129 (1) (2012) 3–11.

[22] European Commission, 2021. Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil' COM/2021/400 final.

[23] UN, The UN Sustainable Development Goals. http://www.un.org/sustainabledevelopment/summit/, 2015.

[24] UN, New Urban Agenda, United Nations, Habitat III Secretariat: Quito, http://habitat3.org/wpcontent/uploads/NUA-English.pdf, 2017.

[25] UN, The Sustainable Development Goals Report 2023: Special edition, Towards Rescue Plan People Planet (2023). https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-GoalsReport-2023.pdf.

[26] Risi, F., Grisel, M., Lorentz, L. A., Rizzi, D., 2023. Data on SDG/NUA impacts/potentials linked with investment propositions uploaded to OPPLA: nature-based solutions' contributions to the global goals. Deliverable 6.1 Report, H2020 CONEXUS project.

[27] C. Adams, M. Moglia, N. Frantzeskaki, Realising transformative agendas in cities through mainstreaming urban nature-based solutions, Urban For. Urban Green. 91 (2024) 128160.

[28] C. Albert, M. Brillinger, P. Guerrero, S. Gottwald, J. Henze, S. Schmidt, E. Ott, B. Schröter, Planning nature-based solutions: Principles, steps, and insights, Ambio 50 (2021) 1446–1461.

[29] R. Lafortezza, J. Chen, C.C Konijnendijk van den Bosch, T.B. Randrup, Nature-based solutions for resilient landscapes and cities, Environ. Res. 165 (2018) 431–441.
[30] C. Raymond, M. Breil, M. Nita, N. Kabisch, M. de Bel, V. Enzi, P. Berry, An impact evaluation framework to support planning and evaluation of nature-based solutions projects. Report prepared by the EKLIPSE Expert Working Group on Nature-Based Solutions to Promote Climate Resilience in Urban Areas, Centre for Ecology and Hydrology, 2017.
[31] ... & P. Kumar, A. Druckman, J. Gallagher, B. Gatersleben, S. Allison, T. S. Eisenman, L. Morawska, The nexus between air pollution, green infrastructure and human health, Environ. Int. 133 (2019) 105181.
[32] ... & P. Dadvand, M.J. Nieuwenhuijsen, M. Esnaola, J. Forns, X. Basagaña, M. Alvarez-Pedrerol, J. Sunyer, Green spaces and cognitive development in primary schoolchildren, Proc. Natl. Acad. Sci. 112 (26) (2015) 7937–7942.
[33] M.D.C. Redondo-Bermúdez, I.T. Gulenc, R.W. Cameron, B.J. Inkson, Green barriers' for air pollutant capture: leaf micromorphology as a mechanism to explain plants capacity to capture particulate matter, Environ. Pollut. 288 (2021) 117809.
[34] C. Basnou, A. Àvila, Avaluació de la contaminació per metalls pesants als horts urbans de Barcelona. Informe inèdit. Assessment of heavy metal pollution in urban gardens of Barcelona, AMB-CREAF, 2022. Report.
[35] M. Van den Bosch, Å. Ode Sang, Urban natural environments as nature-based solutions for improved public health – A systematic review of reviews, Environ. Res. 158 (2017) 373–384.
[36] A. Dumitru, L. Wendling, Evaluating the impact of nature-based solutions: A handbook for practitioners, European Commission EC, 2021.
[37] N. Kabisch, N. Frantzeskaki, R. Hansen, Principles for urban nature-based solutions, Ambio 51 (6) (2022) 1388–1401, https://doi.org/10.1007/s13280-021-01685-w.
[38] B. Kauark-Fontes, L. Marchetti, F. Salbitano, Integration of nature-based solutions (NBS) in local policy and planning toward transformative change, Evid. Barc. Lisbon Turin, Ecol. Soc. 28 (2) (2023).
[39] van der Jagt, S. and Buijs, A., 2021. Assessment framework, Indicators and Participatory Monitoring Process – H2020 CONEXUS project, Deliverable 4.1.
[40] ... & A.P. van der Jagt, A. Buijs, C. Dobbs, M. van Lierop, S. Pauleit, T.B. Randrup, T. Wild, With the process comes the progress: A systematic review to support governance assessment of urban nature-based solutions, Urban For. Urban Green. (2023) 128067.
[41] D. Haase, N. Larondelle, E. Andersson, et al., A Quantitative Review of Urban Ecosystem Service Assessments: Concepts, Models, and Implementation, AMBIO 43 (2014) 413–433, 2014.
[42] H. Bossel, Indicators for sustainable development: theory, method, applications, International Institute for Sustainable Development, Winnipeg, 1999, p. 138.
[43] ... & T.H. Sparks, S.H. Butchart, A. Balmford, L. Bennun, D. Stanwell-Smith, M. Walpole, R.E. Green, Linked indicator sets for addressing biodiversity loss, Oryx 45 (3) (2011) 411–419.
[44] M. Oves, M.S. Khan, A. Zaidi, E. Ahmad, Soil contamination, nutritive value, and human health risk assessment of heavy metals: an overview, in: A. Zaidi, P. A. Wani, M.S. Khan (Eds.), Toxicity of Heavy Metals to Legumes and Bioremediation, Springer, New York, 2012, pp. 1–27, 2012.
[45] C. Ballabio, A. Jones, P. Panagos, Cadmium in topsoils of the European Union–An analysis based on LUCAS topsoil database, Sci. Total Environ. 912 (2024) 168710.
[46] J. De Pablo, V. Martí, X. Martínez, M. Rovira, Determinació dels nivells de fons i de referència d'elements traça als sòls de Catalunya, Centre Tecnològic, 2004. CTM.
[47] FAO/WHO, 2001. Food Additives and Contaminants. Joints FAO/WHO Food Standard Programme ALINORM 01/12A.
[48] M. Cimini, Evaluation of Ecosystem Services provided by NBS and related monitoring indicators, Torino City Lab, 2022. Technical report.
[49] K.C. Seto, J.S. Golden, M. Alberti, B.L. Turner, Sustainability in an urbanizing planet, Proc. Natl. Acad. Sci. 114 (34) (2017) 8935–8938.
[50] ... & S. Khomenko, M. Cirach, E. Pereira-Barboza, N. Mueller, J. Barrera-Gómez, D. Rojas-Rueda, M. Nieuwenhuijsen, Premature mortality due to air pollution in European cities: a health impact assessment, Lancet Planet. Health 5 (3) (2021) e121–e134.
[51] ... & N. Mueller, D. Rojas-Rueda, X. Basagaña, M. Cirach, T. Cole-Hunter, P. Dadvand, M. Nieuwenhuijsen, Urban and transport planning related exposures and mortality: a health impact assessment for cities, Environ. Health Perspect. 125 (1) (2017) 89–96.
[52] M. van den Bosch, M. Nieuwenhuijsen, No time to lose-Green the cities now, Environ. Int. 99 (2017) 343–350.
[53] P. Madejón, T. Marañón, J.M. Murillo, Biomonitoring of trace elements in the leaves and fruits of wild olive and holm oak trees, Sci. Total Environ. 355 (1-3) (2006) 187–203.
[54] P.K. Rai, Impacts of particulate matter pollution on plants: Implications for environmental biomonitoring, Ecotoxicol. Environ. Saf. 129 (2016) 120–136.
[55] Å. Ode Sang, P. Thorpert, A.M. Fransson, Planning, designing, and managing green roofs and green walls for public health–an ecosystem services approach, Front. Ecol. Evol. 10 (2022) 804500.
[56] K.L. Frohlich, L. Potvin, Transcending the known in public health practice: the inequality paradox: the population approach and vulnerable populations, Am. J. Public Health 98 (2) (2008) 216–221.
[57] I. Jarvis, Z. Davis, H. Sbihi, M. Brauer, A. Czekajlo, H. Davies, S. Gergel, M. Guhn, M. Jerrett, M. Koehoorn, T. Oberlander, H. Sbihi, J. Su, M. van den Bosch, Assessing the association between lifetime exposure to greenspace and early childhood development and the mediation effects of air pollution and noise in Canada: a population-based birth cohort study, Lancet Planet. Health 5 (10) (2021) e709-e1.
[58] RCP (Royal College of Physicians), 2016. Every breath we take: the lifelong impact of air pollution. Report of a working party. London.
[59] ... & S. Fossati, D. Valvi, D. Martinez, M. Cirach, M. Estarlich, A. Fernández-Somoano, M. Vrijheid, Prenatal air pollution exposure and growth and cardio-metabolic risk in preschoolers, Environ. Int. 138 (2020) 105619.
[60] H. Yang, X. Huang, D.M. Westervelt, L. Horowitz, W. Peng, Socio-demographic factors shaping the future global health burden from air pollution, Nat. Sustain. 6 (1) (2023) 58–68.
[61] M.D.C. Redondo Bermúdez, J.M. Kanai, J. Astbury, V. Fabio, A. Jorgensen, Green Fences for Buenos Aires: Implementing Green Infrastructure for (More than) Air Quality, Sustainability 14 (7) (2022) 4129.