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EAACI Guidelines on the Importance of Green Space in Urban Environments for Allergy and Asthma Prevention

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ABSTRACT

The allergy and asthma epidemic in urban societies following World War II is mostly caused by changes in the environment, diet and lifestyle. Disconnection of urban populations from the wider environment has reduced the protective factors building up immunological resilience. The European Academy of Allergy and Clinical Immunology (EAACI) guidelines on greenness impact on allergy and

Abbreviations: AD, atopic dermatitis; AR, allergic rhinitis; CI, confidence interval; EAACI, European Academy of Allergy and Clinical Immunology; EtD, evidence to decision; GDG, guideline development group; GRADE, Grading of Recommendations, Assessment, Development and Evaluation; NbS, nature-based solutions; SoF, summary of findings; SR, systematic review; WHO, World Health Organization.

Tari Haahtela, Liam O´Mahony, and Claudia Traidl-Hoffmann (Working group chairs) are joint first co-authors.

Ioana Agache, Marek Jutel, and Cezmi A. Akdis (Guideline group chairs) are joint last co-authors.

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asthma follow the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach and provide eight recommendations encouraging greenness exposure to support immune health. Controlled follow-up studies are still scarce, and the strength of evidence is generally low or moderate at best. For primary prevention of allergy and asthma, most of the evidence indicates beneficial effects. Exposure is also useful for secondary prevention. Asthma patients may feel better and need less medication by combining green space exposure with physical activity. During the high-pollen season, effective seasonal medication is necessary for patients with pollen allergy. In urban planning, implementing appropriate green infrastructure and easy access to green space promotes immune health and reduces risks of air pollution and heatwaves. These EAACI guidelines are the first recommendations highlighting the importance of urban green spaces on immune health and call for prioritising innovative research in this field.

1 | Introduction

The Austrian architect, artist and environmental activist Friedensreich Hundertwasser (1928–2000) started already 70 years ago to integrate natural elements, trees and plants into the buildings (Hundertwasserhaus) to improve natural contacts in the urban environment [1].

The sharp rise in allergy and asthma cases over the past 50 years is largely attributed to changes in the environment, diet and lifestyle. However, there are no comprehensive studies analysing the relative importance of these factors on the allergy risk in any convincing manner. There is also a significant overlap of these three determinants. Living in a biodiverse (natural) environment is often a surrogate marker of the overall lifestyle including diet. Rapid urbanisation [2] and an increasing disconnection from natural surroundings have sparked concern about how reduced exposure to green environments may contribute to the increase in chronic immune-driven conditions, including allergies.

In allergy, the question of green space exposure and location is pivotal, because some of the immediate allergy symptoms are directly caused by environmental exposure, for example, pollen, usually from green space monocultures, with highly allergenic wind-pollinated trees and grass species [3]. To inform and warn the sensitive population, pollen forecasting is commonplace in Europe [4]. As respiratory and conjunctival allergic symptoms are highly environment-dependent, avoidance and premedication have been the first-line strategy to reduce exacerbations. However, avoidance can also reduce an individual's exposure to beneficial factors (e.g., non-pathogenic microbes). The unintended consequences of long-term avoidance of green space for allergic patients may result in dysregulation of molecular pathways that are needed to support immune tolerance.

Greenness means the quality of being green in colour because of being covered with grass, trees, and other plants [5]. *Green space* refers to community space consisting of land (such as parks) rather than buildings [6]. Especially in the urban setting, green space is increasingly valued to support human health as reduced exposure to green environments has been connected to a variety of chronic diseases [7, 8]. Green space exposure also correlates with increased exposure to environmental microbes, biogenic chemicals, physical activity, invigorating sceneries and reduced exposure to urban pollutants.

International Union of Forest Research Organizations (IUFRO) published a report in 2023 on forests, trees and green spaces' effects on human health [9]. The positive effects ranged from mental well-being to reduced cardiovascular events and an overall reduction in mortality. The effect on asthma and allergy was more ambiguous.

The interaction between airborne pollutants and pollen grains in urban environments can enhance the allergenicity of pollen and exacerbate respiratory symptoms [10, 11]. Thus, effective urban interventions should consider both greening strategies and pollution mitigation to improve urban air for human health and environmental sustainability.

The EAACI guidelines aim to improve the prevention and management of allergy and asthma, which are much recognised as environment-driven diseases. Thus, the present guidelines are based on assessing the impact of greenness and urban green space on the risk of new onset allergy and asthma and on symptoms of clinical diseases.

2 | EAACI Guidelines

Delivering high-quality clinical care is a central priority for allergists, pneumologists, paediatricians, dermatologists, epidemiologists and other specialists caring for patients with allergy and asthma. The European Academy of Allergy and Clinical Immunology (EAACI) develops and updates each year resources to help health care professionals and researchers deliver a high standard of care and design the best interventions. They also support evidence-based decisions of policy makers and regulators and engage patients and their caregivers.

EAACI Guidelines are developed using the Grading of Recommendations, Assessment, Development and Evaluation systematic process (GRADE) [12] and are based on available evidence and the clinical experience of all interested stakeholders.

2.1 | Target Audience

The EAACI Guidelines provide a framework for rational decisions. The target groups are: (1) health care professionals specialised in allergy and clinical immunology or a related speciality, (2) primary care practitioners and allied health colleagues who manage allergy and asthma patients, (3) policymakers and regulators as an evidence-informed reference, which helps set standards and goals for greenness implementation and access at international, national and local levels, and (4) individuals living with allergy and asthma, and their caregivers.

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2.2 | Rationale for Green Space Evaluation

In 2016, the World Health Organization (WHO) summarised the evidence for beneficial effects of urban green spaces, such as improved mental health, reduced cardiovascular morbidity and mortality, obesity and risk of type 2 diabetes, and improved pregnancy outcomes [13]. Allergy and asthma were not included.

In 2019, the European Commission called for Nature-based Solutions (NbS) to regenerate nature to make neighbourhoods more liveable, biodiverse, and resilient. NbS has been identified as a key component of the Planetary Health concept [14].

At the 2023 United Nations Climate Change Conference (COP28), Nature, Land Use and Oceans Day saw world leaders focused on efforts to protect and restore nature by channelling finance to natural-climate solutions.

In 2023, the importance of green infrastructures—among others—was pointed out by the Round Table in the European Parliament entitled "Need for an EU One Health-in-all-policies approach: addressing the allergy and asthma pandemic". A Joint Public Statement was addressed to policy makers and EU officers [15].

The present EAACI Guidelines focus on outdoors greenness, although greenness may also be present indoors with green plants and indoor cultivation. Notwithstanding important for the holistic approach recommended for primary prevention of allergy and asthma, diet, physical exercise and other lifestyle details have not been systematically reviewed for the present paper.

3 | Methods

3.1 | Guidelines Development Group, Methodologist Team, and Core Leadership Team

The Guidelines Development Group (GDG), acting also as the Voting Panel, included specialists treating allergies and asthma, biologists, clinical immunologists and epidemiologists (Table S1). The GDG members were trained for their roles, including specific sessions on the GRADE methodology. They defined the project scope, formulated the clinical questions, coordinated the literature search, and drafted the manuscript.

The main clinical question to be addressed was: does exposure to green space in urban environments help prevent the onset or progression (primary and secondary prevention) of allergy and asthma? The eight specified domains addressed were: (1) general state of health, (2) allergic sensitisation, (3–5) asthma, (6) allergic rhinitis (AR), (7) atopic dermatitis (AD), and (8) food allergy. Asthma, AR, AD and food allergy were defined as doctor- diagnosed. Allergic sensitisation to inhaled or food allergens was defined by the presence of specific IgE (positive skin prick test or serum specific IgE). General state of health was defined as the co-existence of physical, mental and immune health.

The Methodology Team conducted the systematic review (SR) for five clinical questions, graded the quality of evidence based on GRADE, and provided input in the format of summary of findings (SoF) tables [15]. The main questions covered by the SR focused on primary prevention having as outcomes new onset: (1) asthma, (2) recurrent wheezing, (3) AR, (4) AD and (5) food allergy. The SR also focused on asthma secondary prevention with critical and important outcomes: exacerbations, disease control, symptom improvement, need for medication and lung function.

In addition to the SR, an evidence-based *narrative review* was generated by the GDG by analysing the most recent and relevant studies on the effects of green space exposure on allergies and asthma.

The Voting Panel voted for the recommendations following the Evidence to Decision (EtD) framework after reviewing the evidence from the SoF tables and the narrative reviews.

The Core Leadership Team (Guideline chairs and Working Group chairs) supervised the project.

Patient representatives from the EAACI Patient Organisations' Committee (POC), European Federation of Allergy and Airways Diseases Patients' Associations (EFA), Global Allergy and Asthma Patient Platform (GAAPP) provided input for the recommendations and for their implementation and dissemination.

In accordance with EAACI policy, all guideline authors disclosed any potential conflicts of interest (COIs) at the beginning, middle, and end of the project. The COI rules were set by the Guideline Oversight Committee led by the EAACI Ethics Committee Chair.

3.2 | Systematic Review of the Evidence

The current guideline recommendations on environmental greenness are partially based on the comprehensive systematic review and meta-analysis examining the preventive effects of urban green spaces compared to non-green environments on asthma and allergic diseases [16].

The SR followed the Cochrane Handbook for Systematic Reviews of Interventions [17] and the guidance of the Cochrane Rapid Reviews Methods Group. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement was adhered to [18]. It included longitudinal studies comparing exposure to green versus non-green areas and their impact on the incidence of asthma and allergic conditions in both children and adults. Primary inclusion criteria focused on non-randomised and cohort studies with a minimum follow-up of 3 years. Where longitudinal evidence was insufficient, the protocol allowed for the inclusion of cross-sectional and case–control studies to address potential data gaps. Studies were included if they evaluated residential greenness exposure difference vegetation index (NDVI), the CORINE land-cover classes (CLC) or residential surrounding

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greyness (RSG). For comparison, *not living in a green environment* was used.

A total of 2698 studies were screened, and 47 studies were examined to determine their eligibility for inclusion. In total, 17 reports were included: 12 assessed asthma risk, six investigated AR rhinitis, one examined food allergy, and one addressed AD. For the impact on asthma the SR included one study assessing the impact of exposure to residential greenness on asthma control.

The conclusions of the systematic review are as follows [16]:

1. Exposure to green areas may decrease the incidence of asthma over the course of the lifetime (606 fewer per 100.000; 95% CI from 2157 fewer to 1335 more) (very low certainty). There was low certainty that exposure to green areas during pregnancy may decrease the incidence of asthma over lifetime up to 9 to 12 years (454 fewer per 100.000; 95% CI from 530 fewer to 378 fewer).
2. On the other hand, exposure to green areas may increase current or recent asthma symptoms over the last 12 months (1262 more per 100.000; 95% CI from 300 more to 2419 more) (low certainty).
3. Uncertain evidence that exposure to green areas may decrease the incidence of AR over the course of the lifetime (5344 fewer per 100.000; 95% CI from 11.076 fewer to 6542 more) (very low certainty). Exposure to green areas may increase the current or recent symptoms of AR over the last 12 months (385 more per 100.000; 95% CI from 2659 fewer to 3933 more) (very low certainty).
4. Uncertain evidence regarding exposure to green areas during pregnancy as having little to no effect on the presence of AD at 6 months of age (72 fewer per 100.000; 95% CI from 126 fewer to 18 fewer).
5. No conclusion on food allergy.

3.3 | Narrative Review of the Evidence

In addition to the SR, an evidence-based *narrative review* was generated by the Guideline Development Group by analysing the most recent and relevant studies on the effects of green space on allergies and asthma. This was done to also consider important associative studies as almost all studies on green environments exposure are cross-sectional. Controlled interventions of the short- and long-term effects of different types of green environments on allergy and asthma prevention or treatment are lacking.

3.3.1 | Farming, Green Environment, Biodiversity

It has been known for a long time, that the traditional farming environment is associated with a reduced risk of allergy and asthma [19, 20]. Children growing up in a rural environment displayed enhanced expression of multiple genes required for regulating aberrant immune responses, including IL-10, inhibitory leukocyte immunoglobulin-like receptors, G protein-coupled receptors and the aryl hydrocarbon receptor [21]. Multiple factors contribute to this protective effect, including dietary patterns and diet quality, exposure to animals and living in a more biodiverse environment. Mechanistically, these exposures are thought to exert effects on the immune regulatory pathways essentially via microbial taxa, microbial metabolites [22–24] and specific carrier-proteins like beta-lactoglobulin present in the stable environment and milk [25, 26].

Skin microbiota patterns differ in children living in rural and urban environment [27]. Recently, the allergy preventive effect of both the farming and non-farming environment could be predicted by the microbial richness of the house dust [28]. This might give an opportunity to modify the urban house dust in a safe way to protect from allergy and other non-communicable diseases [29].

The biodiversity hypothesis [30, 31] emerged from observing the sharp allergy prevalence contrasts between two adjacent areas, Finnish and Russian Karelia [32]. On the Finnish side, the greenness/biodiversity of the adolescent home environment was associated with skin microbiota composition, immune regulation, and allergy risk [33]. Living environment is also a surrogate marker of lifestyle, for example, farming vs. nonfarming, rural vs. urban, thereby influencing contact with air, soil and natural waters, food and physical exercise.

In Northern Finland, living on a farm or in a rural environment during childhood had a protective effect on sensitisation even in middle age [34]. Indeed, the importance of rural, green type of home environment in allergy prevention was suggested in two cohorts of children, aged 3 and 6 years, from Finland and Estonia [35]. Further studies from New Zealand, Denmark, Finland, Canada and Estonia implicated also that exposure to greenness and vegetation diversity may protect from allergic conditions and asthma [36–40]. In Portugal, residing in neighbourhoods surrounded by more vegetation at 10 years, as well as lifetime exposure, were associated with a lower risk of allergic sensitisation to food and aeroallergens [41].

Interestingly, not all green spaces seem equal. A recent study suggested that forest was the most effective exposure to prevent atopic sensitisation at the age of 3 years, followed by grasslands and wetlands, while intensive agricultural land only had a weak effect [40]. Indeed, contact with forest soil-enriched microbiota enhanced immune regulatory responses of children that may reduce the risk of developing immune-mediated diseases [42]. This is important for city planners to consider when designing green space areas, kindergartens and schools within cities.

A recent study indicated that green environment may also be effective for secondary/tertiary prevention as the use of asthma drugs in adults decreased by 30% when increasing visits to green space [43]. However, conflicting results of green space effects on asthma and allergic symptoms have also been reported [44–48]. For example, during pregnancy or early life, high exposure to green space with pollens in spring may be associated with increased risk of asthma years later [49].

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3.3.2 | Quantity and Quality of Greenness

Evaluation of the quantity and quality of greenness is not straightforward. In Karelia, biodiversity was estimated by the abundance of vascular plants (trees, shrubs, grasses, flowering plants, and ferns) in the home yard and the land use characterised within a radius of 3 km [33]. The *Coordination of Information on the Environment* (CORINE) land-cover database was employed, launched by the European Commission in 1990. Since then, other methods to assess green space have also been used. *Normalized difference vegetation index* (NDVI) is widely employed to assess green space and is derived from satellite sensing data. The presence and quality of vegetation are based on the difference in reflectance between near-infrared (NIR) and visible red (RED) wavelengths. With the *Chlorophyll Index green* (CI green, used in agriculture) the health of plants and vegetation can be assessed.

The methods to estimate green space and its quality vary between studies, which increases heterogeneity in their assessment. In addition, measures of plant, microbial, insect or animal biodiversity are usually not included in studies on green spaces. Furthermore, indoor factors such as plants and animals in the home environment are important considerations that provide complementary exposures to those associated with outdoor green spaces.

3.3.3 | Holistic Effects of Green Space

The health effects of green space are mediated by many mechanisms. Exposure to environmental microbiota has been well described. In addition, biogenic volatile organic compounds (BVOCs) in the air are thought to be important [50]. More than 1000 such chemicals have been identified with many of them having anti-inflammatory, anti-oxidative and anxiolytic effects [51]. In the context of allergy, however, their immunological mechanisms and clinical effects remain to be determined.

There are also several other benefits associated with spending time in green spaces. Physical and mental well-being is maintained by reduced exposure to extreme temperatures (heat stress or cold spells) and outdoor and indoor air pollution, increased regular exercise like commuting by walking or bicycling, social integration, and positive mental stimulation by sights, landscapes, sounds, and silence [52]. In a randomised follow-up study of students, even watching a video of a forested landscape demonstrated improved mood, vitality, and enhanced recovery from physical exercise [53]. There are also provisioning services in urban green space like options for gardening, producing food and water supply. In a more forested landscape even picking berries and mushrooms for fresh food is an option. All these activities may support long-term allergy prevention although in short-term, variable respiratory and skin symptoms may occur. Finally, greening of cities slows down global warming and pollution and supports actions against nature loss and biodiversity decline [54]. A favourable trend in promoting healthy urban green spaces is the decreased used of chemical-based pesticides [55].

3.3.4 | Trees to Protect Urban Environment and Health

Urbanisation has intensified the formation of heat islands and deteriorated air quality in cities, highlighting the importance of strategic tree planting to improve the urban environment [56]. Trees play a major role in urban ecosystems co-regulating biogeochemical cycles of nitrogen and carbon as well as hydrological cycle, providing shade, cooling the air through transpiration, and reducing air pollution, positively impacting public health and well-being [57, 58]. These ecological benefits emphasise the need for extended green spaces in urban environments, but with careful selection of tree species for sustainable urban development.

However, urban trees and shrubs face increasing stress from heat, air, water and soil pollution, drought [59], extreme weather, pests, and diseases, which can compromise their resilience and lifespan [60]. Additionally, specific plant species used as ornamentals in urban parks produce allergenic pollen that can trigger symptoms of AR or allergic asthma [61]. It is essential for urban planners and policymakers to consider the allergenic potential of the urban trees and shrubs [62]. This should concern also private property owners who often plant allergenic trees like birch or hazel, shrubs or alien species in their gardens as ornamental plants. A varied selection is recommended as opposed to planting single species, which may be more harmful due to elevated concentrations of one pollen species, for example, birch tree.

Not all trees and shrubs thrive in city environments, where factors like paved surfaces, limited root space, shading, and wind exposure can hinder their growth [63]. Therefore, it is crucial to select plant species that are not only adapted to urban conditions but also capable of providing critical ecosystem services such as habitat quality and diversity. Cooling is essential [56] along with pollution reduction, carbon storage [64, 65] and emitting minimal allergenic pollen, or, alternatively, selecting insect-pollinated species thus also promoting pollinators biodiversity and abundance [61]. Balancing plant gender ratios in urban spaces can help control pollen levels [66]. This is a prerequisite for the development of resilient, sustainable and healthy urban green spaces.

A list of tree and shrub species has been compiled in a pilot study in Central Europe (Augsburg, Germany) that are both climate-resilient for Central Europe and have low allergenic potential, making them suitable for urban environments [67]. However, the requirements for suitable trees and shrubs can vary by location, groundwater levels, soil composition and other site-specific factors [68]. In the United States cities developed within areas with naturally occurring Pinaceae (pine, spruce, fir, cedar, Douglas fir, larch) forests and/or have more Pinaceae species tended to have the lowest pollen index scores [69]. High biodiversity is also vital, as monocultures are more vulnerable to stress [70]. In addition, one needs to assess each tree's specific suitability for the intended planting site, considering local conditions such as soil type, water availability, and other environmental factors, to ensure their long-term success and optimal ecosystem benefits (Table S2). For the city residents, the societal factors, like accessibility to green space, need also to be considered to ensure adequate ecosystemic services.

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While the present Guidelines reflect general principles to be applied to all European countries and regions, the Augsburg list may not be fully relevant to southern European countries or other regions of the world impacted by increasing temperatures and decreasing average rainfall, together with more intense atmospheric phenomena such as storms, which impact the flora of these countries.

3.4 | Formulating Recommendations

The GRADE methodology [71] was used to formulate the *Guideline recommendations* [72]. They are a synthesis of the conclusions provided by the *systematic review* supplemented with reviewing the recent evidence found relevant by the GDG and described in the *narrative review*. They take into consideration the balance of desirable and undesirable consequences, quality of evidence, patients' values and preferences, feasibility, and acceptability of various interventions, use of resources paid for by third parties, equity considerations, impacts on those who care for patients and public health impact.

In addition, the SR evaluation of the relationship between greenness and AR in adults was supplemented by evaluating eight relevant studies included in the *narrative review* [44, 48, 73–78]. It was determined whether their results were consistent with or contradictory to the findings in the systematic review (Table 1).

A conditional recommendation was provided if there were reasons for uncertainty on the benefit–risk profile, especially for low or very low quality of evidence. The underlying values and preferences played a role in formulating recommendations. The perspective for the recommendations was mainly that of professionals and patients, although policymakers and the health system were also considered.

Recommendations were voted on electronically in real time using the Zoom voting platform (https://zoom.us/) managed by an independent member of the EAACI headquarters team. A minimum of 80% of votes in favour of the recommendations was required for approval.

4 | Guideline Recommendations 1–8 (Table S3)

4.1 | General State of Health

Recommendation 1: Visiting and spending time in green space is recommended to support immune health. Also, both mental and general physical health may improve, and the need for medication is reduced.

1. The *Evidence-to-Decision* framework

Reason for recommendation: For urban citizens, a decrease of contact with green spaces and biodiversity may correlate with an increase in chronic non-communicable diseases.

Strength of recommendation: Strong. The evidence base is moderate. Both green space interventions and nature-assisted therapies indicate positive health effects, although the data derive mostly from associative and cross-sectional studies.

Practical implications: In urban settings, the amount of green space must increase, and accessibility must be improved. The decision-makers should be made aware of this. Visiting green space usually means regular exercise that also supports well-being. Green space also provides a buffer zone that protects from noise, heat and air pollution.

4.2 | Sensitisation to Inhalant Allergens

Recommendation 2: Visiting and spending time in green environments around residential neighbourhoods is recommended, especially for families with small children to prevent new-onset allergic sensitisation.

2. The *Evidence-to-Decision* framework

Reason for recommendation: In early childhood, contact with green space around the home may reduce the risk for allergic sensitisation and allergic conditions later in life.

Strength of recommendation: Conditional. The evidence base is not consistent, with conflicting reports. Certain characteristics or types of vegetation diversity of green spaces around the home have provided protection. However, the preventive effect of green space on sensitisation on one hand and provoking allergic symptoms on the other has diverted in the one and same study.

Practical implications: Biodiverse green space around home, especially forests, may give the best protection. Overall greenery may contribute to positive effects as has been shown also with grasslands and wetlands but not with agricultural fields.

4.3 | Asthma

Recommendation 3: Visiting and spending time in green spaces is recommended for preventing new-onset asthma and improving asthma management for patients.

3. The *Evidence-to-Decision* framework

Reason for recommendation: The systematic review identified that residential greenness exposure or green space per se, especially during pregnancy, marginally decreases the lifetime incidence of asthma.

Strength of recommendation: Conditional. Low certainty of evidence. The results of the studies were not consistent, and some studies relied on questionnaire data only to identify asthma cases.

Practical implications: Green spaces may provide a buffer zone from the types of air pollution that damage the respiratory tract, while frequent exposure to environmental microbes may help promote regulatory immune responses.

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TABLE 1 | Relationship between greenness and the development of allergic rhinitis mainly in adults according to 8 relevant studies selected for the narrative review.

Study	Agreement or disagreement	Key points
Weng et al. (2024) [73]	Partial agreement	• 10% increase in green space within a 300 m radius was associated with 2.5% lower incidence of allergic rhinitis • No excess risk above a certain threshold of green areas • No statement about a change over time
Nordeide Kuiper et al. (2021) [74]	Partial disagreement	• No association found between green areas and asthma or rhinitis • Increased green areas were associated with low lung function in all age windows (higher risk of lower limit of normal) • Timeframe: lifelong
Fuertes et al. (2014) (children) [44]	Uncertainty of results	• Different associations depending on the region: higher risks in urban areas, lower risks in rural areas • Results vary depending on urbanisation and geographical location
Liu et al. (2023) [75]	Agreement/ disagreement: Inconsistent associations depending on the study	• Negative association between green spaces and asthma in young children (100 m) • Positive association between green spaces and allergic rhinitis in younger children, but not in older children
Kim et al. (2020) [76]	Partial agreement, Disagreement to some of the current symptoms	• Highest level of green areas was significantly associated with a decreased risk of allergic rhinitis • No indication of increased current allergic symptoms, but protective effect.
Paciência et al. (2023) [48]	Disagreement/ partial approval	• Early childhood exposure to green spaces in spring increases the risk of allergic rhinitis into young adulthood • Summer exposure, on the other hand, reduces the risk
Sun et al. (2020) [77]	Agreement	• Green spaces can reduce health risks, including respiratory diseases • More green space in residential areas can protect older people from the possibility of exacerbating allergic symptoms such as rhinitis
Stas et al. (2021) [78]	Partial agreement	• Green spaces can reduce the severity of tree pollen allergies, but only if the density of allergenic trees is low • Grassy areas, wooded areas, and Alnus density were found to be protective against severe allergy symptoms, but only on the day of the severe allergy event • Air pollution contributes to more severe allergy symptoms

Note: According to the systematic review, there is uncertain evidence that exposure to green areas may decrease the incidence of allergic rhinitis on the lifetime and increase the presence of allergic rhinitis with current or recent symptoms over the last 12 months. The studies in the table were examined regarding this conclusion and determined whether the results were consistent with or contradictory to the findings in the previous systematic review.

Recommendation 4: Pollen-allergic asthma patients are recommended to enjoy a green environment most of the year but should consider a temporary increase in medication during the high-pollen season.

4. The *Evidence-to-Decision* framework

Reason for recommendation: Exposure to green areas may increase the current or recent asthma symptoms.

Strength of recommendation: Conditional. The evidence base is low as no randomised controlled trials compare differently medicated pollen-allergic asthma patients visiting green areas.

Practical implications: Frequent visits to green space have also been associated with reduced use of asthma medication in urban environments. The asthma phenotype in adulthood is often not dominated by type 2 immune responses and is not associated with IgE, that is, not exacerbated by pollen or other allergen exposure [79]. In general, activities and physical exercise in green environments are useful and help control symptoms and improve health outcomes.

Recommendation 5: Asthma patients are recommended to combine exposure to green areas with regular physical activity to improve their asthma control.

5. The *Evidence-to-Decision* framework

Reason for recommendation: Adult asthma patients may feel better and need less asthma controller and reliever medication by increasing visits to green space combined with regular physical activity.

Strength of recommendation: Conditional. The evidence is uncertain as it is based only on one cross-sectional study.

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Practical implications: Asthma patients should be encouraged to enjoy outdoor activities and not limit physical activity due to their disease. Avoiding physical activity in green spaces may lead to unintended consequences, such as weight gain and obesity.

4.4 | Allergic Rhinitis

Recommendation 6: Allergic rhinitis patients are recommended to enjoy green spaces most of the year but patients with

TABLE 2 | Most important reasons and restrictions to visit green space according to a questionnaire carried out in Finland among adult citizens and healthcare professionals ($n = 1539$) [98].

Agreement with the reason to visit green space	Agreement with the reason restricting visit to green space
1. Clean, fresh air (68%)	1. Bad weather, darkness (47%)
2. Beautiful environment, landscape (55%)	2. Difficulty to get going, tiredness (44%)
3. Silence, lack of noise (54%)	3. Lack of time (32%)
4. Green space near home (46%)	4. Poor condition, physical restrictions (20%)
5. Closeness of water; lake, river, sea (34%)	5. Spoiled green space (logging, construction, real estate development, littering) (17%)
6. Rich nature, forest, plants, animals (34%)	

BOX 1 | Recommendations and Considerations for Policy Makers and for Urban Planning [101].

Policy makers

- Greenness, green space must be of high priority in all urban constructing and planning as they support human health and sustainability of the city environment and promote the ecological balance [66]. Examples are green playground areas, green and traffic-free walking paths, allowing natural processes in green areas, and enabling and respecting animal habitats in green areas. Outdoor air pollution could be partially controlled by planting non-allergenic tree lines around the pollution sources. Policy makers should allow that city residents can easily use green space and adapt individually (e.g. planting flowers, shrubs or trees).
- Green space themes should be considered in school and daycare curricula.
- In planning and decision making, multi-sectoral experts must be included, including health care professionals, ecologists, aerobiologists, communities and non-governmental patient organisations.
- *Nature-based Solutions (NbS)* should be favoured [102]. They are inspired and supported by nature, cost-effective, provide environmental, social and economic benefits, and help build resilience (EU 2019)
- Engagement of city dwellers in acts of urban greening, or environmental stewardship, collectively support the social movement for greater access to the natural environment. This intervention is particularly salient for disadvantaged communities in promoting greater resilience, health, and well-being.

Urban planning

- Natural forests generally maintain greater native biodiversity and ecological complexity, although city parks may exhibit even higher species richness due to human cultivation. Balancing the introduction of diverse plant species with the preservation of native flora sustains ecological health in both urban and natural environments [103, 104].
- The risk of respiratory and skin allergic reactions caused by breathing pollen or skin contact with allergenic trees or plants should be considered. In general, urban planning policy should prioritise the selection of native species with low allergenic potential.
- Proximity and accessibility of green space must be guaranteed. The needs and restrictions of city residents of different ages must be considered while planning green space and structure for different services (day care, old-age homes, sports facilities).
- Dense urban constructing and extensive covering of the soil with asphalt and concrete do not leave space for greenness to support health.
- Rewilding of some area increases human contact with wider nature.
- Green space prevents floods and damage to the buildings, which may increase moisture and mould with respiratory health risk.
- In traffic arrangements, greenness and trees reduce air pollution and noise.
- Trees and greenness are needed not only for human health but also for urban runoff waters, reduction of carbon footprint and slowing down nature loss. *Nature positivity* (NPI) aims to halt and reverse nature loss.
- The so-called 3–30-300 rule states that every city resident should see at least 3 trees from home, have 30% tree canopy cover in the neighbourhood and live not more than 300 m away from the nearest park or green space [105]. Future studies should more precisely test this rule for effects on immune health.

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seasonal rhinitis should consider a temporary increase in medication during the high-pollen season.

6. The *Evidence-to-Decision* framework

Reason for recommendation: There is no evidence that exposure to green areas increases current or recent symptoms of AR. There is uncertain evidence that exposure to green areas decreases the lifetime incidence of AR.

Strength of recommendation: Conditional. Research on the relationship between greenness and the development of allergic rhinitis in adults is limited and the results are heterogeneous and unclear.

Practical implications: People with allergic rhinitis are encouraged to spend time in green spaces, but they should consider a temporary increase in medication during pollen season. The exposure can also be reduced by wearing a mask, sunglasses and a hat with a brim.

4.5 | Atopic Dermatitis

Recommendation 7: Exposure to green spaces in childhood is recommended as it may reduce the risk of new-onset atopic dermatitis.

7. The *Evidence-to-Decision* framework

Reason for recommendation: The skin microbiota and regulatory immune response were improved when children were exposed to green spaces, especially when handling soil from the forest floor.

Strength of recommendation: Conditional. Studies focused on new-onset atopic dermatitis are limited. Regarding exposure to green spaces during pregnancy, the evidence is inconclusive, suggesting it may have little to no effect on the incidence of atopic dermatitis in infants at six months of age.

Practical implications: Children should be encouraged to play with and handle soil, especially soil from the forest.

4.6 | Food Allergy

Recommendation 8: Spending time in green spaces during infancy is recommended to reduce the risk of new-onset food allergen sensitisation.

8. The *Evidence-to-Decision* framework

Reason for recommendation: Infants who grow up close to green spaces, especially forests, have lower rates of sensitisation to food allergens.

Strength of recommendation: Conditional. Research on the relationship between greenness and the development of food allergy is limited, with only two studies published correlating exposure to green spaces and food allergen sensitisation.

BOX 2 | Research Gaps and Recommendations for Future Studies on the Effect of Green Space on Allergy and Asthma.

Study type

- Longitudinal studies, follow-ups, controlled interventions (case-controls), real-life studies; rigorous standardised definition of greenness exposure and of outcomes, demonstration of causality through replications of larger-scale studies.

Primary and secondary prevention on allergy and asthma

- New-onset sensitisation, clinical course and symptoms.
- Effect of age: young children, school-aged children, adults, elderly.
- Start and duration of effect, short- and long-term effects, dose–response.
- Mechanisms of effect (microbes, biogenic chemicals, mental and socio-cultural factors).
- Effect on healthcare use and medication, effect on individual and societal disease burden.
- Cost benefits: direct healthcare costs, indirect costs (disability, working capacity).
- Validation of diagnostics of nature deficiency in clinical practice [94].

Impact of the use of green space

- Time spent in green space.
- Activities in green space: dog walking, birdwatching, butterfly counting, gardening, etc.
- Visits to green space combined with physical exercise: walking, jogging, cycling, playing.
- Use of indoor plants.

Impact of urban green space characteristics

- Availability and accessibility.
- Distance from home.
- Quality of green space: diversity, forest, tree and plant species (allergenicity), wildlife, landscapes, etc.

Impact of societal factors

- Equity issues, low-income citizens, low-quality residential areas.
- Social contacts with other people.

Adverse effects, risks

- Pollen, insects, ticks, parasites, pathogenic microbes. Toxic dust and outdoor air pollutants and pesticides. Effect of climate change. Societal barriers to use the green space, for example, insecurity, fear of violence, financial constraints, cultural factors.

Practical implications: Parents should be encouraged to bring infants frequently into green spaces to reduce their risk of food allergen sensitisation.

Note. The GRADE system favours the expression "may be recommended" for a conditional recommendation where the evidence is not consistent. Here, a straighter expression "is recommended" is used as the guidelines are based not only on the

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systematic review but also on the narrative review and long-term clinical experience.

5 | Discussion

Assessing studies of long-term primary or secondary/tertiary allergy prevention is challenging due to the major confounders of early sensitisation and common, environment-dependent symptoms in patients [80].

For primary prevention of allergy and asthma, most of the evidence indicates beneficial effects of green space: (1) protection against sensitisation, (2) reduction of the lifetime incidence of asthma, and (3) lower risk of atopic dermatitis. For allergic rhinitis and food allergy, the evidence is more contradictory, highlighted in Table 1.

For secondary prevention, the exposure to green space in urban environments is especially relevant for pollen-allergic individuals. The conclusion of both the systematic and narrative reviews is comforting. However, another systematic review found pollen exposure as a potential risk factor for asthma exacerbation [3]. Visiting green space is safe, but during the high-pollen season, a temporary increase of medication is recommended. In the long run, allergen immunotherapy (AIT) is a potential disease-modifying treatment, allowing an increased threshold for greenness exposure before evoking symptoms.

The quality of green space for disease or symptom prevention has not been systematically evaluated. However, for prevention of sensitisation, forest around homes during early childhood prevented sensitisation better than agricultural land in one study [40]. This is in line with the biodiversity hypothesis. Less biodiverse city parks, and urban green space differ markedly from forests. Controlled follow-ups to compare effects of different types of green space on allergy prevention or symptoms are, however, lacking.

The optimal duration of time spent in green spaces to achieve health benefits is often poorly defined. However, visiting green spaces three to four times per week has been associated with reduced use of asthma medication [43]. Increasing outdoor activity improved perceived health [81] and spending at least 120 min a week in nature was associated with good health [82]. However, it is not possible with the current evidence base to recommend a minimum amount of time needed to achieve optimal immune benefits.

The human body is an ecosystem, and greenness alone has little effect, if not closely contacted. A visit to green space provides a mixture of biogenic chemicals and microbes to breathe [83], and microbes to touch via plants, soil and natural waters. This promotes immune regulation and tolerance, which may be further strengthened by physical exercise and favourable climate [84].

Human senses guide us to make safe connections with the wider environment. Socio-cultural and mental experiences drive the contact.

Green space is not without dangers. Many city residents are not accustomed to moving in forests and facing wildlife. Insects, ticks, parasites and pathogenic microbes are true dangers in some environments. Bad weather may also pose risks. Thunderstorm-related phenomena (thunderstorm asthma) can

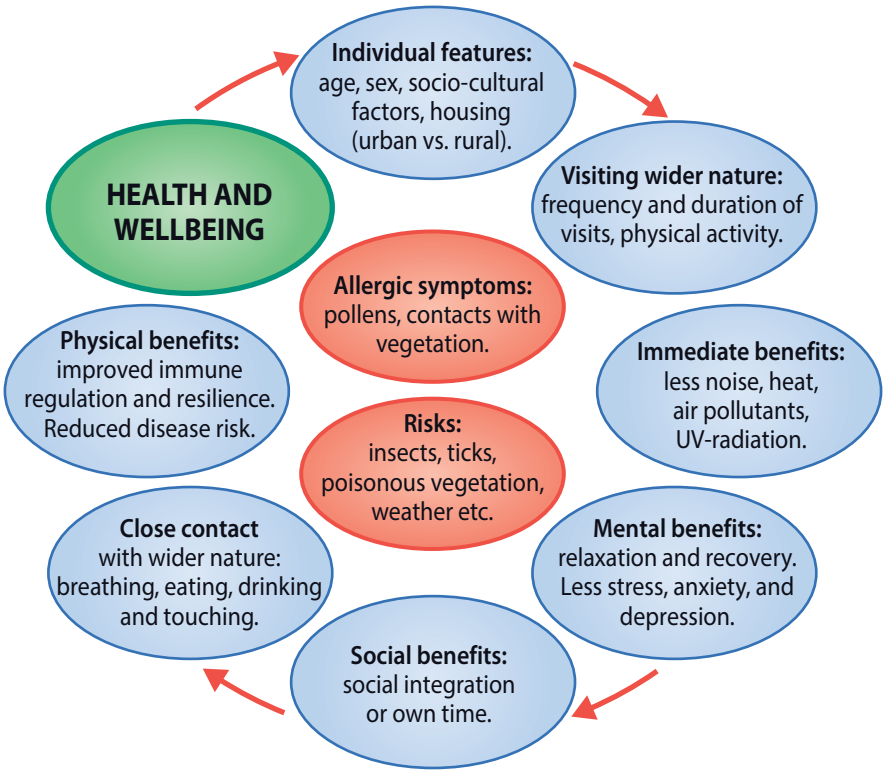

FIGURE 1 | Health Wheel. Visiting green environment, greenness or green space, for health and well-being. Individual features, potential benefits and risks.

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TABLE 3 | Improving nature connection in urban everyday life for immune tolerance and health. These suggestions are not restricted to systematically reviewed green space but includes also other measures with evidence.

Suggestions	Selected references
1. Main principle: *Take natural elements back to the city and housing environment. Put hands into the soil!*	[42, 111]
2. "Biodiverse eating" – less meat and more fruits, vegetables, and roots. Consider fermentation products, fish, fasting. Avoid sugary drinks	[112]
3. Consider growing something green by yourself to eat (on house yard, balcony, roof terrace, indoors)	[113]
4. Consider gardening as a hobby (even small-scale gardening is useful). Allergy-friendly green roof gardens are most welcome	[113, 114]
5. Keep green plants both at home and workplace but avoid allergenic plants like *Ficus benjamina*. Keep the plants in good shape to avoid mould	[115–118]
6. Visit regularly natural environments, green space (e.g., 2–3 times per week for one hour). Forest is especially refreshing. Walk, jog, cycle	[43, 82]
7. Consider taking part of activities in nature, e.g., hiking, birdwatching, butterfly counting, photographing	[119]
8. Consider animal contact (e.g., horse), having a pet (e.g., a dog)	[120, 121]
9. Avoid excess use of cleaning chemicals, disinfectants and insecticides	[122]
10. Enjoy leisure time in nature, including spending time in a holiday home, if feasible. "Pick and eat berries from the bush and apples from the tree"	
11. Increase social interaction and contacts with other people	[123]
12. Do not smoke, no maternal smoking, avoid tobacco smoke	[124]

Note: Mild allergy symptoms often disappear when immune tolerance improves. More *severe symptoms*, like moderate to severe asthma, often become milder and cause less disability along with improved tolerance and general health.

lead to sudden exacerbations due to the fragmentation and dispersion of allergenic particles [85–87]. Even toxic dust, outdoor pollutants and pesticides in the urban green space (parks) may compromise the health benefits in certain situations [88]. While not specifically focusing on pollution in green space, a recent study from Australia indicated a general association between air pollution (small particulate matter, nitrogen oxide) and persistent peanut allergy in children [89].

Urbanisation with scientific and technical progress has provided safety, health and life years, but endangered immune tolerance. Air pollution is a serious global health risk and the fine particulate matter, PM2.5, diesel exhaust particles (DEP) and ozone, may specifically reduce immune tolerance (reviewed in [55]). Peaks of air pollution (both gaseous and particulate) can enhance the allergenicity of airborne pollen and increase respiratory inflammation.

Nature loss of the wider environment is a global threat [90] but is also taking place in the ecosystem of the human body along with the impoverished microbiome [91–93]. Nature deficiency conceptualises nature loss in the human body and calls for validating biomarkers for diagnosis and management [94]. Nature prescriptions may find plausible formats in patient care if they help to deploy evidence-based protective factors instead of only avoiding risk factors. Forest bathing (*shinrin-yoku*) is an example of a holistic approach [95].

The Finnish Allergy Programme (2008–2018) was a national, real-world intervention aimed to improve immune tolerance and promote allergy prevention and general health not only by better management but also by encouraging closer contact with nature. The results were most favourable and cost savings remarkable [96, 97]. Major exacerbations of allergic conditions caused by visiting green space did not come up. The outcomes should be replicated in more controlled settings.

In 2023, the Finnish Allergy, Skin and Asthma Federation asked the citizens and healthcare professionals about the use of green space [98] (Table 2). Clean, fresh air was a major reason to visit green space, while bad weather or darkness was a major restriction. Exacerbations of allergic symptoms did not feature as an important restriction. Healthcare providers considered green space visits most useful to prevent depression (86%), musculoskeletal disorders (67%), allergic conditions (47%), and cardiovascular diseases (42%).

Health professionals are in a key position to integrate public health promotion with environmental care [99–101]. Fighting against air pollution is an example of positive synergistic effects. Actions to reduce emissions are widely taken, but at the same time, trees and greenness should be increased in urban settings [67, 102]. Their health protective function supports all citizens, allergy and asthma patients among them, by reducing air pollution, mitigating heat waves and stormwaters.

Recommendations for policy makers and for urban planning are presented in Box 1.

In the regional health and environment programme in the Finnish City of Lahti, *Nature Step to health 2022–2032*, the public health goals were scaled up from allergy and asthma to types 1 and 2 diabetes, obesity and depression [106]. Environmental goals, mitigating climate change and stopping nature loss, were integrated into the same action plan. Today's public health guidelines should incorporate principles of environmental sustainability and not only advance clinical practices. Urban green space as a health determinant represents a concrete opportunity to simultaneously promote health and environmental benefits

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[107–109]. Here, we added a criterion (*Desirable effect on environmental sustainability*) to the GRADE Evidence-to-Decision framework to address the broader connections and to set a precedent for EAACI guideline work.

These are the first recommendations highlighting the importance of urban green spaces on immune health and should open a whole new field of research. The community should be confident in performing studies examining immune-environment interactions in more detail. We anticipate pivotal future studies, which we expect will strengthen the present guidelines [110]. Research gaps and recommendations for future studies are presented in Box 2.

5.1 | Conclusion

The many health aspects of green space in the urban environment are demonstrated in Figure 1. At the society level, green infrastructure should be prioritised in urban planning. Natural and rural elements can be favoured in the urban environment: for example, diverse greening, rewilding, planting trees, gardening, green roofs, indoor greenery, small-scale farming, small animal yards, nature-friendly daycare, support of local food and promoting walking and cycling (Table 3). A close collaboration between policy makers, urban planners and medical professionals is necessary. As for health care providers, it is essential not only to medicate symptoms but also to provide trusted advice for health-promoting lifestyle habits. Increasing time spent in the green environment and contact with it will provide multiple benefits, including improvement of immune regulatory pathways and barrier defense for allergy and asthma prevention [125].

Author Contributions

Tari Haahtela, Liam O'Mahony, Claudia Traidl-Hoffman (Working group chairs): conceptualization; methodology; roles/writing – original draft; and writing – review and editing. Ioana Agache, Marek Jutel, Cezmi A. Akdis (Guideline group chairs): conceptualization; methodology; roles/writing – review and editing. All other authors: conceptualization; methodology; and writing – review and editing.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Participants of the Guidelines Development Group (GDG), acting also as the Voting Panel, in alphabetical order. **Table S2:** A list of tree and shrub species based on a pilot study in Central Europe (Augsburg, Germany). They represent (or are well adapted to) the indigenous vegetation of the regional flora, are climate-resilient for Central Europe, and have low allergenic potential, making them suitable for urban green spaces (61). Each tree's suitability for the intended planting site should be assessed considering local conditions such as soil type, water availability, and other environmental factors, to ensure long-term success and optimal ecosystem benefits. **Table S3:** all70182-sup-0003-TableS3.docx. *Evidence-to-Decision, EtD* frameworks for each of the 8 Recommendations.

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