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THE RELATIONSHIP BETWEEN GREEN SPACE DENSITY AND THE PREVALENCE OF RESPIRATORY DISEASES IN LARGE CITIES

Salomova Feruza Ibodullayevna
Sadullayeva Xosiyat Abduraxmanovna
Tashkent State Medical University

ABSTRACT	KEYWORDS
The density of green spaces in large cities directly affects the respiratory health of the population. This analytical study statistically assessed the relationship between green space density, PM2.5 concentrations, and the prevalence of respiratory diseases (asthma, chronic obstructive pulmonary disease (COPD), allergic rhinitis) across 25 megacities from 2010 to 2024. Correlation and regression models were applied using WHO (2023), GBD (2024), and advanced epidemiological datasets. The results show that a 10% increase in green space coverage corresponded to a 6–9% reduction in PM2.5 levels and a 4.3–7.1% decrease in respiratory disease prevalence. These findings confirm the strategic importance of urban greening in public health and urban planning policies.	Green spaces, respiratory diseases, PM2.5, urbanization, asthma, COPD, epidemiology, urban ecology, correlation, regression.

Introduction

Urbanization in the modern era represents a paradox in which socioeconomic advancement and ecological risk emerge simultaneously. Population densification, transportation activity, industrial emissions, and infrastructure expansion have significantly increased atmospheric pollutants—particularly fine particulate matter (PM2.5), nitrogen oxides, and ozone. These pollutants substantially contribute to premature mortality associated with respiratory and cardiovascular diseases worldwide. According to WHO estimates, outdoor air pollution caused approximately 4.2 million premature deaths in 2019, underscoring the critical importance of urban environmental health.

Green spaces, an essential component of urban ecology, not only provide aesthetic value but also directly influence public health by regulating microclimate, filtering air pollutants, capturing particulate matter, and reducing stress. Comparative analyses using Normalized Difference Vegetation Index (NDVI) and other remote-sensing indicators demonstrate that the extent and distribution of green spaces can significantly affect PM2.5 levels; several megacity studies report moderate to strong inverse associations between green space density and particulate pollution. Moreover, the type of green space (parks, street vegetation, riparian corridors), its spatial configuration, and morphological features (density, canopy height, spacing) play critical roles in determining pollutant mitigation efficiency.

Epidemiological studies and meta-analyses have consistently demonstrated strong associations between airborne pollutants (particularly PM2.5) and respiratory outcomes, including asthma, chronic obstructive pulmonary disease (COPD), bronchitis, allergic rhinitis, and respiratory mortality. Global Burden of Disease (GBD) and State of Global Air reports show that PM2.5 exposure substantially contributes to global disease burden, with particularly high impacts in regions such as South Asia and parts of Africa. Air pollution not only triggers acute respiratory symptoms but also contributes to long-term complications such as reduced lung function, chronic disease development, and impaired childhood growth.

The literature on the health benefits of green spaces is multifaceted. While evidence strongly supports the role of vegetation in filtering air pollutants and improving microclimatic conditions, some studies emphasize contextual variability, indicating that vegetation may under certain conditions trap pollutants and increase local concentrations. These mixed findings highlight the need to consider green space type, geographic characteristics, meteorological patterns, proximity to traffic corridors, and urban design parameters when assessing environmental health benefits. Systematic reviews and meta-analyses suggest an overall positive association between green space exposure and improved respiratory outcomes; however, more robust cohort studies and spatially explicit models are needed to strengthen causal inference.

Green spaces also influence respiratory health indirectly by promoting physical activity, psychological well-being, and social cohesion—factors that collectively enhance immune resilience and reduce vulnerability to respiratory illness. Therefore, expanding urban green infrastructure should be recognized as both an environmental and a public-health strategy. Integrated economic analyses suggest that such interventions can reduce healthcare expenditures in the long term.

The purpose of this study, as outlined in the introduction, is to systematically analyze the relationship between green space density, PM2.5 levels, and respiratory disease prevalence in major global cities, and to develop scientifically grounded policy recommendations using empirical literature and global datasets (WHO, GBD, State of Global Air). The study also examines the effectiveness of different types of green spaces, the role of regional characteristics, and the potential impact of adaptive urban policies such as green corridors, street-tree expansion, and optimized park networks.

Objective of the Study

To determine the statistical relationship between green space density, PM2.5 concentrations, and the prevalence of respiratory diseases in large cities; to develop an epidemiological model; and to provide evidence-based recommendations for urban planning and public health policy.

Materials and Methods

Study design: Retrospective ecological-epidemiological analysis (2010–2024).

Data sources: WHO Urban Air Database (2023–2024); Global Burden of Disease (GBD) 2024 dataset; ESA Sentinel-2 and Landsat 8 NDVI data (for green space density); Health department statistics of megacities (asthma, COPD, rhinitis prevalence)

Variables analyzed: Green space density (% of total urban area); Annual mean PM2.5 concentration ($\mu g/m^3$), Prevalence of respiratory diseases (per 100,000 population per year)

Statistical methods: Pearson correlation; Multivariable linear regression; Spatial autocorrelation analysis.

Results

Based on our analytical review and the existing literature, several clear trends and associations—both direct and indirect—were identified between green space density, ambient particulate matter (particularly $PM_{2.5}$), and respiratory disease prevalence in large metropolitan areas.

Greenness and respiratory health: overall indicators. A systematic review and meta-analysis—*Greenness and chronic respiratory health issues: a systematic review and meta-analysis* (Tang et al., 2023)—which synthesized 35 studies, demonstrated that a 0.1-unit increase in NDVI (Normalized Difference Vegetation Index) was associated with reductions in asthma, chronic obstructive pulmonary disease (COPD), and lung cancer incidence. The pooled relative risks were: asthma RR = 0.92 (95% CI: 0.85–0.98), COPD-related mortality RR = 0.95 (95% CI: 0.92–0.99), and lung cancer RR = 0.62 (95% CI: 0.40–0.95). These findings indicate that higher levels of urban greenness are linked to improved respiratory health outcomes.

Age-stratified analyses also highlight important patterns. For instance, among adolescents aged 13–18, asthma incidence was significantly lower in areas with higher vegetative density, with a reported RR = 0.91 (95% CI: 0.83–0.99). This suggests that greenness plays a particularly protective role in the respiratory health of children and adolescents.

Urban greening and ambient air pollution ($PM_{2.5}$). The study *Effect of Green Space Environment on Air Pollutants PM2.5, PM10, CO, O3 ...* (Meo et al., 2021) reported substantially lower concentrations of $PM_{2.5}$, PM_{10}, CO, and O_3 in green-space-buffered urban zones.

Specifically, $PM_{2.5}$ levels were notably reduced in greener areas, highlighting the filtration and deposition function of vegetation in mitigating urban air pollution.

A more recent analysis—*The effects of urban green space and road proximity on indoor traffic-related PM2.5, NO2, and BC exposure in inner city schools* (Matthaios et al., 2024)—demonstrated that increased NDVI values and greater distance from major roads significantly reduced indoor exposures to traffic-derived pollutants.

For example, within a 270-m buffer zone, the regression coefficients indicated decreases of $PM_{2.5}$: −0.068 (95% CI: −0.124, −0.013), NO_2: −0.139, and BC: −0.060. At a 1230-m buffer, the reductions were even more pronounced, underscoring the protective effect of green spatial configuration at multiple scales.

Furthermore, the study *Long-Term Greenness Effects of Urban Forests to Reduce Particulate Matter and Asthma Visits* (Jeong et al., 2025) found that urban blocking forests significantly reduced long-term PM_{10} and $PM_{2.5}$ concentrations and were associated with fewer asthma-related medical visits between 2006 and 2023. This effect was strongest in vulnerable age groups—particularly children (≤11 years) and older adults (≥65 years).

Green space structure and respiratory disease: direct and indirect pathways. The study *Association between Green Space Structure and the Prevalence of Asthma: A Case Study of Toronto* (Dong et al., 2021) examined multiple vegetation types (trees, shrubs, grasslands) and structural attributes (tree diversity, canopy arrangement). The results indicated that higher structural complexity—especially greater tree species diversity—significantly reduced asthma incidence among children and adolescents (0–19 years). In adults, the protective effect was weaker and mainly tied to tree diversity alone.

A systematic review by Mueller and colleagues (2000–2021), which analyzed 108 studies, found that approximately two-thirds reported a positive (protective) association between greenness and respiratory health; however, only 31% of these results reached statistical significance. This emphasizes that the health effects of greenness are context-dependent—shaped by vegetation type, urban morphology, geography, and pollution sources.

Summary Table of Observed Trends

Study / Meta-analysis	**Greenness Metric**	**Main Respiratory Outcome**	**Notes**
Tang 2023 (meta-analysis)	NDVI (+0.1 increase)	↓ Asthma (RR 0.92), ↓ COPD mortality (RR 0.95), ↓ Lung cancer (RR 0.62)	Multi-city, multi-country
Meo et al. 2021	Green vs. non-green zone	↓ $PM_{2.5}$, PM_{10}, CO, O_3	Demonstrates pollution mitigation
Matthaios 2024	NDVI (270–1230 m buffer)	↓ Indoor $PM_{2.5}$, NO_2, BC	Traffic-related exposures in schools
Jeong 2025	Urban blocking forest	↓ PM_{10} / $PM_{2.5}$, ↓ asthma visits	Strong long-term effect
Dong 2021 (Toronto)	Green space structure	↓ Childhood asthma incidence	Tree diversity as key factor

Note: "↓" indicates a decrease; pollutant concentration reductions shown as "$PM_{2.5}$, PM_{10} ... lower."

Discussion

The findings of this study and the reviewed literature indicate that urban greenness is an important—though highly context-dependent—determinant in reducing the burden of respiratory diseases. Meta-analyses and large-scale systematic reviews have generally identified an inverse association between green space coverage and asthma, chronic obstructive pulmonary disease (COPD), and respiratory mortality. For example, an increase of 0.1 in NDVI has been linked to measurable reductions in asthma and other chronic respiratory outcomes. While this confirms an overall protective trend, the magnitude of effect varies substantially across countries, climates, city morphology, and the specific types of green infrastructure present.

From a mechanistic perspective, two primary pathways—physical and social—stand out. The physical pathway includes particulate deposition by vegetation, buffering of emission sources (e.g., "green barriers" between traffic corridors and residential areas), and microclimatic cooling that can reduce secondary pollutant formation. Several monitoring studies, including assessments of indoor environments in schools, show that variations in greenness and distance from roadways are associated with reductions in indoor $PM_{2.5}$, NO_2, and ultrafine toxic particles. These patterns underscore the tangible health benefits for residential and educational settings. At the same time, evidence also shows that under certain aerodynamic conditions—such as strong prevailing winds or narrow street canyons—dense or poorly selected vegetation may trap pollutants. This suggests that hydrodynamic and spatial considerations should be incorporated into vegetation design.

The social-behavioral pathway contributes indirectly to respiratory health through increased physical activity, reduced stress, and enhanced social cohesion. These factors support immune resilience and may improve respiratory outcomes independently of chemical air-quality improvements. For this reason, evaluations of green space effects should integrate behavioral and social variables rather than relying solely on pollutant metrics.

However, discrepancies between empirical findings and the broader literature must not be overlooked. Some studies have reported weak or even reversed associations between greenness and $PM_{2.5}$—for example, in poorly ventilated urban corridors where vegetation obstructs airflow and prevents pollutant dispersion. These findings serve as a caution for urban planners: the type, height, density, and spatial configuration of vegetation must be strategically designed to avoid unintended negative effects.

Methodologically, the main limitations observed in our integrative review stem from the characteristics of the underlying studies. Many existing analyses rely on ecological or cross-sectional designs, limiting causal inference. Additionally, remote sensing indicators such as NDVI may not capture important qualitative features of vegetation—such as canopy height, species diversity, understory structure, and biological activity—that influence pollutant mitigation.

Biological and allergenic factors must also be considered. Green spaces can increase aeroallergen loads and act as triggers for allergic rhinitis or certain forms of asthma. This risk is particularly relevant in areas with high concentrations of allergenic tree species or poorly planned vegetation composition.

In terms of policy and practice, our synthesis suggests that investment in green infrastructure can be an effective urban health strategy, especially when implemented alongside broader interventions such as reducing transportation and industrial emissions. Organizations like WHO and State of Global Air emphasize the severe health risks posed by $PM_{2.5}$; therefore, greening initiatives must be coordinated with cleaner transport systems, improved energy infrastructure, and stricter emission controls. Greenness is not a standalone solution, but it is a cost-effective and multifaceted public health investment.

Practical recommendations include establishing green corridors and blocking forests to mitigate traffic-related pollution; situating schools and child-focused facilities away from major roadways and enhancing vegetation around them; optimizing vegetation design in street canyons to improve airflow; prioritizing low-allergen, native species; and ensuring equitable distribution of green spaces to promote environmental justice. Such strategies not only improve air quality but also support physical activity, mental well-being, and broader community health.

Conclusion

A substantial inverse relationship between green space density and the prevalence of respiratory diseases in large cities has been consistently demonstrated across epidemiological studies, meta-analyses, and multi-city observational or clinical investigations. Urban green spaces support respiratory health not only by reducing concentrations of $PM_{2.5}$, NO_2, and other harmful aerosols, but also by promoting physical activity and psychological well-being. However, the magnitude of these benefits varies depending on vegetation type, city morphology, and transportation load.

1. Increased green space density is consistently associated with reduced respiratory disease burden. A 0.1-unit increase in NDVI is linked to measurable decreases in asthma, chronic obstructive pulmonary disease, and respiratory mortality across diverse urban settings.
2. Vegetation effectively reduces major air pollutants—including $PM_{2.5}$, NO_2, and ultrafine toxic particles—especially when integrated into well-designed “green barriers,” urban forests, and multilayered tree systems that optimize deposition and dispersion processes.
3. The health impact of urban greenness is not universal. It varies significantly by climate conditions, traffic density, street geometry, and vegetation structure. Therefore, greening interventions must be grounded in scientifically informed landscape design frameworks.

4. Expanding urban green infrastructure is a cost-effective public health strategy, most impactful when implemented alongside measures to decarbonize transportation, reduce industrial emissions, and improve urban energy systems.

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