Scilight

Urban and Building Science

https://www.sciltp.com/journals/ubs

Article

Uncovering the Air Quality Benefits of Urban Forests Using UAV Surveys

Lihua Huang [1], Sohail Ahmad [1], Chunping Miao [1,*], Fengxian Chen [2], Leila Mohaghegh [3] and Ali Cheshmehzangi [4]

[1] School of Architecture, Chang'an University, Xi'an 710061, China
[2] Institute of Bio- and Geosciences, IBG-3 Agrosphere, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany
[3] Sharif Energy, Water and Environment Institute (SEWEI), Sharif University of Technology, Tehran 11155-8639, Iran
[4] School of Architecture, Design and Planning, University of Queensland, Brisbane, QLD 4072, Australia
* Correspondence: miaochunping@chd.edu.cn

How To Cite: Huang, L.; Ahmad, S.; Miao, C.; et al. Uncovering the Air Quality Benefits of Urban Forests Using UAV Surveys. *Urban and Building Science* **2025**, *1*(1), 12. https://doi.org/10.53941/ubs.2025.100012

Received: 6 October 2025
Revised: 16 December 2025
Accepted: 19 December 2025
Published: 23 December 2025

Abstract: Urban forests play a critical role in air quality regulation in urban areas. This study aimed to utilize unmanned aerial vehicles to monitor the concentrations of NO_2, O_3 and PM_{10} at multiple heights during the autumn days in 2022 to evaluate the vertical effects of urban forests on air quality in Shenyang, China. Result showed that NO_2 concentrations at 0–1.5 m were 46.99 ± 12.86 μg/m^3 in the streets, which was significantly lower than 51.64 ± 7.33 μg/m^3 in forests at midday. However, there was no significant difference in O_3 and PM_{10} concentrations at 0–1.5 m between in the forests and in the street. NO_2 and O_3 concentrations at 1.5–30 m in the forests were significantly lower at that at 1.5–30 m in the street, while PM_{10} concentrations at 1.5–30 m in the forests were significantly higher at that at 1.5–30 m in the street. The purifying effects of the urban forests on NO_2, O_3 and PM_{10} gradually strengthened from midday to afternoon.

Keywords: urban forests; vertical distribution; air quality

1. Introduction

The rapid expansion of urban areas in recent decades has led to significant deterioration in air quality [1,2]. Key air pollutants include particulate matter with aerodynamic diameters under 10 μm (PM_{10}), nitrogen dioxide (NO_2), and ozone (O_3) [8]. Their elevated concentrations are associated with impaired lung function, aggravated respiratory diseases, thereby posing serious health risks to urban populations [4–6].

Urban forests have been recognized as a main natural-based solution to mitigate air pollution in urban areas [7]. They can change air pollutant concentrations in different ways: (1) Trapping air pollutants: Trees can catch and hold air pollutants like dust and soot on their leaves, branches, and bark, acting as natural air filters [8,9]. (2) Absorbing gases: Trees can absorb and transform in gaseous pollutants like NO_2 and sulfur dioxide (SO_2) through their leaves, using or breaking them down inside their tissues [10,11]. (3) Releasing VOCs: Some trees emit volatile organic compounds (VOCs), which can react with other pollutants to form ozone or fine particles, worsening local air quality [12,13]. (4) Changing airflow: The three-dimensional structure of trees modifies wind flow and microclimatic conditions and influence the dispersion or accumulation of air pollutants in certain areas [14–16]. These combined ways position urban forests as critical components of urban environmental management with the potential to mitigate air pollution when appropriately planned and managed.

The effectiveness of urban forests in reducing air pollution depends on factors such as tree species, canopy density and local environmental conditions [17]. Park trees reduced annual PM_{10} concentrations at the respiration height by about 10% through deposition, with oriental plane trees contributing 9.3% of this reduction [18]. In Summer when tree canopies were full developed, the dense tree cover increased NO_2 concentrations but decreased

$PM_{2.5}$ concentrations in in Rotterdam, the Netherlands [19]. The simulation of aerodynamics and deposition model found that urban trees were most effective at reducing air pollutants with a height of 4–6 m [20].

The influence of urban forests on air pollutant dispersion and deposition was central to their regulatory function, as these processes were inherently linked to the horizonal and vertical distribution of air pollutants [21,22]. However, most previous studies on urban forests and air pollution have focused on ground-level monitoring, which provided limited insight into the vertical and horizontal distribution of pollutants [7]. Recent advancements in unmanned aerial vehicles (UAVs) technology offer new possibilities for high-resolution air quality assessments at different altitudes [23]. UAVs enable the collection of pollutant data across various heights, providing a more comprehensive understanding of how urban forests influence NO_2, O_3 and PM_{10} concentrations [24].

Thus, this study aimed to fill the existing research gap by utilizing UAVs to monitor the concentrations of three key air pollutants: NO_2, O_3 and PM_{10} vertically and horizontally within urban forests. By comparing the air pollutant removal capacity of urban forests at different heights and examining how pollutant concentrations vary horizontally, we further assessed the influence of urban forests on air pollutant dispersion. The findings provide valuable insights into the regulatory role of urban forests in air quality management and enhance our understanding of how forests structure shapes air pollutant dispersion patterns.

2. Methods

2.1. Study Sites

The study was conducted in Shenyang Arboretum, located in the central region of Shenyang, Northeast China (41°48′11.75″ N, 123°25′31.18″ E) (Figure 1). In 2022, the annual average air pollution levels in Shenyang were as follows: PM_{10}: 56 μg/m^3, NO_2: 30 μg/m^3, O_3 (90th percentile, 8-h max average): 145 μg/m^3. During 2022, there were 45 days when the Air Quality Index (AQI) exceeded 100, accounting for 12.3% of the year. Among these polluted days, PM_{10} was the main pollutant on 2.2% of the days. Additionally, NO_2 and O_3 levels were significant contributors to air pollution, with O_3 reaching a 90th percentile concentration of 145 μg/m^3 based on the maximum 8-h sliding average, and NO_2 recording an annual average concentration of 30 μg/m^3.

The arboretum, covering approximately 5 hectares, features flat terrain with deep, fertile soil rich in forest humus and a neutral pH of 7.0. The arboretum is dominated by native northeastern tree species, featuring a mix of deciduous broadleaf taxa (e.g., *Phellodendron amurense*, *Celtis hungana*, *Quercus mongolica*, *Juglans mandshurica*, *Ulmus pumila*) and evergreen conifers such as *Abies holophylla*. The vegetation forms a naturally stratified community consisting of four distinct layers: the tree canopy, shrub layer, herbaceous stratum, and ground cover. Two air pollution monitoring sites were established: one within the urban forest and the other on a nearby street to compare air quality. The street site served as a control to assess the impact of the urban forest on pollution reduction.

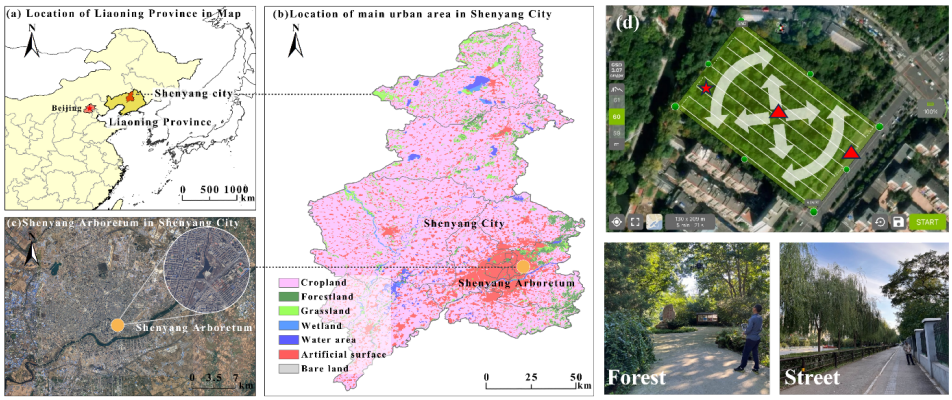

Figure 1. (**a**) Location of Shenyang in China, (**b**,**c**) Location of Shenyang Arboretum in Shenyang, Liaoning Province, (**d**) Triangle: vertical observation sites, Star: fixed observation site, Line: horizontal observation routes

2.2. Data Collection

A Dajiang M100 quadcopter UAV was utilized for conducting both vertical and horizontal air quality assessments. The UAV was fitted with the Sniffer4D V2, a portable air monitoring system designed to measure PM_{10}, O_3 and NO_2 concentrations, along with air temperature, relative humidity, and atmospheric pressure in real time. The UAV has a weight of 2.355 kg and a maximum payload capacity of 3.6 kg. It can ascend at a speed of 5 m/s

and descend at 4 m/s, ensuring high-precision operation, with a vertical hovering accuracy of ±0.5 m and a horizontal accuracy of ±2.5 m.

The Sniffer4D V2 is a lightweight, compact device with dimensions of 158 × 103 × 87.5 mm^3 and a weight of less than 500 g. It employs a miniaturized laser photometer that applies light scattering principles to determine PM_{10} concentrations with a high resolution of 1 $\mu g/m^3$. Additionally, NO_2, O_3 detection is based on electro chemical technology, which generates electrical signals proportional to gas concentrations, achieving a detection resolution of less than 1 ppb.

To ensure the accuracy and reliability of the measurements, the Sniffer4D sensor was calibrated against readings from nearby fixed monitoring stations. The linear regression results demonstrated good agreement with coefficients of determination (R^2) of 0.83 for the PM_{10} sensor and 0.88 for the NO_2 sensor (Figure A1). In addition, four days in the autumn monitoring period were randomly selected for repeated measurements to reduce potential randomness in the dataset and to minimize the influence of background concentration fluctuations on the results. After data acquisition, all datasets were screened for anomalies, and outliers were removed prior to subsequent statistical analyses to enhance the robustness and validity of the final datasets.

The study was conducted during the autumn of 2022 to assess the air purification capabilities of urban forests in autumn. The autumn was chosen because that air pollutant concentrations were typically higher during this season, coupled with meteorological conditions such as temperature inversion and weaker atmospheric circulation, which exacerbated air pollutant accumulation. Four vertical and two horizontal flights were conducted per day, with each flight lasting approximately 20 min [7]. The "first flight" and "second flight" refer to measurements conducted at midday and afternoon, respectively to examine how background air pollutant concentrations influence the air purification of the urban forest. The two flights were analyzed separately to highlight potential differences in air pollutant regulation under varying atmospheric conditions, rather than as repeated measures of the same flight route.

The vertical measurements of air pollutants (PM_{10}, NO_2, and O_3) were taken twice at 2:00 PM and 4:00 PM ranging from 0 to 120 m, while horizontal measurements occurred at 3:00 PM on autumn days (6, 11, 13 and 14 October). The horizontal measurements were conducted over the area spanned 130 m × 209 m, divided into nine parallel routes, each with a length of 209 m [7]. The horizontal flights were included primarily to improve our understanding of lateral air pollutant dispersion patterns across the forested area. In addition, meteorological conditions including wind speed, wind direction, air temperature, relative humidity were recorded before each flight, and measurements were performed only under stable weather conditions to minimize atmospheric variability. To supplement these observations, background air pollutant concentrations and microclimate conditions were recorded from a 20-m-high monitoring tower situated within the forest.

2.3. Data Analysis

This study analyzed the variations in PM_{10}, NO_2 and O_3 concentrations between urban streets and forests at four height ranges: 0–1.5 m, 1.5–30 m, 30–60 m and 60–120 m. To determine whether these differences were statistically significant a *t*-test was performed. Before conducting t-test the data were assessed for normality and homogeneity of variance to ensure the reliability of the results. A *p*-value below 0.05 indicated a significant difference while a *p*-value above 0.05 suggested no significant variation between the two environments. The *t*-tests were conducted in SPSS (version 18.0), and figures were produced using Hiplot.

3. Results

Figure 2 Shows NO_2, O_3 and PM_{10} concentrations at the height of 0–1.5 m, 1.5–30 m, 30–60 m and 60–120 m in the urban streets and forests, as collected by two flights during the clear autumn days and overcast autumn days. During the first flight, NO_2 concentrations at 0–1.5 m were 46.99 ± 12.86 $\mu g/m^3$ in the streets, which was significantly higher than that 51.64 ± 7.33 $\mu g/m^3$ in forests (Table 1). At 1.5–30 m NO_2 concentrations were 46.83 ± 11.42 $\mu g/m^3$ in the streets and 49.61 ± 7.67 $\mu g/m^3$ in forests. At 0–1.5 m and 1.5–30 m NO_2 concentrations in streets were significantly lower than in the forests. However, at 30–60 m and 60–120 m NO_2 concentrations in forests (45.37 ± 8.32 $\mu g/m^3$ and 43.52 ± 6.99 $\mu g/m^3$) were significantly higher than streets (42.98 ± 9.97 $\mu g/m^3$ and 41.55 ± 10.48 $\mu g/m^3$). During the second flight no significant difference was found in NO_2 concentrations at 0–1.5 m between in the streets (60.23 ± 8.42 $\mu g/m^3$) and forests (61.83 ± 5.08 $\mu g/m^3$). At 1.5–30 m NO_2 concentrations were 56.95 ± 9.44 $\mu g/m^3$ in the streets, which was significantly higher than 53.15 ± 10.50 $\mu g/m^3$ in forests. At 30–60 m NO_2 concentrations were 51.19 ± 7.23 $\mu g/m^3$ in the streets, also significantly higher than 49.92 ± 6.20 $\mu g/m^3$ in forests. At 60–120 m NO_2 concentrations were 48.39 ± 5.99 $\mu g/m^3$ in the streets, which was significantly lower than 49.75 ± 5.27 $\mu g/m^3$ in forests.

During the first flight, no significant difference was found in O_3 concentrations at 0–1.5 m between streets (191.99 ± 71.84 μg/m^3) and forests (196.40 ± 57.98 μg/m^3). However, O_3 concentrations at 1.5–30 m, 30–60 m and 60–120 m were 191.05 ± 69.29 μg/m^3, and 197.71 ± 72.16 μg/m^3, and 198.08 ± 71.62 μg/m^3 respectively (Figure 2, Table 1). These values were significantly lower than those in forests, which were 211.36 ± 63.03 μg/m^3 at 1.5–30 m, 210.90 ± 64.42 μg/m^3 at 30–60 m, and 205.42 ± 64.49 μg/m^3 at 60–120 m. During the second flight there was no significant difference was found in O_3 concentrations between the streets and forests (Figure 2).

During the first flight, no significant difference was found in PM_{10} concentrations at 0–1.5 m between streets (68.43 ± 57.19 μg/m^3) and forests (64.49 ± 47.08 μg/m^3). However, PM_{10} concentrations at 1.5–30 m in streets (61.60 ± 53.08 μg/m^3) were significantly lower than forests (72.03 ± 53.03 μg/m^3). But there was no significant difference was found at 30–60 m and 60–120 m between in streets and forests as shown in Figure 2. During the second flight there was no significant difference in PM_{10} concentrations at 0–1.5 m, 1.5–30 m, 30–60 m, and 60–120 m between the streets 48.63 ± 47.13 μg/m^3, 61.44 ± 51.08 μg/m^3, 65.17 ± 53.87 μg/m^3 and 67.00 ± 52.72 μg/m^3 and forests 47.62 ± 51.61 μg/m^3, 66.28 ± 49.43 μg/m^3, 67.57 ± 52.61 μg/m^3 and 65.01 ± 53.36 μg/m^3 respectively (Figure 2).

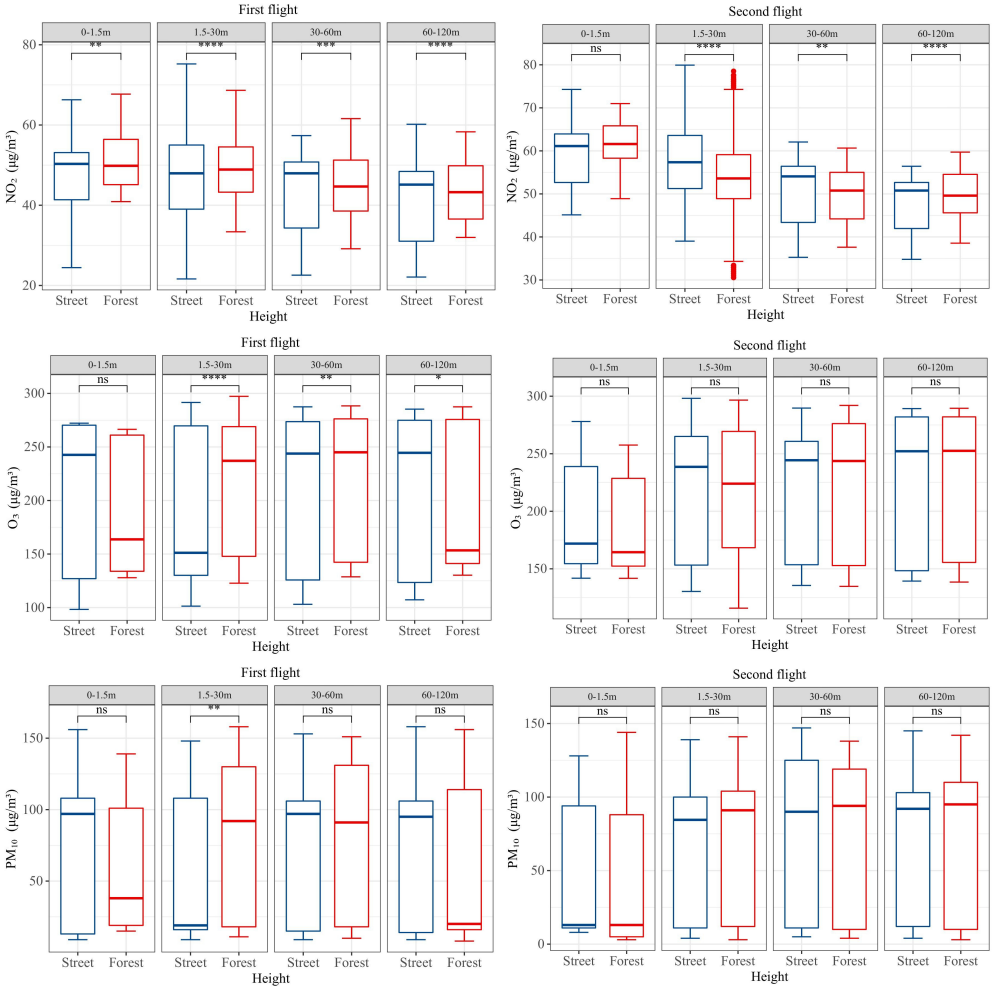

Figure 2. Comparison of NO_2, O_3 and PM_{10} concentrations between street and forests at 0–1.5 m, 1.5–30 m, 30–60 m, and 60–120 m, respectively. ns indicates no significant differences, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$

Table 1. NO_2, O_3 and PM_{10} concentrations in street and forests at 0–1.5 m, 1.5–30 m, 30–60 m, and 60–120 m, respectively.

Pollutants	Sampling Height (m)	First Flight		Second Flight	
		Street	Forest	Street	Forest
NO_2	0–1.5	46.99 ± 12.86	51.64 ± 7.33	60.23 ± 8.42	61.83 ± 5.08
	1.5–30	46.83 ± 11.42	49.61 ± 7.67	56.95 ± 9.44	53.15 ± 10.50
	30–60	42.98 ± 9.97	45.37 ± 8.32	51.19 ± 7.23	49.92 ± 6.20
	60–120	41.55 ± 10.48	43.52 ± 6.99	48.39 ± 5.99	49.75 ± 5.27

Table 1. *Cont.*

Pollutants	Sampling Height (m)	First Flight		Second Flight	
		Street	Forest	Street	Forest
O_3	0–1.5	191.99 ± 71.84	196.40 ± 57.98	199.41 ± 50.26	190.16 ± 43.33
	1.5–30	191.05 ± 69.29	211.36 ± 63.03	212.18 ± 58.40	216.45 ± 60.35
	30–60	197.71 ± 72.16	210.90 ± 64.42	212.22 ± 58.59	216.29 ± 60.54
	60–120	198.08 ± 71.62	205.42 ± 64.49	217.85 ± 60.62	216.77 ± 59.37
PM_{10}	0–1.5	68.43 ± 57.19	64.49 ± 47.08	48.63 ± 47.13	47.62 ± 51.61
	1.5–30	61.60 ± 53.08	72.03 ± 53.03	61.44 ± 51.08	66.28 ± 49.43
	30–60	68.48 ± 57.13	71.56 ± 52.86	65.17 ± 53.87	67.57 ± 52.61
	60–120	69.00 ± 54.82	68.88 ± 56.01	67.00 ± 52.72	65.01 ± 53.36

Figure 3 shows the horizontal distribution of PM_{10}, NO_2, and O_3 at heights of 30 m and 60 m, respectively. Generally, the concentrations of NO_2, O_3 at 30 m were relatively lower compared to at 60 m. Conversely, PM_{10} concentrations at 30 m were relatively higher than at 60 m. The horizontal distribution of PM_{10}, NO_2, and O_3 at 30 m and 60 m showed generally homogeneous patterns, with a few localized hotspots or low-concentration pockets appearing along the flight routes. Figure 4 presents wind rose plots illustrating wind direction and wind speed on autumn days in urban forests. In this study, wind direction was categorized into 16 directions: N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, and NNW. Among them, the wind direction with the highest frequency is NNE, followed by N.

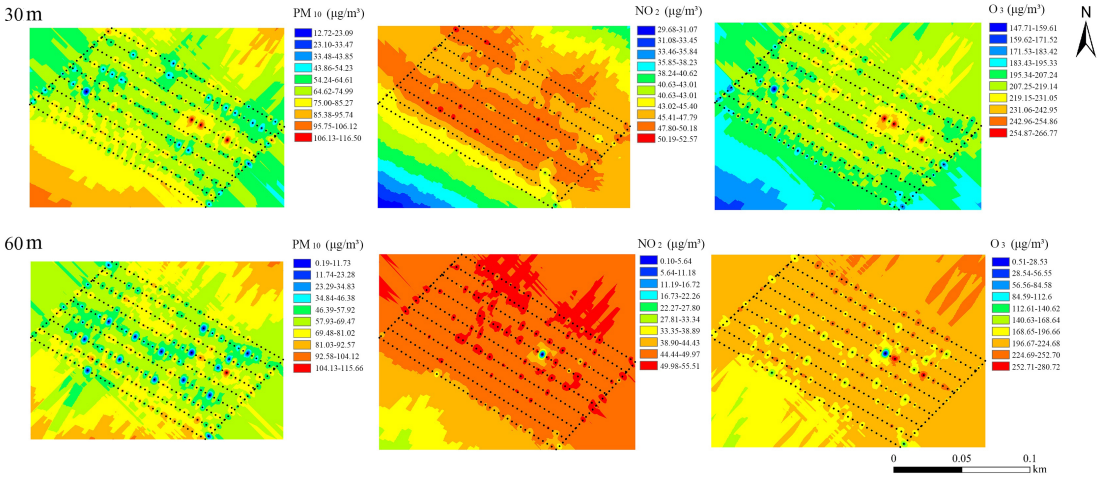

Figure 3. Horizonal distribution of PM_{10}, NO_2, and O_3 at 30 m and 60 m, respectively.

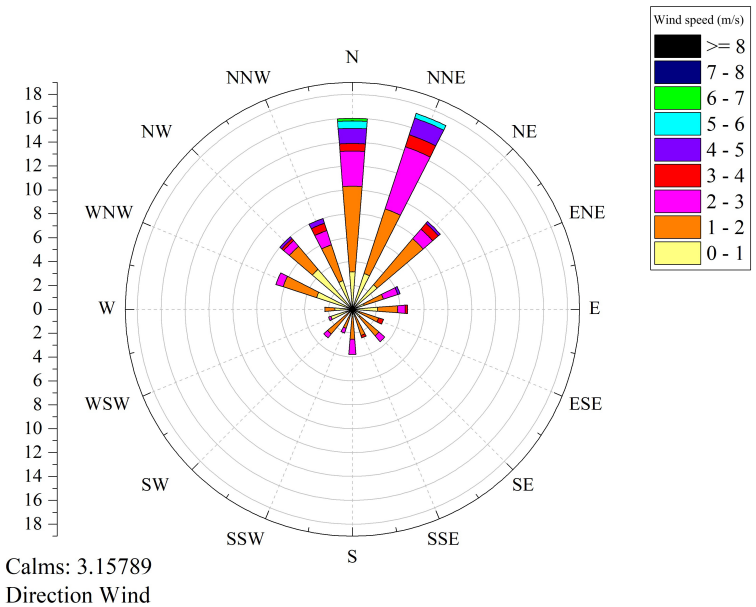

Figure 4. Wind rose chat showing wind direction frequencies and speed distribution.

4. Discussion

Previous researches have demonstrated the positive influence of urban forests for cities. Urban green spaces including forests, meadows, parks, and grassy lawns were commonly associated with improvements in air quality, mitigation of the urban heat island effect, increased biodiversity, carbon sequestration, and noise reduction, all of which enhance urban life and well-being [25]. Similarly, Previous researches effectively demonstrated the use of UAVs to capture both vertical and horizontal variations in air pollutant concentrations, offering a comprehensive understanding of the impact of urban forests on air quality [7]. Although this study also investigated the vertical variation of pollutant concentrations within urban forests, we focus on the major air pollutants (NO_2, O_3 and PM_{10}) identified by the World Health Organization in 2024, whereas primarily examined $PM_{2.5}$ and SO_2.

In this study, we compared the differences of air pollutant (NO_2, O_3 and PM_{10}) concentrations between forests and streets at different height levels to make up for the deficiencies of previous research. The results indicated that NO_2 concentrations at 0–1.5 m, 1.5–30 m, 30–60 m,60–120 m in forests were higher than streets during the first flight (Figure 2). The reason was the forest canopy might trap NO_2, resulting in a negative effect on NO_2 concentrations in forests at low height [26]. At midday, the stronger solar radiation and higher NO emissions in streets accelerated NO_2 photolysis and the NO-NO_2-O_3 cycling, promoted rapid oxidation of NO to NO_2, leading to lower NO_2 concentrations in streets than in the shaded forest canopy, where photolysis rates were weaker [27]. And at higher height ranges, air movement was generally stronger, allowing pollutants to easily diffuse from lower to upper layers. Therefore, the NO_2 concentration in streets might be influenced by urban structure and the urban heat island effect, causing higher NO_2 concentrations to rise to these heights. In contrast, the effect of the forest canopy diminished, resulting in slightly higher NO_2 concentrations in the forest [28].

In the afternoon, NO_2 concentrations at 1.5–30 m, 30–60 m in forests were slightly lower than streets, but higher in forests than streets at 60–120 m (Figure 2). Similar results were found in O_3 concentrations. The purifying effect of the urban forest canopy on NO_2 and O_3 gradually strengthened from midday to afternoon [29]. During the afternoon, as boundary-layer height increases and canopy turbulence was enhanced, ventilation improves and the forest canopy begins to function more effectively as a reactive and deposition surface. Consequently, NO_2 concentrations in forests became lower than those in street environments at 1.5–60 m, indicating strengthened air pollutant removal. The slightly higher NO_2 levels observed at 60–120 m above forests might reflect the upward transport of canopy-processed air and the interaction with regionally transported background NO_2, rather than local emissions [15,30,31].

In the afternoon, PM_{10} concentrations at 1.5–30 m were lower in the street than in the forest. At midday, PM_{10} concentrations at 1.5–30 m were higher inside the urban forest than in the surrounding street areas, indicating a pronounced particle-trapping effect of the canopy [32]. This pattern was consistent with the reduced wind speed and enhanced surface roughness inside forests, which limited particle dispersion and promoted the retention of coarse particles within the lower canopy layer. However, during the afternoon, PM_{10} concentrations showed no significant differences between forests and street environments across all vertical levels. The weakening of the trapping effect in the afternoon might be attributed to increased atmospheric turbulence and a higher boundary-layer height, which enhanced vertical mixing and facilitated the dispersion of particles previously accumulated within the canopy [33,34].

The horizontal distribution at 30 m and 60 m showed that the concentrations of NO_2 and O_3 at 30 m were lower than those at 60 m, while the concentrations of PM_{10} at 30 m were higher than those at 60 m (Figure 3). This difference indicated that the mechanisms of pollutant dispersion and deposition in urban forests are complex and varied with altitude and environmental conditions [35]. Horizontally, air pollutant concentrations exhibited relatively homogeneous distributions at both heights, aside from a few localized hot and cold spots. Wind directions during the autumn sampling days were predominantly from the NNE and N, with relatively stable patterns and limited directional shifts (Figure 4). This prevailing wind regime indicates that both the street and forest sampling sites were exposed to similar upwind conditions during the UAV measurements. Such consistency helps minimize potential wind-induced biases when comparing pollutant concentrations between forests and streets.

In addition, the prevailing N and NNE observed during the sampling period were generally aligned with the street orientation (Figures 1 and 4). This alignment implied that air pollutants generated by traffic within the street canyon were largely transported along the street axis rather than toward the adjacent urban forest. Limited street-derived pollutants were advected into the forested area under these wind conditions, and the forest exhibited stronger air pollutant removal capacity in the afternoon compared with midday. During the afternoon, the combined effects of increased boundary-layer height, enhanced canopy turbulence, and minimal horizontal pollutant transport from streets allowed the forest canopy to function more effectively as a depositional and reactive surface [7,18,20].

This study highlights the value of examining the combined regulatory effects of urban forests on air pollutants across multiple heights, which remains underrepresented in current research. Based on the results, we recommend that urban forests be strategically planned in locations parallel to the prevailing wind direction, particularly where street orientations are aligned with dominant winds. Moreover, we suggest that residents prioritize afternoon periods for recreational activities within urban forests to reduce exposure to elevated air pollutant concentrations typically observed during midday. However, several limitations should be acknowledged. Firstly, the study focused primarily on air pollutant concentration patterns but did not fully incorporate the dynamic micro-environmental conditions such as air temperature, relative humidity and wind speed that could affect air pollutant concentrations. Secondly, the vertical patterns observed might vary with tree species composition, canopy density, and structural heterogeneity, which were not explicitly compared.

5. Conclusions

Studying the vertical and horizontal effects of urban forests on pollutant concentrations provides important insights for optimizing their role in mitigating urban air pollution and improving the urban microclimate. In this study, UAV-based field measurements equipped with the portable Sniffer4D V2 system were conducted during autumn to characterize pollutant patterns across multiple heights and environments. At 0–1.5 m at midday, NO_2 and O_3 concentrations in forests (46.99 ± 12.86 μg/m^3 and 196.40 ± 57.98 μg/m^3, respectively) were significantly higher than those measured along streets. By contrast, during the afternoon, NO_2 and O_3 concentrations at the same height were significantly lower inside forests than in streets, indicating that the air pollutant removal capacity of urban forests strengthened from midday to afternoon. Additionally, PM_{10} concentrations at 1.5–30 m were significantly higher in forests than in streets at midday, whereas no significant differences were detected between the two environments in the afternoon. These results collectively demonstrated the dynamic, time-dependent, and height-specific regulatory effects of urban forests on air pollutants, underscoring the need to incorporate vertical processes into urban air-quality planning and urban forest design.

Author Contributions

L.H.: visualization, writing—original draft preparation; S.A.: writing—original draft preparation; C.M.: conceptualization, data curation, methodology, software, writing—reviewing and editing; F.C.: writing—reviewing and editing; L.M.: writing—reviewing and editing; A.C.: writing—reviewing and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data will be available on request

Conflicts of Interest

Given the role as Editorial Board Member, Chunping Miao had no involvement in the peer review of this paper and had no access to information regarding its peer-review process. Full responsibility for the editorial process of this paper was delegated to another editor of the journal.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the author used ChatGPT3.5 to polish language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Appendix A

Figure of linear regression of PM_{10} and NO_2 concentrations between acquired from Sniffer4D and tower (See Figure A1).

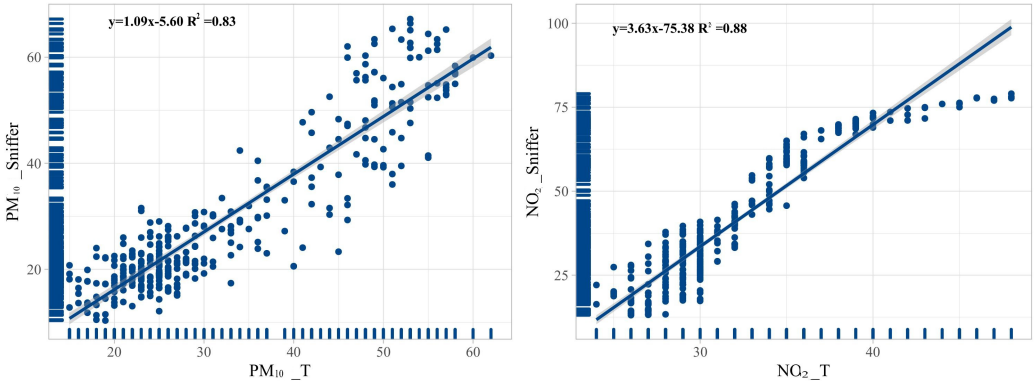

Figure A1. linear regression of PM_{10} and NO_2 concentrations between acquired from Sniffer4D and tower.

References

1. WHO. *Air Pollution and its Impact on Public Health*; World Health Organization Report; WHO: Geneva, Switzerland, 2021.
2. Wania, A.; Bruse, M.; Blond, N.; et al. Analysing the influence of different street vegetation on traffic-induced particle dispersion using microscale simulations. *J. Environ. Manag.* **2012**, *94*, 91–101.
3. WHO. *Ambient (Outdoor) Air Pollution*; World Health Organization Report; WHO: Geneva, Switzerland, 2024.
4. Du, Z.; Li, H.; Chen, S.; et al. Advancements in machine learning for spatiotemporal urban on-road traffic-air quality study: A review. *Atmos. Environ.* **2025**, *346*, 121054.
5. Hsu, H.-C.; Tarekegn, G.B.; Getnet, M.E.; et al. UAV-Based real-time air quality monitoring and prediction using machine learning approach. IEEE Internet Things J. 2025, 12, 27915–27928.
6. Huang, X. The impact of PM_{10} and other airborne particulate matter on the cardiopulmonary and respiratory systems of sports personnel under atmospheric exposure. Atmosphere 2023, 14, 1697.
7. Miao, C.; Hu, T.; Liu, Y.; et al. Interpreting the relationship between urban forests and air quality: Horizontal and vertical investigations utilizing unmanned aerial vehicles. *Urban Clim.* **2025**, *61*, 102394.
8. Zhang, X.; Huang, T.; Zhang, L.; et al. Trends of deposition fluxes and loadings of sulfur dioxide and nitrogen oxides in the artificial Three Northern Regions Shelter Forest across northern China. *Environ. Pollut.* **2015**, *207*, 238–247.
9. Wang, C.; Ren, Z.; Dong, Y.; et al. Efficient cooling of cities at global scale using urban green space to mitigate urban heat island effects in different climatic regions. *Urban For. Urban Green.* **2022**, *74*, 127635.
10. Gong, C.; Xian, C.; Wu, T.; et al. Role of urban vegetation in air phytoremediation: Differences between scientific research and environmental management perspectives. *NPJ Urban Sustain.* **2023**, *3*, 24.
11. Gong, C.; Xian, C.; Cui, B.; et al. Estimating NO_x removal capacity of urban trees using stable isotope method: A case study of Beijing. China. *Environ. Pollut.* **2021**, *290*, 118004.
12. Ren, F.; Qiu, Z.; Liu, Z.; et al. Trees help reduce street-side air pollution: A focus on cyclist and pedestrian exposure risk. *Build. Environ.* **2023**, *229*, 109923.
13. Ahn, J.W.; Dinh, T.-V.; Park, S.-Y.; et al. Characteristics of biogenic volatile organic compounds emitted from major species of street trees and urban forests. *Atmos. Pollut. Res.* **2022**, *13*, 101470.
14. Vranckx, S.; Vos, P.; Maiheu, B.; et al. Impact of trees on pollutant dispersion in street canyons: A numerical study of the annual average effects in Antwerp. Belgium. *Sci. Total Environ.* **2015**, *532*, 474–483.
15. Xing, Y.; Brimblecombe, P. Dispersion of traffic derived air pollutants into urban parks. *Sci. Total Environ.* **2018**, *622*, 576–583.
16. Miao, C.P.; Cui, A.; Xiong, Z.; et al. Vertical evaluation of air quality improvement by urban forest using unmanned aerial vehicles. *Front. Ecol. Evol.* **2022**, *10*, 1045937.
17. Mircea, M.; Borge, R.; Finardi, S.; et al. The role of vegetation on urban atmosphere of three European cities. Part 2: Evaluation of vegetation impact on air pollutant concentrations and depositions. *Forests* **2023**, *14*, 1255.
18. Moftakhar Juybari, M.; Heshmatol Vaezin, S.M.; Moeinaddini, M.; et al. Effectiveness of urban parks in reducing ambient PM_{10} through deposition and dispersion: Towards greener cities. *Environ. Dev. Sustain.* **2025**. https://doi.org/10.1007/s10668-025-06072-z.

19. Fry, J.; Ooms, P.; Maarten Krol, M.; et al. Effect of street trees on local air pollutant concentrations (NO_2, BC, UFP, $PM_{2.5}$) in Rotterdam, the Netherlands. *Environ. Sci. Atmos.* **2025**, *5*, 394.
20. Hashad, K.; Yang, B.; Gallagher, J.; et al. Impact of roadside conifers vegetation growth on air pollution mitigation. *Landsc. Urban Plan.* **2023**, *229*, 104594.
21. Liu, C.; Huang, J.; Hu, X.; et al. Evaluation of WRF-Chem simulations on vertical profiles of $PM_{2.5}$ with UAV observations during a haze pollution event. *Atmos. Environ.* **2021**, *252*, 118332.
22. Yao, J.; Wu, S.; Cao, Y.; et al. Dry deposition effect of urban green spaces on ambient particulate matter pollution in China. *Sci. Total Environ.* **2023**, *900*, 165830.
23. Villa, T.F.; Gonzalez, F.; Miljievic, B.; et al. An overview of small unmanned aerial vehicles for air quality measurements: Present applications and future prospectives. *Sensors* **2016**, *16*, 1072.
24. Roostaei, V.; Gharibzadeh, F.; Shamsipour, M.; et al. Vertical distribution of ambient air pollutants ($PM_{2.5}$, PM_{10}, NO_x, and NO_2); A systematic review. *Heliyon* **2024**, *10*, 39726.
25. Moura, B.B.; Nissim, W.G.; Manzini, J.; et al. The role of urban forests in tackling air and soil pollution in Italian cities. *Urban For. Urban Green.* **2025**, *113*, 129066.
26. Bortolazzi, A.; Ros, L.D.; Rodeghiero, M.; et al. The canopy layer, a biogeochemical actor in the forest N-cycle. *Sci. Total Environ.* **2021**, *776*, 146024.
27. Guan, J.; Solomon, S.; Madronich, S.; et al. Inferring the photolysis rate of NO_2 in the stratosphere based on satellite observations. *Atmos. Chem. Phys*. **2023**, *23*, 10413–10422.
28. Vuilleumier, L.; Bamer, J.T.; Harley, R.A.; et al. Evaluation of nitrogen dioxide photolysis rates in an urban area using data from the 1997 Southern California Ozone Study. *Atmos. Environ.* **2001**, *35*, 6525–6537.
29. Grundström, M.; Pleijel, H. Limited effect of urban tree vegetation on NO_2 and O_3 concentrations near a traffic route. *Environ. Pollut.* **2014**, *189*, 73–76.
30. Ren, Y.; Qu, Z.; Du, Y.; et al. Air quality and health effects of biogenic volatile organic compounds emissions from urban green spaces and the mitigation strategies. *Environ. Pollut.* **2017**, *230*, 849–861.
31. Wang, R.; Xu, S.; Ping, Q.; et al. Differential responses of tree species to elevated ozone and increasing air temperature: Implications for foliar functional traits, carbon sequestration, and their relationship under mixed planting. *Forests* **2024**, *15*, 2183.
32. Huang, Y.; Cai, Y.; Jiao, J.; et al. The impact of meteorological factors and canopy structure on PM2.5 dynamics under different urban functional zones in a subtropical city. Forests 2025, 16, 479.
33. Yang, Y.; Xu, Y.; Duan, Y.; et al. How can trees protect us from air pollution and urban heat? Associations and pathways at the neighborhood scale. *Landsc. Urban Plan.* **2023**, *236*, 104779.
34. Li, Y.H.; Halik, Ü.; Abudumutailifu, M.; et al. Effects of leaf microstructure characteristics of urban trees on atmospheric particulates retention capacity. *Acta Ecol. Sin.* **2022**, *42*, 2228–2236.
35. Lindén, J.; Gustafsson, M.; Uddling, J.; et al. Air pollution removal through deposition on urban vegetation: The importance of vegetation characteristics. *Urban For. Urban Green.* **2023**, *81*, 127843.