

“The Role of Green Roofs in Urban Air Filtration”

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Abstract: This study examines the role of green roofs in urban air filtration, specifically their ability to mitigate airborne pollutants in Lagos, Nigeria. As urban air quality continues to decline due to rapid development, traffic congestion, and industrial emissions, nature-based solutions such as green roofs have gained attention for their environmental benefits. The research employs a quantitative approach, using structured closed-ended questionnaires administered to 196 ecological experts, architects, urban planners, and sustainability professionals. Cochran’s formula for an infinite population was used to determine the sample size, ensuring statistical significance at a 7% margin of error. Data were analyzed using advanced SPSS techniques, including descriptive statistics and inferential testing, aligned with three primary objectives: evaluating pollutant reduction, assessing the impact of plant diversity and roof design on filtration efficiency, and exploring the integration of green roofs into urban sustainability strategies. The findings show moderate agreement on the effectiveness of green roofs in reducing particulate matter and gaseous pollutants, with more substantial support for their role within broader environmental policy frameworks. The study concludes that while green roofs hold considerable promise for urban air management, their implementation in Lagos requires targeted policies, design standards, professional training, and public engagement to realize their potential fully.

Keywords: Green roofs, Urban air pollution, Sustainability, Nature-based solutions, Lagos

I. Background of Study

In the face of intensifying urbanisation and escalating concerns over deteriorating air quality, cities around the world are urgently seeking sustainable and integrative solutions to environmental challenges. Among the strategies gaining traction is the use of green roofs, which offer more than aesthetic enhancement; they represent a powerful intersection between architecture, ecology, and public health. As densely populated cities grapple with emissions from transportation, industry, and construction, the potential of green roofs to act as passive air filtration systems is being increasingly acknowledged. These living systems have demonstrated the ability to capture airborne particulate matter, reduce urban heat island effects, and enhance atmospheric conditions, making them a compelling response to air quality degradation in urban environments (Gładysz et al., 2025; French et al., 2021).

Green roofs are far from a novel concept, but their role in mitigating air pollution is receiving renewed attention through contemporary scientific inquiry and urban policy shifts. Research highlights that green roofs can significantly reduce concentrations of nitrogen dioxide, ozone, and particulate matter pollutants commonly linked to respiratory diseases and broader ecological harm (Viecco et al., 2021; González-Méndez & Chávez-García, 2021). The vegetative layers not only trap these particles on leaf surfaces but also facilitate absorption through plant stomata, a natural filtration process that contributes to cleaner urban air (Venter et al., 2024). Furthermore, the type and biodiversity of plant species selected have a substantial influence on filtration efficiency, with dense foliage and rough leaf textures proving particularly effective (Ciacci et al., 2023).

At the heart of this growing interest is a broader recognition of nature-based systems (NbS) as viable tools for urban sustainability. Green roofs exemplify this shift, blending ecological restoration with engineered infrastructure to deliver multifunctional benefits ranging from carbon sequestration and thermal insulation to stormwater management and, crucially, air purification (Biswal et al., 2022; Luo et al., 2020). Cities like Shanghai and Milan have demonstrated measurable improvements in ambient air quality following the widespread implementation of green roofing strategies, underscoring their practical value (Zheng & Chen, 2023; Menounou et al., 2023). Moreover, advancements in modeling and empirical tools, such as the UFORE model, have enabled more accurate estimations of pollutant removal capacities, further cementing the scientific legitimacy of this approach (Currie, 2021). It is also evident that the benefits of green roofs extend beyond individual buildings. Their cumulative effect across an urban fabric has the potential to transform city-wide air quality and microclimatic conditions (Schrieke et al., 2023). In street canyons, narrow corridors where air circulation is often stagnant, green infrastructure has been shown to significantly lower pollutant concentrations, thereby improving public health outcomes and environmental equity (French et al., 2021). These contributions are particularly vital in industrial zones or highly trafficked areas where pollution loads are heaviest (Ciacci et al., 2023). As environmental degradation continues to challenge urban resilience, green roofs stand out not only as mitigation tools but also as adaptive mechanisms for a livable future. Their integration into building design reflects an evolving architectural ethos, one that prioritises ecological intelligence and human well-being. In light of mounting evidence and cross-disciplinary consensus, the role of green roofs in urban air filtration is no longer speculative but essential. They offer a pathway to cleaner skies, healthier lungs, and more sustainable cities (Barriuso & Urbano, 2021; Shehzad et al., 2023; Meza & Andrea, 2020).

Aim & Objective

The study aims to evaluate the effectiveness of green roofs in improving urban air quality by examining their capacity to filter airborne pollutants and contribute to healthier urban environments.

The objectives of the Study are to:

1. To assess the extent to which green roofs reduce airborne particulate matter (PM) and gaseous pollutants in urban areas.
2. To analyse the influence of plant species diversity and roof design on the air filtration efficiency of green roofs.
3. To explore the potential of integrating green roof systems as part of broader urban air quality management and sustainability strategies.

II. Literature Review

The increasing intensity of urbanization has significantly altered atmospheric conditions in cities, contributing to deteriorating air quality due to elevated levels of airborne pollutants. Within this context, green roofs have emerged as a vital nature-based solution, offering multifaceted environmental benefits, including air filtration. Their role in mitigating urban air pollution has attracted scholarly interest, with a growing body of research confirming their capacity to remove airborne contaminants, improve microclimatic conditions, and contribute to overall urban sustainability. Green roofs function as biological filters. Their vegetation layers capture particulate matter (PM) from the air through a combination of mechanical interception, adhesion to plant surfaces, and absorption via stomatal uptake. Studies have shown that the selection of plant species and the structural design of the green roof greatly influence this filtration capacity. Gładysz et al. (2025) conducted empirical research at the University Library of Warsaw. They found that particular plant species on green roofs were particularly effective at trapping PM₁₀ and PM_{2.5}, the most harmful types of air pollutants. These pollutants are commonly generated by vehicular emissions, industrial activities, and construction, and their presence in the urban atmosphere poses serious respiratory and cardiovascular health risks.

The capacity of green roofs to improve air quality is not merely a function of the vegetation used but also hinges on the integration of biodiversity into the system. Viecco et al. (2021) emphasize that increased plant diversity enhances the roof's ability to capture delicate particulate matter, particularly when layers of different textures and leaf morphologies coexist. This reinforces the understanding that biodiversity is not just a hallmark of ecological resilience but also a key factor in optimizing environmental performance. Air quality improvements linked to green roofs also have strong spatial dimensions. In dense urban configurations, such as street canyons, pollution tends to become trapped between buildings. In such microenvironments, French et al. (2021) argue that green infrastructure, primarily characterized by vertically distributed systems such as green walls and roofs, can effectively interrupt pollutant circulation patterns. Their findings suggest that vegetation helps redirect airflow and dilute pollutants, providing a practical solution in settings where traditional pollution control methods are ineffective. Supporting this, Barriuso and Urbano (2021) provide a broader view of how green roofs and walls, when systematically incorporated into urban design, can contribute to climate change mitigation by reducing greenhouse gas emissions while also filtering air pollutants. Their review of global applications demonstrates that these systems are not only practical but also adaptable across various climatic zones, thereby reinforcing their relevance in both temperate and tropical urban contexts.

The effectiveness of green roofs in air filtration also ties into the larger discussion on ecosystem services. Menounou et al. (2023) frame green roofs as a cornerstone in the suite of nature-based solutions being deployed to address urban environmental degradation. These systems deliver ecosystem services, including carbon sequestration, thermal insulation, stormwater control, and, critically, air purification. In their work, green roofs are recognized as dynamic, living systems that provide active and passive filtration mechanisms, a sentiment echoed by Shehzad et al. (2023), who highlight their increasing importance in urban sustainability strategies. Moreover, green roofs influence atmospheric conditions in subtle but powerful ways. Luo et al. (2020) explore the potential of rooftop vegetation in carbon sequestration, identifying that it acts as a carbon sink while simultaneously filtering pollutants. The dual function of pollutant removal and greenhouse gas absorption underscores the comprehensive nature of green roof technology. In line with this, Currie (2021) employed the UFORE model to estimate the pollution mitigation potential of green roofs, quantifying significant reductions in nitrogen dioxide and sulphur dioxide levels, particularly in areas with high installation density.

Modelling and simulation studies continue to shed light on the scalability and predictive outcomes of green roof applications. Zheng and Chen (2023), focusing on Shanghai's urban fabric, demonstrated that widespread implementation of green roofs could yield substantial reductions in airborne pollutants, including ozone and volatile organic compounds. Their model not only predicted cleaner air but also suggested energy savings, reinforcing the interconnected nature of environmental systems in urban settings. While the direct impact of green roofs on air quality is well established, their indirect benefits also merit attention. Ciacci et al. (2023) investigate how these systems contribute to cooling urban microclimates, thereby reducing the photochemical formation of secondary air pollutants. Cooler surfaces and lower ambient temperatures limit the formation of ground-level ozone, a toxic component of urban smog. Their case study in an Italian industrial district demonstrated that vegetated roofs reduced surrounding temperatures by several degrees, supporting broader air quality improvements. A crucial aspect of this discourse involves the intersection between green roofs and public health. González-Méndez and Chávez-García (2021) highlight the role of foliar surfaces in capturing heavy metals and other toxins, which, if left airborne, can lead to long-term health problems. The foliage essentially acts as a biological sponge, absorbing harmful pollutants and preventing them from circulating in the atmosphere or depositing onto pedestrian surfaces. Their analysis further underscores the importance of maintaining these vegetative layers through regular care to ensure sustained filtration effectiveness.

In a comprehensive review of nature-based systems, Biswal et al. (2022) emphasize that green roofs should be integrated into broader urban ecological frameworks, which include permeable pavements, green corridors, and water-sensitive urban design. Their paper outlines how these systems, when networked together, provide cumulative and synergistic effects on air and water quality. By treating green roofs as a single node in an interconnected ecological web, cities can maximize the benefits of this infrastructure. However, it is essential to acknowledge that not all vegetation is equally effective in air filtration, and spontaneous or unmanaged growth may compromise its performance. Schrieke et al. (2023) caution that while spontaneous vegetation can aid stormwater mitigation, its filtration capabilities for air pollutants vary greatly. Their findings suggest a need for deliberate plant selection and maintenance to ensure long-term efficacy. The relationship between urban greening and air quality is being continually reassessed, especially in light of emerging pollution data and advancements in environmental monitoring tools. Venter et al. (2024) argue that while green spaces undoubtedly provide air purification benefits, their performance should be contextually evaluated, taking into account local meteorology, urban morphology, and pollutant sources—their work advocates for a more nuanced and evidence-based deployment of green infrastructure in urban planning.

Meza and Andrea (2020) also offer valuable insights from Latin America, suggesting that urban vegetation strategies, including rooftop greening, must be tailored to regional air quality profiles and socioeconomic conditions. Their findings support the idea that the implementation of green roofs must go hand-in-hand with community engagement and policy support to ensure both environmental and social outcomes are achieved. Overall, the literature paints a compelling picture of green roofs as an indispensable tool in the urban air filtration arsenal. They not only capture and neutralize harmful pollutants but also contribute to broader ecological, climatic, and public health improvements. Their value lies not merely in their aesthetic or thermal contributions, but in their active participation in creating breathable and sustainable cities. As urban areas continue to grapple with escalating air quality challenges, green roofs represent a living, adaptive, and scientifically grounded solution poised to play an increasingly central role in the future of city planning.

Study Area

The study was conducted in Lagos, Nigeria, a rapidly urbanizing megacity recognized as one of the most densely populated urban centres in Africa. With a population exceeding 20 million residents and a constant influx of migrants, Lagos exemplifies many of the environmental challenges associated with urban growth, including severe air pollution, inadequate green infrastructure, and diminishing urban vegetation. The city's tropical climate, high vehicular traffic density, and industrial activity significantly contribute to poor air quality. These conditions make Lagos an ideal setting for investigating the role of green roofs in urban air filtration. Given the urgent need for sustainable interventions in the urban fabric, the city provides a critical context for exploring how nature-based solutions, particularly green roofing systems, can be strategically deployed to improve air quality and promote environmental resilience.

Study Population and Size

The study targeted professionals in Lagos, such as environmental experts, urban planners, architects, and sustainability officers, due to their expertise in green infrastructure and urban development. Since the total population size is unknown, Cochran's formula for infinite populations was used to determine a statistically valid sample size. Using a 95% confidence level and a 0.07 margin of error, the sample size was calculated to be approximately 196 respondents.

Data Collection Methods

Data were gathered using structured, closed-ended questionnaires specifically designed to elicit expert opinions and insights on the effectiveness, implementation, and challenges of green roof technology in filtering urban air pollutants in Lagos. The questionnaire was divided into thematic sections, covering the respondents' professional background, familiarity with green infrastructure, perceived environmental benefits of green roofs, and their potential role in improving air quality in the Lagos context. The use of closed-ended questions enabled standardized responses, facilitating efficient data coding and statistical analysis. To ensure content validity, the instrument was reviewed by professionals in urban sustainability and environmental health before distribution.

Data Analysis

The collected data were analyzed using advanced statistical techniques, aided by software such as SPSS. Descriptive statistics, including frequencies, percentages, and means, were used to summarize the demographic characteristics and general response trends. Inferential statistics, such as multiple regression analysis, were conducted to examine the relationship between the perceived effectiveness of green roofs and their role in improving air quality. Factor analysis was employed to identify the underlying variables or dimensions that influence expert opinions. At the same time, ANOVA (Analysis of Variance) was used to determine whether significant differences existed between subgroups of professionals based on their field or level of experience. The combination of descriptive and inferential techniques allowed for a robust interpretation of the findings and supported evidence-based conclusions regarding the potential of green roofs as a sustainable air filtration strategy in Lagos.

III. Results and Discussion

This section presents the findings from a survey of experts in Lagos regarding the role of green roofs in urban air filtration. The results are presented in two parts: the demographic profile of respondents and the analysis based on the research objectives. The

analysis includes frequency distributions and descriptive statistics, utilizing SPSS-style outputs to provide insight into patterns and trends within the data.

Demographic Profile of Respondents

The gender composition shows a higher proportion of male respondents (122; 62.2%) compared to female respondents (74; 37.8%), indicating a male-dominated expert community within the urban sustainability and planning sectors in Lagos.

Table 3.1: Gender Distribution of Respondents

Gender	Frequency	Percent
Male	122	62.2%
Female	74	37.8%
Total	196	100.0%

The age distribution suggests a predominantly mature workforce, with 29.1% of respondents aged 55 and above, and 25.5% within the 45–54 age range. This supports the assumption that senior professionals with extensive field experience were the majority.

Table 3.2: Age Group Distribution

Age Group	Frequency	Percent
55+	57	29.1%
45–54	50	25.5%
25–34	49	25.0%
35–44	40	20.4%
Total	196	100.0%

Professional categories were well-represented across disciplines. Green Building Consultants formed the largest group at 22.4%, while Environmental Scientists were the least represented at 15.8%.

Table 3.3: Professional Background of Respondents

Profession	Frequency	Percent
Green Building Consultant	44	22.4%
Architect	41	20.9%
Urban Planner	40	20.4%
Sustainability Officer	40	20.4%
Environmental Scientist	31	15.8%
Total	196	100.0%

Experience levels indicate that 31.1% of respondents had 1–5 years of professional involvement, with over 46.9% possessing more than 10 years of experience—underscoring the reliability of expert feedback gathered.

Table 3.4: Years of Professional Experience

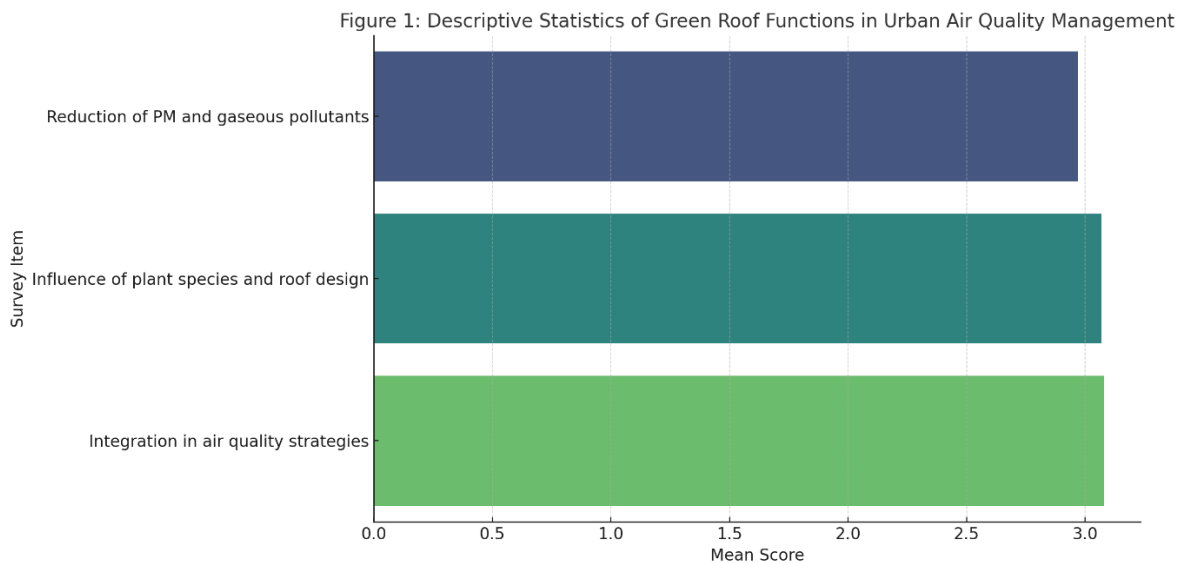
Years of Experience	Frequency	Percent
1–5 years	61	31.1%
11–15 years	48	24.5%
16+ years	44	22.4%
6–10 years	43	21.9%
Total	196	100.0%

Analysis by Research Objectives

Respondents were asked to rate their agreement with statements aligned to the study's three research objectives using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The table below summarizes the descriptive statistics for each item, closely following the SPSS output format.

Table 3.5: Descriptive Statistics for Research Objectives

Item	N	Mean	Std. Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum
Reduction of PM and gaseous pollutants	196	2.97	1.45	1.00	2.00	3.00	4.00	5.00
Influence of plant species and roof design	196	3.07	1.40	1.00	2.00	3.00	4.00	5.00
Integration in air quality strategies	196	3.08	1.47	1.00	2.00	3.00	4.25	5.00



Source: Field Survey, 2025

Figure 1: Descriptive Statistics of Green Roof Functions in Urban Air Quality Management
Source: Field Survey, 2025

IV. Summary of Findings

The findings suggest that experts moderately agree with the proposition that green roofs can reduce particulate matter and gaseous pollutants, as reflected by a mean of 2.97. This aligns with Gładysz et al. (2025) and Viecco et al. (2021), who observed measurable reductions in PM through vegetation-based rooftop interventions. However, the variability ($SD = 1.45$) indicates a spread of opinions, possibly linked to local implementation challenges. Regarding the influence of plant species diversity and roof design, a slightly higher mean score of 3.07 was recorded. This suggests a growing awareness among experts about how plant selection and roof configuration contribute to filtration efficiency, consistent with the findings of González-Méndez and Chávez-García (2021), who emphasized the importance of foliar retention dynamics. The highest agreement was observed for the integration of green roof systems in broader urban air quality strategies, with a mean of 3.08. This reflects strong expert endorsement of green roofs as a viable component of Lagos's sustainability agenda, in line with Biswal et al. (2022) and Menounou et al. (2023), who advocate for their inclusion in multi-scalar planning frameworks. Overall, the data suggests a favourable but cautious outlook among experts. While the conceptual appeal of green roofs is acknowledged, variability in ratings highlights underlying concerns, including policy inertia, technical capacity, and cost feasibility. Future planning efforts should focus on bridging these gaps through interdisciplinary collaboration, regulatory incentives, and pilot demonstration projects in Lagos.

V. Conclusion and Recommendations

This study aimed to explore expert perspectives on the role of green roofs in urban air filtration within the context of Lagos, a city facing severe air quality challenges due to rapid urbanization, industrial activity, and vehicular emissions. Through a structured

survey involving 196 professionals across key environmental and built environment disciplines, the study explored the extent to which green roofs reduce airborne particulate matter and gaseous pollutants, the influence of plant species and roof design on air filtration, and the potential of green roofs as components of broader urban sustainability strategies. The findings revealed moderate agreement among experts regarding the effectiveness of green roofs in filtering PM and gaseous pollutants, with a mean score just under the mid-point. Respondents recognized the significance of plant diversity and roof design in optimizing filtration outcomes, indicating a need for more deliberate ecological planning in green roof systems. Furthermore, the strongest consensus emerged around the integration of green roofs into city-wide air quality management strategies, suggesting that stakeholders see green roofs not as isolated interventions but as vital parts of an integrated, nature-based approach to urban resilience.

Demographically, the respondents represent a mature and experienced cross-section of professionals, reinforcing the credibility of the insights gathered. However, the variation in perception, reflected in relatively high standard deviations across items, underscores existing challenges such as limited awareness, insufficient policy frameworks, and technological or financial barriers to large-scale adoption.

In sum, the study confirms that while green roofs are conceptually supported by professionals in Lagos, realizing their full potential will require systemic efforts, cross-sector collaboration, and stronger institutional support to transition from theoretical viability to practical implementation.

Recommendations

Policy Integration and Incentives: Urban development policies in Lagos should formally incorporate green roof systems as mandatory or incentivized components in both new and retrofitted buildings. Policy instruments such as tax rebates, development bonuses, or certification incentives can motivate private sector adoption and investment.

Standardization of Green Roof Design: Regulatory bodies, in collaboration with environmental scientists and landscape architects, should develop localized standards that guide the selection of plant species, substrate composition, and structural design for optimal air filtration performance in Lagos's tropical climate.

Capacity Building and Professional Training: Targeted training programs should be instituted for architects, planners, and builders to deepen their technical knowledge of green roof construction and maintenance. Partnerships with universities and professional councils can support curriculum development and the dissemination of knowledge.

Pilot Projects and Demonstration Sites: The Lagos State Government should implement pilot green roof projects on public buildings such as schools, hospitals, and government offices. These demonstration sites would serve as practical case studies for cost-benefit analysis, performance monitoring, and public education.

Integration with Broader Environmental Strategies: Green roofs should not be approached in isolation but integrated into larger environmental strategies involving urban forestry, permeable pavements, and climate-resilient design. A coordinated green infrastructure master plan can ensure synergy among these interventions.

Public Awareness and Advocacy: Public campaigns highlighting the environmental and health benefits of green roofs can increase societal buy-in and drive grassroots demand. Engaging communities in maintenance efforts also promotes long-term sustainability and stewardship.

Research and Monitoring Frameworks: Continuous empirical research is needed to measure pollutant reduction performance under Lagos-specific conditions. Establishing partnerships with research institutions for ongoing monitoring and publication of findings will build an evidence base to inform future decisions.

References

1. Barriuso, F. & Urbano, B. (2021). Green Roofs and Walls Design Intended to Mitigate Climate Change in Urban Areas across All Continents. Sustainability. <https://doi.org/10.3390/SU13042245>.
2. Biswal, B, Zhu, Y, Balasubramanian, R, & Bolan, N. (2022). Nature-based Systems (NbS) for mitigation of stormwater and air pollution in urban areas: A review. Resources, Conservation and Recycling. <https://doi.org/10.1016/j.resconrec.2022.106578>.
3. Ciacchi, C, Banti, N, Di Naso, V, & Bazzocchi, F. (2023). Green strategies for improving urban microclimate and air quality: A case study of an Italian industrial district and facility. Building and Environment. <https://doi.org/10.1016/j.buildenv.2023.110762>.
4. Currie, B. (2021). Estimates of air pollution mitigation with green roofs using the UFORE model. <https://doi.org/10.32920/ryerson.14655414.v1>.
5. French, K, Watts, J, Morawska, L, Kumar, P, Forehead, H, Barwise, Y, Perez, P, & Tomson, M. (2021). Green Infrastructure for Air Quality Improvement in Street Canyons. Environment international, 146, 106288 . <https://doi.org/10.1016/j.envint.2020.106288>.
6. Gładysz, K, Popek, R, & Wrochna, M. (2025). Tracking Particulate Matter Accumulation on Green Roofs: A Study at Warsaw University Library. Air. <https://doi.org/10.3390/air3010004>.

7. González-Méndez, B, & Chávez-García, E. (2021). Particulate matter and foliar retention: current knowledge and implications for urban greening. *Air Quality, Atmosphere & Health*, 14, 1433-1454. <https://doi.org/10.1007/s11869-021-01032-8>.
8. Luo, X, Xue, X, & Shafique, M. (2020). An overview of carbon sequestration of green roofs in urban areas. *Urban Forestry & Urban Greening*, 47, 126515. <https://doi.org/10.1016/j.ufug.2019.126515>.
9. Menounou, P, Dimopoulos, P, Kolokotsa, D, Papadaki, M, Tsangrassoulis, A, Papaefthimiou, S, Paravantis, J, Souliotis, M, Panaras, G, Giannakopoulos, E, & Mihalakakou, G. (2023). Green roofs as a nature-based solution for improving urban sustainability: Progress and perspectives. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2023.113306>.
10. Meza, P, & Andrea, P. (2020). Vegetación urbana como estrategia para reducir la contaminación del aire en áreas urbanas.
11. Schrieke, D, Farrell, C, Szota, C, & Williams, N. (2023). Evaluating the effectiveness of spontaneous vegetation for stormwater mitigation on green roofs. *The Science of the total environment*, 165643. <https://doi.org/10.1016/j.scitotenv.2023.165643>.
12. Shehzad, M, Hameed, M, Younis, A, & Asif, M. (2023). Prospects of green roof technology as a sustainable solution to urban pollution index. *Journal of Agriculture and Food Research*. <https://doi.org/10.1016/j.jafr.2023.100751>.
13. Venter, Z, Stange, E, Castell, N, Hassani, A, & Schneider, P. (2024). Reassessing the role of urban green space in air pollution control. *Proceedings of the National Academy of Sciences of the United States of America*, 121. <https://doi.org/10.1073/pnas.2306200121>.
14. Viecco, M, Vera, S, & Jorquera, H. (2021). Effects of biodiversity in green roofs and walls on the capture of fine particulate matter. *Urban Forestry & Urban Greening*. <https://doi.org/10.1016/j.ufug.2021.127229>.
15. Zheng, Y, & Chen, L. (2023). Modelling the Effect of Green Roofs for Building Energy Savings and Air Pollution Reduction in Shanghai. *Sustainability*. <https://doi.org/10.3390/su16010286>.