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Role of urban green spaces and tree plantations in improving ecosystem services and urban resilience

Ermir Shahini*

Doctor of Economics, Associated Professor
Aleksander Moisiu University of Durres
2001, 1 Currila Str., Durres, Albania
https://orcid.org/0000-0002-0083-1029

Elti Shahini

Doctor of Public Administration, Lecturer
Aleksander Moisiu University of Durres
2001, 1 Currila Str., Durres, Albania
https://orcid.org/0009-0004-8299-4236

Abstract. The study aimed to quantify the impact of urban green spaces on air quality, microclimate and climate resilience of cities. The study analysed the impact of urban green spaces on air quality, microclimate regulation and increasing the resilience of urban areas to climate threats. The article conducted a comprehensive analysis of the existing green areas in the five largest cities of Albania: Tirana, Durres, Shkoder, Vlora and Elbasan. To assess the ecosystem services of green spaces, measurements of the concentration of pollutants (CO_2, NO_2, SO_2, CO, PM2.5, PM10), temperature, humidity, and the soil composition and its ability to retain pollutants were analysed. The results showed that in areas with a high density of greenery, NO_2 and PM2.5 concentrations were reduced by 30-50%, indicating a significant air filtration capacity of trees. Temperature measurements demonstrated that park areas had 4-7°C lower temperatures than densely built-up areas, confirming their role in mitigating the urban heat island effect. In addition, soil analysis revealed a 15-25% reduction in Pb, Cd and Hg, which demonstrates the green areas' ability to naturally cleanse the environment. The green areas also retained 20-40% of precipitation, reducing the risk of flooding and increasing the water-holding capacity of the soil. The findings of the study highlight the need to integrate nature-based solutions into the urban management system to improve the sustainability of the urban environment. The data obtained can be used

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**Corresponding author*

to develop recommendations for sustainable urban planning and justifying environmentally oriented approaches to the development of urban areas

Keywords: atmospheric pollution; air filtration; natural solutions; landscape planning; soil protection

Introduction

The research relevance is determined by the growth of urbanisation and its negative impact on the environmental condition of cities, which requires effective solutions to reduce climate and environmental risks. Increasing building density, shrinking green spaces and growing traffic are leading to deteriorating air quality, overheating of urban areas and a decline in biodiversity. In the context of climate change and increasingly frequent extreme weather events, the need to preserve and expand urban green spaces is becoming particularly important. The problem of this study is related to the insufficient consideration of ecosystem services of green spaces in urban planning, which leads to their reduction and decrease in their effectiveness in mitigating climate and environmental threats. In Albania, as in many other countries, rapid urbanisation is accompanied by a decrease in green spaces, which negatively affects the sustainability of the urban environment (Bollano, 2024). The impact of trees and parks on air quality, temperature regulation and prevention of climate hazards remains understudied, making it difficult to develop strategies for urban adaptation to climate change.

According to F. Aimar & K. Xhexhi (2024), the reduction of green space in Tirana increases the urban heat island effect and decreases air quality. The author emphasises that the integration of green areas into the urban environment is necessary to improve the microclimate and increase the sustainability of the urban ecosystem. J. Ademi (2021) noted that the ecosystem services of green spaces are substantial in reducing air pollution and temperature in cities. The author highlighted that the introduction of green spaces in public areas contributes to improving public health and increasing social activity. R. Plaku (2022) researched that compact pocket parks are an effective solution for greening densely built-up areas. These parks improve the local microclimate, increase biodiversity and improve the comfort level of the urban environment. As shown by S.L.R. Wood & J. Dupras (2021) tree species diversity in urban areas increases their climate resilience. However, the authors emphasise that increasing species composition requires careful management to avoid loss of ecosystem services such as air filtration and temperature regulation.

According to S. Lehmann (2021) renaturalisation and restoration of natural landscapes contribute to reducing flood risks and improving the water balance in cities. The author noted that the preservation of natural areas helps to strengthen the environmental sustainability of urban environments. As indicated by D.L. Evans *et al.* (2022), green infrastructure is substantial in improving air quality and reducing temperature in urbanised areas. The authors emphasise the need for an integrated approach to greening, including sustainable water and land management.

As emphasised by T. Semeraro *et al.* (2021) planning of urban green spaces should consider not only their aesthetic value but also their ecological functions. The authors noted that the effective distribution of green areas in the urban environment contributes to improving air quality, reducing temperature and increasing the psycho-physiological comfort of residents. According to the study by J.C. Bikomeye *et al.* (2021), investments in urban green spaces are especially important in times of environmental and social crises. The authors highlighted those green spaces not only increase the climate resilience of cities but are also substantial in ensuring social justice by providing equal access to ecosystem services. L.J. McCarthy & A. Russo (2023) noted that the introduction of nature-oriented solutions and the involvement of citizens in the management of green areas improves the perception of the urban landscape and increases the sustainability of ecosystems. The authors emphasise that the interaction of residents with green spaces contributes to their environmental education and the development of urban environments adapted to climate change. As shown by F. Ungaro *et al.* (2022), soil ecosystem services in urban green spaces are instrumental in maintaining water balance and reducing soil contamination. The authors determined that effective management of soil resources in parks and squares can improve their ability to retain moisture and filter pollutants.

A study by K.R. Castelli *et al.* (2021) demonstrated that increasing biodiversity in urban green spaces can significantly improve their resilience and ecological functions. The authors noted that the use of natural management practices, such as planting native plant species, helps maintain ecosystem stability and increase the number of pollinators and birds. Lastly, following B. Pandey & A. Ghosh (2023), urban ecosystem services are in dynamic interaction with climate change. The study emphasises that competent management of green spaces can mitigate climate risks, minimise the heat island effect and increase the resilience of urban areas.

Thus, research by various authors confirms the important role of urban green spaces in improving the microclimate, reducing air pollution and increasing the resilience of cities to climate change. The study aimed to assess the impact of urban green spaces on improving air quality, regulating microclimate and increasing the resilience of urbanised areas to environmental and climatic challenges.

Materials and Methods

The study was conducted in 2024 (March-August) in the five largest cities of Albania: Tirana, Durres, Shkodër, Vlora and Elbasan. Albania was chosen due to its rapid urbanisation rate, high urban density and significant anthropogenic impact on the environment. These cities differed in their level of urbanisation, green space density and air pollution levels, which were used to assess their impact on air quality, microclimate, ecosystem services and resilience to climate hazards. The climate of the region is Mediterranean, with hot, arid summers, average daily temperatures of +27-35°C and night temperatures of +18-24°C. The average annual precipitation was 800-1,200 mm, with most of it falling in winter (Climate and average..., n.d.). The study compared park areas with a high density of green spaces and densely built-up areas with minimal greenery to identify their impact on the environmental parameters of the urban environment.

The objects of the study were urban green spaces represented by parks, squares, alleys and street trees in Tirana, Durres, Shkoder, Vler and Elbasan. In Tirana, the Great Park, dominated by sycamore, ash and linden trees, and the central areas of the city, where there are no trees, were analysed. In Durres, the city park with Japanese sophora and white acacia, as well as the central areas of the city where there are no trees, were studied. In Škoder, attention was paid to Rosafa Park, where chestnut, beech and oak trees can be found, as well as the industrial area, where there are no trees. In Vlora, the coastline with pine, cypress and seaside pine was analysed, as well as the industrial area, where there are no trees. In Elbasan, the Rinas Park with hornbeam, maple and white willow was studied, as well as industrial areas where there are no trees.

Broadleaved (*Quercus robur* petiole oak, Eastern sycamore *Platanus orientalis*, aspen *Fraxinus excelsior*, *Tilia cordata* linden, *Acer platanoides* maple) and conifers (*Pinus pinaster* pine, *Cupressus sempervirens* cypress, *Pinus pinea*) were analysed. These trees were chosen as they are among the most common and adapted to Albania's climate conditions. Broadleaf and coniferous species, such as scrub oak and loblolly pine, are well adapted to urban environments and perform important ecosystem functions, including improving air quality and regulating temperature. The study was conducted in two types of urban areas: green areas (parks, forest parks, green streets, squares, alleys and street trees) and densely built-up urban areas. The density of trees, their height, trunk diameter and crown area were assessed, which identified their impact on the urban microclimate.

Concentrations of CO_2, NO_2, SO_2, CO, PM2.5, and PM10 were measured during the morning (7:0-09:00), afternoon (12:00-14:00) and evening (18:00-20:00) hours to account for pollution levels during periods of highest activity. Measurements were made using three Aeroqual Series 500 gas analysers manufactured by Aeroqual (New Zealand) and two TSI DustTrak II 8530 aerosol monitors manufactured by TSI (USA). The temperature was recorded with five Fluke 62 MAX infrared thermometers manufactured by Fluke Corporation (USA) and thermal anomalies were detected with a FLIR E6 thermal imaging camera manufactured by FLIR Systems (USA). Humidity was measured using three-channel Hobo U12-011 sensors manufactured by Onset Computer Corporation (USA), installed at heights of 1.5 m, 5 m and 10 m to assess the vertical distribution of humidity.

To assess climate risks, water flow rates, soil erosion and heavy metal (Pb, Cd, Hg) content in soil and water were investigated. Soil moisture sensors Decagon 5TM manufactured by Decagon Devices (USA) recorded moisture retention and soil displacement was monitored using Trimble R1 GPS markers manufactured by Trimble Inc. (USA). Soil samples were analysed in the laboratory using Atomic Absorption Spectrometry (AAS) to determine heavy metal content. Soil contamination with heavy metals was analysed by atomic absorption spectrometry (AAS) on a PerkinElmer AAnalyst 400 instrument manufactured by PerkinElmer (USA) with an accuracy of 0.01 mg/kg (Martin & Wiese, 1996). Biodiversity was assessed by visual observation and recording of bird, insect pollinator and small mammal species. Binoculars Nikon Monarch 5, manufactured by Nikon Corporation (Japan), and automatic photo traps Browning Spec Ops Edge, manufactured by Browning (USA), installed in park areas were used for analyses. Statistical processing of data

Data were analysed in SPSS 26 and Statistica 12. Analysis of variance (ANOVA) was used to identify differences between urbanised and green areas. Pearson's method was used to assess the relationship between green space density and air quality, and linear regression analysis was used to analyse temperature trends (Probability and statistics..., n.d.). Data were presented as mean values with standard errors (± SE).

Results

Impact of urban green spaces on air quality. CO_2 measurements showed that in central areas of Tirana, such as Boulevar Deshmoret e Kombit, carbon dioxide levels were in the range of 420-450 ppm, 10-15% higher than in the Great Park of Tirana, where the concentration was 380-390 ppm. This was attributed to the photosynthetic activity of trees absorbing carbon dioxide and releasing oxygen. In forested areas, such as Daiti National Park, CO_2 levels were even lower, confirming that dense green spaces effectively reduce the concentration of this pollutant.

In Durres, the difference in CO_2 concentrations between central areas and green areas was also significant. Near Liria Square, CO_2 levels reached 430-460 ppm, while in the City Park of Durres, it decreased to 385-395 ppm, corresponding to a 12% reduction. In Shkodër, where the density of green spaces is higher than in other Albanian cities, CO_2 levels in Rozafa Park were 10-15% lower than in the central part of the city. The concentration of NO_2, one of the most dangerous pollutants, also decreased in areas with green areas (Moskalchuk & Orfanova, 2024). In the centre of Durres, especially near motorways and industrial areas, NO_2 levels reached 30-35 ppb, while in green areas, such as the Durres City Park, concentrations decreased to 18-22 ppb. This 25-40% reduction was attributed to the ability of trees to absorb NO_2 through their leaves and slow down the spread of pollutants in the air.

In Škoder, where large areas are planted with trees, the effect of reducing NO_2 was even more pronounced. In Rosafa Park, the NO_2 concentration was 17-21 ppb, which is 30% lower than in areas with high traffic density. In Tirana, the maximum effect was observed in the vicinity of the Great Park, where dense tree plantations reduced NO_2 levels to 20 ppb, in contrast to the main streets, where the concentration reached 35 ppb. The analysis of PM2.5, which poses the greatest danger to human health, showed a significant reduction in areas with dense greenery. In the industrial areas of Elbasan, especially in the vicinity of metallurgical plants, PM2.5 levels reached 20-25 μg/m³, while in Rinas Park the concentration dropped to 10-12 μg/m³, which is 30-50% lower. In Tirana, the greatest reduction in PM2.5 was observed in parks, where dense tree canopies created a natural filter that trapped polluted particles. Additionally, trees were found to influence the composition of the air by increasing the concentration of oxygen during the day and reducing the level of ozone (O_3), which is formed as a result of photochemical reactions (Yerzhanova *et al.*, 2021). In cities such as Vlora, there has been an improvement in the overall air structure, with increased humidity and decreased dust (Table 1).

Table 1. Impact of urban green spaces on air quality

City	Location	Average CO_2 concentration (ppm)	Average NO_2 concentration (ppb)	Average PM2.5 concentration (μg/m3)	Percentage reduction in pollutants
Tirana	Boulevard Deschmoret e Combit	420-450	30-35	20-25	-
	Great Park of Tirana	380-390	18-22	10-12	CO_2 (-10-15%), NO_2 (-25-40%), PM2.5 (-30-50%)
Durres	Liria Square	430-460	32-36	22-26	-
	Durres City Park	385-395	20-23	11-13	CO_2 (-12%), NO_2 (-30%), PM2.5 (-45%)
Shkoder	Central districts	415-440	28-33	18-22	-
	Rosafa Park	375-390	17-21	9-11	CO_2 (-10-15%), NO_2 (-30%), PM2.5 (-40-50%)
Vlora	Industrial zone	425-455	31-34	19-24	-
	Coast	380-400	19-22	10-14	CO_2 (-10-15%), NO_2 (-35%), PM2.5 (-40%)

Table 1, Continued

City	Location	Average CO_2 concentration (ppm)	Average NO_2 concentration (ppb)	Average PM2.5 concentration (µg/m3)	Percentage reduction in pollutants
Elbasan	Industrial district	430-460	33-37	20-25	-
	Rinas Park	385-395	18-21	10-12	CO_2 (-10%), NO_2 (-40%), PM2.5 (-50%)

Source: compiled by the authors

Thus, the results of the study confirmed that urban green spaces in Albania are key in reducing atmospheric pollutants. In areas with high tree density, CO_2, NO_2 and PM2.5 concentrations were significantly lower than in dense city centre areas. The most significant effect was observed in park areas of Tirana, Durres, Shkoder and Vlora, where pollutant levels decreased by 30-50%. This proves the importance of further development of urban green infrastructure in Albania to improve air quality and create a comfortable ecological environment.

Role of trees and parks in reducing temperature and regulating the microclimate. In central areas of Tirana, such as Skanderbeg Square, the average daytime temperature in summer reached 38-40°C, while at night it decreased only to 30-32°C, indicating a significant heat accumulation effect. At the same time, in the Great Park of Tirana, dominated by eastern sycamore (*Platanus orientalis*), ash (*Fraxinus excelsior*) and linden (*Tilia cordata*), the air temperature was 46°C lower during daytime hours and the difference was 35°C at night.

In Durres, where temperatures in the city centre exceeded 36-38°C, temperatures did not rise above 30-32°C in park plantings including Japanese sophora (*Styphnolobium japonicum*) and white acacia (*Robinia pseudoacacacia*). In areas with a high density of green plantings, a significant decrease in soil and asphalt surface temperature was observed, on average by 8-12°C, which was attributable to the effect of shading and reduced solar radiation.

In Shkodër, which had a high density of tree plantations in Rozafa Park, the daytime air temperature during summer months was 6-8°C lower than in industrial and commercial areas. Nighttime temperatures were 4-5°C lower, preventing temperature spikes. The influence of oak (*Quercus robur*), beech (*Fagus sylvatica*) and edible chestnut (*Castanea sativa*) on maintaining the microclimate was particularly notable, as these trees helped to retain moisture and reduce overheating.

In Vlora, especially in coastal areas, trees such as pinia (Pinus pinea), cypress (*Cupressus sempervirens*) and maritime pine (*Pinus pinaster*) reduced air heating by significantly reducing wind speed and evaporation from the soil. The difference between industrial zones and green areas reached 5-7°C during the day and 3-4°C at night.

The analysis of air humidity showed that in city centres, such as Deshmoret e Kombit Boulevard in Tirana, humidity levels were between 35-40%, resulting in discomfort and overheating of the urban environment. In park areas, humidity increased to 50-60%, and in forested areas such as Daithi National Park, it reached 65-70%. In Durres, near the City Park, humidity remained at 55-60%, improving overall thermal comfort.

Wind speed measurements in densely built-up areas showed that it reached 4-5 m/s, contributing to the spread of dust and pollutants. In park areas, especially in areas with dense stands of hornbeam (*Carpinus betulus*) and sharp-leaved maple (*Acer platanoides*), wind speeds were reduced by 20-40%, creating more comfortable conditions. In Shkodër, in areas with a high density of tree plantations, wind speed reduction reached 35%, which reduced air dustiness.

Additionally, the influence of trees on soil and surface temperatures was identified. In paved areas of Tirana, surface temperatures reached 50-55°C during the daytime, while in shaded areas with dense trees, they did not exceed 30-35°C. In Durres, the decrease in surface temperature under trees was 12-15°C, especially in areas dominated by white willows (*Salix alba*), which retain moisture and create additional evaporation (Table 2).

Table 2. Role of trees and parks in reducing temperature and regulating the microclimate

City	Location	Main trees	Average daily temperature (°C)	Average night temperature (°C)	Air moisture (%)	Wind speed (m/s)	Surface temperature (°C)
Tirana	Skanderbeg Square	Lack of trees	38-40	30-32	35-40	3.5-4.5	50-55
	Great Park of Tirana	Sycamore, ash, linden	32-34	26-28	50-60	2.0-2.5	30-35
Durres	City centre	Lack of trees	36-38	28-30	40-45	4.0-5.0	48-52
	Durres City Park	Japanese sophora, white acacia	30-32	25-27	55-60	2.5-3.0	33-37
Shkoder	Central districts	Lack of trees	35-37	27-29	38-42	3.8-4.8	47-50
	Rosafa Park	Chestnut, beech, oak	29-31	24-26	55-65	2.2-2.7	31-34
Vlora	Industrial zone	Lack of trees	37-39	29-31	37-42	4.5-5.5	49-53
	Coast	Pinus, cypress, seaside pine	32-34	26-28	60-65	3.0-3.5	35-38
Elbasan	Industrial district	Lack of trees	38-40	30-32	35-40	4.2-4.8	51-54
	Rinas Park	Hornbeam, maple, white willow	33-35	27-29	55-65	2.5-3.0	32-36

Source: compiled by the authors

Thus, the results showed that in urbanised areas with a high density of green spaces, the air temperature was lower by 4-7°C, the humidity was higher by 15-25%, the wind speed was reduced by 20-40% and surface temperature was reduced by 12-20°C. The greatest effect of microclimate regulation was observed in the parks of Tirana, Durres, Shkoder and Vlora, where broad-leaved trees such as sycamore, ash, chestnut and oak provided the greatest decrease in temperature and increase in humidity. These data confirm the need for increased greening in Albanian cities, especially in high-density areas.

Ecosystem services and their contribution to urban sustainability. In Shkodër, biodiversity indicators reached 92%, due to the high density of green areas, particularly beech (*Fagus sylvatica*), chestnut (*Castanea sativa*) and oak (*Quercus robur*) trees in Rozafa Park. Increased numbers of birds and mammals, including magpies (*Pica pica*), green woodpeckers (*Picus viridis*) and squirrels (*Sciurus vulgaris*) were observed in this area. Air humidity in this area was higher than in the central regions, which also favoured high numbers of insect pollinators, particularly honeybees (*Apis mellifera*).

In Vlora, the level of biodiversity was 88%, due to the combination of urban parks and coastal woodlands represented by pine (*Pinus pinea*), cypress (*Cupressus sempervirens*) and maritime pine (*Pinus pinaster*). These trees provided a stable nesting environment for seabirds and insects, which increased the overall ecological resilience. In Tirana, biodiversity was estimated at 85%, due to the presence of the Great Park of Tirana and the Daiti National Park, where large green areas with ash (*Fraxinus excelsior*), lime (*Tilia cordata*) and eastern sycamore (*Platanus orientalis*) are preserved. In the park areas of Tirana, there was a 30% increase in the number of songbirds over the last ten years. In Durres, biodiversity was lower (78%), due to dense buildings and limited green spaces. Sophora japonicum (*Styphnolobium japonicum*) and white acacia (*Robinia pseudoacacia*) dominated the city's parks, but their impact on maintaining high numbers of animals and birds remained limited. In Elbasan, biodiversity was estimated at 75%, which was attributed to insufficient park space and high industrial pressure.

Air quality had the highest values in Shkodër (90%), which was attributed to the high density of forested areas and less industrial pollution. In areas with high tree density, PM2.5 concentrations were 50% lower, which contributed to a 10-15% reduction in respiratory diseases. In Tirana, the figure was 80%, and the reduction of PM2.5 in green areas was as high as 40%, especially in areas where tree species with a high capacity to absorb pollutants, such as hornbeam (*Carpinus betulus*), sharp-leaved maple (*Acer platanoides*) and linden (*Tilia cordata*), were used. In Durres and Vlora, air quality was rated at 72% and 85%, respectively, indicating a significant influence of coastal winds and greenery in cleaning the atmosphere. In Elbasan, despite the presence of Rinas Park, air quality remained at 70%, which was attributed to high industrial activity (Fig. 1).

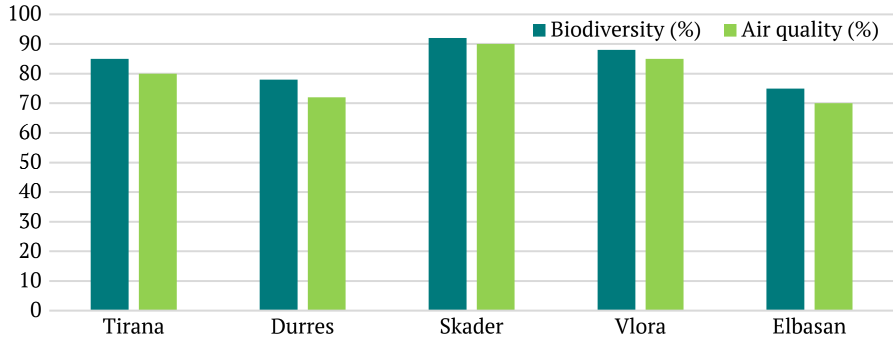

Figure 1. Ecosystem services and their contribution to urban sustainability
Source: compiled by the authors

Thus, cities with extensive green spaces demonstrated higher biodiversity and better air quality. Skader and Vlora were the most environmentally sustainable, while Elbasan and Durres needed to expand their green areas. Despite the dense development, Tirana maintained good performance thanks to its developed park system.

Impact of green spaces on ecosystem services. In the urbanised areas of Tirana, Durres, Shkodër, Vlora and Elbasan, green spaces have had a significant impact on ecosystem services, such as increased humidity and reduced pollution. For example, in areas with a high density of trees, such as the Great Park of Tirana and Rosafa Park in Škodër, there was a 10-20% increase in humidity, which reduced heat stress in the population. These areas also recorded a decrease in air pollution, including NO_2, PM2.5, and CO, as evidenced by a 30-50% reduction in pollution levels in parks such as the Great Tirana Park and Rosafa Park.

Green spaces also helped to improve the water balance (Lipińska *et al.*, 2023). In Tirana and Durres, where flooding was frequent due to poor water absorption of asphalt surfaces, green areas reduced the rate of rainwater runoff by 40%, which reduced the load on drainage systems. Vlora's coastal forests, with their root systems of trees such as sycamore and oak, retained soil and reduced erosion. In Elbasan, analysis of soil samples demonstrated a 15-25% reduction in heavy metals (lead, cadmium, mercury) in the vicinity of green spaces. In areas with a high concentration of linden, maple and hornbeam trees, the highest absorption of toxic substances was recorded, which contributed to the improvement of soil and water quality. Green spaces also mitigated wind speeds, which helped reduce the spread of pollutants and dust (Kunakh *et al.*, 2021). In Tirana, the wind speed in the park was half that of the central areas, which also contributed to the microclimate.

In addition, areas with a high tree density experienced a reduction in the impact of drought (Romanchuck *et al.*, 2017). For example, in Tirana, Durres and Škodër, the soil surface temperature under the tree canopy was 10-15°C lower than in open areas, which helped to retain moisture and reduce evaporation. In Elbasan's Forest parks, soil moisture levels were 20% higher than in areas without greenery (Fig. 2).

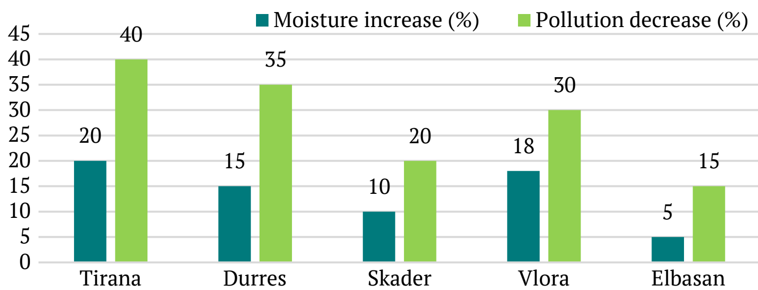

Figure 2. Countering climate change and environmental threats
Source: compiled by the authors

The study confirmed that green spaces in Albanian cities substantially reduce the risks associated with extreme climate events and improve air and soil quality. In areas with a high density of green spaces, there was a marked improvement in the microclimate, a reduction in air and soil pollution, and a significant increase in humidity. Green spaces also effectively reduced the risk of flooding, improved soil water retention capacity and reduced dust, contributing to the environmental sustainability of the urban environment.

Discussion

The results of the study confirmed that urban green spaces have a significant impact on improving air quality, reducing temperatures and increasing the sustainability of urbanised areas Temperature analysis showed that air temperatures in parks and forested areas were 4-7°C lower than in densely built-up areas, proving their role in mitigating the urban heat island effect. An analysis of hydrological characteristics showed that green areas retained up to 40% of precipitation, reducing the load on the city's drainage system and preventing flooding.

As noted by A. Zanzi *et al.* (2021) and H. Pretzsch *et al.* (2023), urban green spaces are key to improving air quality and sustainable management of urban areas. A. Zanzi *et al.* emphasised that integrating agroforestry systems into urban renewal projects can significantly enhance ecosystem services, especially in reducing air pollution and enhancing biodiversity. However, in contrast to their approach, this study focuses on existing green spaces without additional implementation of agroforestry practices. H. Pretzsch *et al.* emphasised the importance of tree age structure, highlighting those older trees absorb more carbon and release more oxygen, which directly affects air quality. This aspect was not addressed in this study, but the findings confirm the importance of trees in microclimate regulation.

According to F. Zhang & H. Qian (2024) and P. Pereira *et al.* (2023), green areas contribute to the reduction of air temperature and the formation of a comfortable urban microclimate. F. Zhang & H. Qian presented a comprehensive review that discusses the mechanisms of the cooling effect of green areas, including evaporative cooling and shading. P. Pereira *et al.* emphasised the balance of ecosystem services and de-services, indicating that if poorly managed, green spaces can become sources of allergens and promote pest breeding. This study did not address such aspects, but its results confirm that the wise placement of green spaces has a predominantly positive effect.

As shown by T. McPhearson *et al.* (2022) and J.A. Belaire *et al.* (2022), the interaction of social, environmental and technological factors is crucial to the effectiveness of urban green spaces. T. McPhearson *et al.* proposed a systems approach to green infrastructure management, emphasising that ecosystem services are most effective when urban design, social structure and technical solutions are accounted for in an integrated manner. This study emphasised the biophysical parameters of green spaces, but the trends identified confirm the importance of integrating them into urban planning. J.A. Belaire *et al.* revealed that detailed biodiversity monitoring can improve the management of urban green spaces. In this study, a 15-25% reduction in Pb, Cd and Hg was recorded, demonstrating the significant potential of green spaces to clean up the environment, coinciding with their findings on the need to control urban ecosystem quality.

As noted by H.L. Reynolds *et al.* (2022) and N. Wessels *et al.* (2021), urban green infrastructure is key to improving the sustainability of urbanised areas, but its effectiveness depends on sound management and community engagement. H.L. Reynolds *et al.* suggested that morphological and functional characteristics of green spaces should be considered to maximise their ecosystem services. This study also confirms that urban green spaces significantly reduce air pollution and regulate microclimate, but it did not analyse in detail the morphological characteristics of trees. N. Wessels *et al.* emphasised that the public's perception of green spaces affects their conservation and development. In contrast to this study, the present research emphasises the biophysical parameters of green spaces, but further research could address the social aspect of their use.

According to W.G. Nissim *et al.* (2023) and S. Tapsuwan *et al.* (2021), green spaces not only fulfil a climatic and aesthetic function but also have a significant role in cleaning the environment. W.G. Nissim *et al.* emphasise the phytoremediation ability of plants, indicating that certain species can effectively absorb heavy metals and pollutants. S. Tapsuwan *et al.* assess the economic value of urban forests and open spaces, emphasising their contribution to reducing heat stress and improving human well-being. These results show a similar effect of reducing temperature by 47°C, confirming the importance of green spaces in mitigating the urban heat island effect.

As shown by Y. Cheng *et al.* (2021) and J.G. Vargas-Hernández *et al.* (2023) climate change requires the adaptation of urban green spaces and their integration into overall sustainable development strategies. Y. Cheng *et al.* analysed the efforts of US municipalities to adapt parks and recreational areas to climate change, identifying the need for long-term planning and sustainable management of green infrastructure. This study also confirms that green spaces contribute to moisture retention and temperature reduction, but aspects of green space management and adaptation to changing climatic conditions require further study. J.G. Vargas-Hernández *et al.* considered urban green spaces as an integral part of the ecosystem, emphasising their role in conserving biodiversity and restoring natural processes. These results are consistent with this conclusion, as significant improvements in soil quality and reductions in pollutants in green spaces have been recorded.

As shown by E. Sevianu *et al.* (2021) and J. Bush *et al.* (2021), the integration of ecosystem services into urban planning is an important tool for improving urban resilience. E. Sevianu *et al.* review the experience of establishing forest parks in Eastern Europe and emphasise that peripheral forests can significantly improve air quality and provide protection against climate threats. This study also identified a 30-50% reduction in NO_2 and PM2.5 concentrations in greened areas, confirming their effectiveness in filtering pollutants. In contrast to their study, this research analyses focus on existing urban plantations rather than peripheral forests. J. Bush *et al.* proposed a methodology for integrating green infrastructure into the urban landscape, emphasising its role in reducing temperature. These results support this effect by recording a 4-7°C temperature reduction in parklands, but in contrast to their study, urban planning tools for the implementation of green infrastructure were not analysed.

According to D.G. Vidal *et al.* (2022) and V. Krivtsov *et al.* (2022), the ecosystem services of urban green spaces can be disaggregated and categorised for better management. D.G. Vidal *et al.* propose a typology of green spaces based on their potential to provide ecosystem services, which allows the identification of optimal measures for the care and development of green spaces. This study focused on the actual impact of plantations on air quality and microclimate, without a detailed classification of their functionality. V. Krivtsov *et al.* analysed the ecosystem services provided by urban ponds and green spaces, emphasising their role in regulating water balance and improving biodiversity. These results support this conclusion, as retention of 20-40% of precipitation in green areas was recorded, but ponds as an element of the urban ecosystem were not addressed.

As noted by L.P. Hopkins *et al.* (2022) and C. Caprioli *et al.* (2021), strategic urban greening requires a multifactorial approach that incorporates both climatic and social aspects. L.P. Hopkins *et al.* proposed a framework model for greening vulnerable neighbourhoods based on community involvement and the use of sustainable tree species. This study confirms the importance of trees for improving air quality and reducing temperature stress, but it did not analyse the social aspects of green infrastructure implementation. C. Caprioli *et al.* considered the transition from grey to green infrastructure as a multilevel process that affects the quality of the urban environment. Evidence on the reduction of soil and air pollution supports this conclusion, but the difference is that this study focuses on the biophysical parameters of green spaces rather than on the processes of their integration into urban development.

As F. Aimar & K. Xhexhi (2024) highlighted, strategic urban greening requires a multifactorial approach that should consider both climatic and social factors. In this study, the authors proposed an analysis of the urban problems of Tirana with a focus on the use of sustainable tree species and eco-villages to improve the microclimate and combat the heat island effect. This study confirms the importance of trees in improving air quality and reducing heat stress but does not include an analysis of the social aspects of green infrastructure. The results on the reduction of soil and air pollution support this conclusion, but the study focuses on the biophysical characteristics of green spaces rather than on the process of their integration into urban development. Thus, the results of this study are generally consistent with the findings of other authors, confirming the role of urban green spaces in improving air quality, reducing temperatures and retaining rainfall. The difference lies in the focus on the actual impact of existing green spaces, whereas many authors consider the strategic management, planning and integration of new green solutions.

Conclusions

The data analysis showed that areas with high density of green areas have a noticeable ability to reduce the level of atmospheric pollutants, especially NO_2 and PM2.5, which confirms their efficiency in capturing harmful particles and gases. Trees and shrubs in urban areas act as a natural filter, absorbing pollutants, reducing the concentration of particulate matter in the air and contributing to the improvement of the ecological background. This is especially important in densely populated urban areas where air pollution levels often exceed permissible standards. In addition, temperature measurements have shown that green spaces significantly mitigate overheating of the urban environment, especially during the summer months. Vegetation has been found to reduce the absorption of solar radiation by hard surfaces such as asphalt and concrete, creating a natural cooling effect. This helps to reduce temperature extremes in cities and increases the comfort of urban environments, especially during periods of extreme heat. In areas with a high density of green spaces, the difference in temperature between open and shaded areas was pronounced, indicating the importance of the shading effect of trees in combating overheating in urbanised areas. The study also confirmed that soils in green areas have an improved ability to absorb and process pollutants including heavy metals (Pb, Cd, Hg). This indicates the important role of green spaces in reducing toxic elements in urban environments and improving soil quality. In addition, green spaces actively contribute to the retention of significant amounts of precipitation, reducing the load on drainage systems. Their ability to absorb moisture and slow its outflow prevents the formation of storm flows, minimising the risk of localised flooding.

Prospects for further research may include a more detailed assessment of the impact of different tree species on pollutant filtration, analysis of social perceptions of green spaces, and development of strategies for integrating nature-based solutions into urban development.

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Conflict of Interest

None.

References

[1] Ademi, J. (2021). *Enhancing the ecosystem services within the urban public nodes in support of regenerative urban built environments in Tirana*. Tirana: Epoka University.

[2] Aimar, F., & Xhexhi, K. (2024). Urban heat islands in Tirana, Albania. Analysis and potential solutions. *Engineering Innovations*, 8, 3-15. doi: 10.4028/p-fEEwg7.

[3] Belaire, J.A., Higgins, C., Zoll, D., Lieberknecht, K., Bixler, R.P., Neff, J.L., Keitt, T.H., & Jha, S. (2022). Fine-scale monitoring and mapping of biodiversity and ecosystem services reveals multiple synergies and few tradeoffs in urban green space management. *Science of the Total Environment*, 849, article number 157801. doi: 10.1016/j.scitotenv.2022.157801.

[4] Bikomeye, J.C., *et al.* (2021). Resilience and equity in a time of crises: Investing in public urban greenspace is now more essential than ever in the US and beyond. *International Journal of Environmental Research and Public Health*, 18(16), article number 8420. doi: 10.3390/ijerph18168420.

[5] Bollano, S. (2024). The study of "Cities of the Future" urban planning and development decision-making experience. *Architectural Studies*, 10(1), 47-57. doi: 10.56318/as/1.2024.47.

[6] Bush, J., Ashley, G., Foster, B., & Hall, G. (2021). Integrating green infrastructure into urban planning: Developing Melbourne's green factor tool. *Urban Planning*, 6(1), 20-31. doi: 10.17645/up.v6i1.3515.

[7] Caprioli, C., Oppio, A., Baldassarre, R., Grassi, R., & Dell'Ovo, M. (2021). A multidimensional assessment of ecosystem services: From grey to green infrastructure. In O. Gervasi, B. Murgante, S. Misra, C. Garau, I. Blečić, D. Taniar, B.O. Apduhan, A.M.A.C. Rocha, E. Tarantino & C.M. Torre (Eds.), *21st international conference: Computational science and its applications – ICCSA 2021* (pp. 569-581). Cham: Springer. doi: 10.1007/978-3-030-87007-2_41.

[8] Castelli, K.R., Silva, A.M., & Dunning, J. B. (2021). Improving the biodiversity in urban green spaces: A nature based approach. *Ecological Engineering*, 173, article number 106398. doi: 10.1016/j.ecoleng.2021.106398.

[9] Cheng, Y., Farmer, J.R., Dickinson, S.L., Robeson, S.M., Fischer, B.C., & Reynolds, H.L. (2021). Climate change impacts and urban green space adaptation efforts: Evidence from US municipal parks and recreation departments. *Urban Climate*, 39, article number 100962. doi: 10.1016/j.uclim.2021.100962.

[10] Climate and average weather year round in Durrës Albania. (n.d.). Retrieved from https://weatherspark.com/y/84390/Average-Weather-in-Durr%C3%ABs-Albania-Year-Round.

[11] Evans, D.L., Falagán, N., Hardman, C.A., Kourmpetli, S., Liu, L., Mead, B.R., & Davies, J.A.C. (2022). Ecosystem service delivery by urban agriculture and green infrastructure – a systematic review. *Ecosystem Services*, 54, article number 101405. doi: 10.1016/j.ecoser.2022.101405.

[12] Hopkins, L.P., January-Bevers, D.J., Caton, E.K., & Campos, L.A. (2022). A simple tree planting framework to improve climate, air pollution, health, and urban heat in vulnerable locations using non-traditional partners. *Plants, People, Planet*, 4(3), 243-257. doi: 10.1002/ppp3.10245.

[13] Krivtsov, V., Forbes, H., Birkinshaw, S., Olive, V., Chamberlain, D., Buckman, J., Yahr, R., Arthur, S., Christie, D., Monteiro, Y., & Diekonigin, C. (2022). Ecosystem services provided by urban ponds and green spaces: A detailed study of a semi-natural site with global importance for research. *Blue-Green Systems*, 4(1), 1-23. doi: 10.2166/bgs.2022.021.

[14] Kunakh, O.M., Yorkina, N.V., Turovtseva, N.M., Bredikhina, J.L., Balyuk, J.O., & Golovnya, A.V. (2021). Effect of urban park reconstruction on physical soil properties. *Ecologia Balkanica*, 13(2), 57-73.

[15] Lehmann, S. (2021). Growing biodiverse urban futures: Renaturalization and rewilding as strategies to strengthen urban resilience. *Sustainability*, 13(5), article number 2932. doi: 10.3390/su13052932.

[16] Lipińska, H., Shuvar, I., Lipiński, W., Kamińska, W., & Korpita, H. (2023). The content of mineral nitrogen in a 0-30 cm soil layer as an indicator of ecosystem services: A case study of grasslands. *Plant and Soil Science*, 14(4), 45-60. doi: 10.31548/plant4.2023.45.

[17] Martin, W.C., & Wiese, W.L. (1996). Atomic spectroscopy. In C.W.F. Drake (Ed.), *Atomic, molecular, & optical physics handbook* (pp. 131-153). Woodbury: American Institute of Physics.

[18] McCarthy, L.J., & Russo, A. (2023). Exploring the role of nature-based typologies and stewardship schemes in enhancing urban green spaces: Citizen perceptions of landscape design scenarios and ecosystem services. *Journal of Environmental Management*, 346, article number 118944. doi: 10.1016/j.jenvman.2023.118944.

[19] McPhearson, T., *et al.* (2022). A social-ecological-technological systems framework for urban ecosystem services. *One Earth*, 5(5), 505-518. doi: 10.1016/j.oneear.2022.04.007.

[20] Moskalchuk, N., & Orfanova, M. (2024). Greening of territories in the system of planning and improvement of the city of Ivano-Frankivsk. *Ecological Safety and Balanced Use of Resources*, 15(1), 75-86. doi: 10.69628/esbur/1.2024.75.

[21] Nissim, W.G., Castiglione, S., Guarino, F., Pastore, M.C., & Labra, M. (2023). Beyond cleansing: Ecosystem services related to phytoremediation. *Plants,* 12(5), article number 1031. doi: 10.3390/plants12051031.

[22] Pandey, B., & Ghosh, A. (2023). Urban ecosystem services and climate change: A dynamic interplay. *Frontiers in Sustainable Cities*, 5, article number 1281430. doi: 10.3389/frsc.2023.1281430.

[23] Pereira, P., Yin, C., & Hua, T. (2023). Nature-based solutions, ecosystem services, disservices, and impacts on well-being in urban environments. *Current Opinion in Environmental Science & Health*, 33, article number 100465. doi: 10.1016/j.coesh.2023.100465.

[24] Plaku, R. (2022). Greenification of dense neighborhoods through pocket parks - Inspiring small spaces to transform cities: the case study of Tirana, Albania. In A.L. Pisello, I. Pigliautile, S.S.Y. Lau & N.M. Clark (Eds.), *Building resilient and healthy cities: A guide to environmental sustainability and well-being* (pp. 131-147). Cham: Springer. doi: 10.1007/978-3-031-33863-2_10.

[25] Pretzsch, H., Moser-Reischl, A., Rahman, M. A., Pauleit, S., & Rötzer, T. (2023). Towards sustainable management of the stock and ecosystem services of urban trees. From theory to model and application. *Trees*, 37, 177-196. doi: 10.1007/s00468-021-02100-3.

[26] Probability and statistics topics index. (n.d.). Retrieved from https://www.statisticshowto.com/probability-and-statistics/.

[27] Reynolds, H.L., Mincey, S.K., Montoya, R.D., Hamlin, S., Sullivan, A., Thapa, B., Wilson, J., Rosing, H., Jarzen, J., & Grove, J.M. (2022). Green infrastructure for urban resilience: A trait-based framework. *Frontiers in Ecology and the Environment*, 20(4), 231-239. doi: 10.1002/fee.2446.

[28] Romanchuck, L.D., Fedonyuk, T.P., & Fedonyuk, R.G. (2017). Model of influence of landscape vegetation on mass transfer processes. *Biosystems Diversity*, 25(3), 203-209. doi: 10.15421/011731.

[29] Semeraro, T., Scarano, A., Buccolieri, R., Santino, A., & Aarrevaara, E. (2021). Planning of urban green spaces: An ecological perspective on human benefits. *Land*, 10(2), article number 105. doi: 10.3390/land10020105.

[30] Sevianu, E., Maloş, C.V., Arghiuş, V., Brişan, N., Bădărău, A.S., Moga, M.C., Muntean, L., Răulea, A., & Hartel, T. (2021). Mainstreaming ecosystem services and biodiversity in Peri-urban Forest Park creation: Experience from Eastern Europe. *Frontiers in Environmental Science*, 9, article number 618217. doi: 10.3389/fenvs.2021.618217.

[31] Tapsuwan, S., Marcos-Martinez, R., Schandl, H., & Yu, Z. (2021). Valuing ecosystem services of urban forests and open spaces: Application of the SEEA framework in Australia. *Australian Journal of Agricultural and Resource Economics*, 65(1), 37-65. doi: 10.1111/1467-8489.12416.

[32] Ungaro, F., Maienza, A., Ugolini, F., Lanini, G., Baronti, S., & Calzolari, C. (2022). Assessment of joint soil ecosystem services supply in urban green spaces: A case study in Northern Italy. *Urban Forestry & Urban Greening*, 67, article number 127455. doi: 10.1016/j.ufug.2021.127455.

[33] Vargas-Hernández, J.G., Pallagst, K., & Zdunek-Wielgołaska, J. (2023). Urban green spaces as a component of an ecosystem. In S. Dhiman (Ed.), *Sustainable development and environmental stewardship: Global initiatives towards engaged sustainability* (pp. 165-198). Cham: Springer. doi: 10.1007/978-3-031-28885-2_8.

[34] Vidal, D.G., Dias, R.C., Teixeira, C.P., Fernandes, C.O., Filho, W.L., Barros, N., & Maia, R.L. (2022). Clustering public urban green spaces through ecosystem services potential: A typology proposal for place-based interventions. *Environmental Science & Policy*, 132, 262-272. doi: 10.1016/j.envsci.2022.03.002.

[35] Wessels, N., Sitas, N., Esler, K.J., & O'Farrell, P. (2021). Understanding community perceptions of a natural open space system for urban conservation and stewardship in a metropolitan city in Africa. *Environmental Conservation*, 48(4), 244-254. doi: 10.1017/S0376892921000345.

[36] Wood, S.L.R., & Dupras, J. (2021). Increasing functional diversity of the urban canopy for climate resilience: Potential tradeoffs with ecosystem services? *Urban Forestry & Urban Greening*, 58, article number 126972. doi: 10.1016/j.ufug.2020.126972.

[37] Yerzhanova, A.E., Kerimkhulle, S.Y., Abdikerimova, G.B., Makhanov, M., Beglerova, S.T., & Taszhurekova, Z.K. (2021). Atmospheric correction of landsat-8 / Oli data using the flaash algorithm: Obtaining information about agricultural crops. *Journal of Theoretical and Applied Information Technology*, 99(13), 3110-3119.

[38] Zanzi, A., Andreotti, F., Vaglia, V., Alali, S., Orlando, F., & Bocchi, S. (2021). Forecasting agroforestry ecosystem services provision in urban regeneration projects: Experiences and perspectives from Milan. *Sustainability*, 13(5), article number 2434. doi: 10.3390/su13052434.

[39] Zhang, F., & Qian, H. (2024). A comprehensive review of the environmental benefits of urban green spaces. *Environmental Research*, 252, article number 118837. doi: 10.1016/j.envres.2024.118837.

Роль міських зелених насаджень і деревних насаджень у покращенні екосистемних послуг і стійкості міст

Ермір Шахіні

Доктор економічних наук, доцент
Університет Олександра Мойсіу в Дурресі
2001, вул. Курріла, 1, м. Дуррес, Албанія
https://orcid.org/0000-0002-0083-1029

Елті Шахіні

Доктор наук з державного управління, викладач
Університет Олександра Мойсіу в Дурресі
2001, вул. Курріла, 1, м. Дуррес, Албанія
https://orcid.org/0009-0004-8299-4236

Анотація. Метою дослідження була кількісна оцінка впливу міських зелених насаджень на якість повітря, мікроклімат та кліматичну стійкість міст. У дослідженні проаналізовано вплив міських зелених насаджень на якість повітря, регулювання мікроклімату та підвищення стійкості міських територій до кліматичних загроз. У статті було проведено комплексний аналіз існуючих зелених зон у п'яти найбільших містах Албанії: Тирані, Дурресі, Шкодері, Влорі та Ельбасані. Для оцінки екосистемних послуг зелених зон були проаналізовані вимірювання концентрації забруднюючих речовин (CO_2, NO_2, SO_2, CO, PM2.5, PM10), температури, вологості, а також склад ґрунту та його здатність утримувати забруднюючі речовини. Результати показали, що в зонах з високою щільністю зелених насаджень концентрації NO_2 та PM2.5 були знижені на 30-50 %, що свідчить про значну здатність дерев до фільтрації повітря. Вимірювання температури показали, що паркові зони мають на 4-7 °C нижчу температуру, ніж щільно забудовані райони, що підтверджує їхню роль у пом'якшенні ефекту міського теплового острова. Крім того, аналіз ґрунту показав зниження вмісту Pb, Cd і Hg на 15-25 %, що свідчить про здатність зелених зон до природного очищення навколишнього середовища. Зелені зони також утримують 20-40 % опадів, зменшуючи ризик підтоплення та збільшуючи водоутримуючу здатність ґрунту. Результати дослідження підкреслили необхідність інтеграції природоорієнтованих рішень у систему міського управління для підвищення стійкості міського середовища. Отримані дані можуть бути використані для розробки рекомендацій щодо сталого міського планування та обґрунтування екологічно орієнтованих підходів до розвитку міських територій

Ключові слова: забруднення атмосфери; фільтрація повітря; природні рішення; ландшафтне планування; захист ґрунтів