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Urban Microclimate In Relation To Urbaniza-Tion And Urban Greening Of Tirana City

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Abstract
Urban microclimates comprise indicators that affect local climate and environmental conditions, impacting public health and quality of life. Given the expansion of cities, population growth, varied building types, informal urbanization, increased transportation, and reduced green spaces, questions arise about the relationship between microclimates, urban green spaces, and urbanization forms. Are these microclimate indicators and their influencing factors integrated into the urban planning process? Issues like greenhouse gas emissions, rising temperatures, lower air humidity, and inadequate urban greenery capacity suggest the need for a comprehensive approach.

The primary challenge we address in our methodological framework is to identify the interconnected relationships between urban greening, urbanization, and microclimate indicators. Using a GIS-based methodology combined with field observation, we aim to clarify these connections. This framework involves evaluating urban greenery within Tirana's administrative units, measuring microclimate indicators, and assessing pollutant discharge across different land cover types, while considering variations in building typologies and green spaces.

Preliminary results show significant differences in microclimate indicators across various locations within Tirana, with maximum temperature disparities of 6-8 degrees Celsius during the summer, air humidity variances of 25-30%, variations in solar radiation, and greenhouse gas emissions. Optimal microclimate conditions are found within green spaces. These early findings underscore the importance of incorporating urban microclimate indicators into urban planning, action plans, and short- and long-term strategies to foster sustainability and increase green areas in line with EU standards.

Future research will expand this topic by including additional indicators, drawing from the experiences of European cities that have installed green infrastructure to reduce atmospheric pollutants and improve urban microclimates. This study will highlight key findings on the relationships and effects of urban greenery and urbanization patterns on microclimate indicators, as well as offer strategies to mitigate environmental and public health impacts.

Keywords
microclimate, green surface, urbanization, urban heat islands, urban sustainability, GIS

INTRODUCTION

The urban microclimate includes indicators that influence local climate and environmental conditions, affecting the health and quality of life of residents. Factors such as city expansion, population growth, urbanization, transportation, climate change, shifts in land use, and the reduction of urban greenery have significant environmental and health consequences. This is due to the increase in greenhouse gases, air temperature, changes in air humidity levels, and other microclimatic indicators. This study aims to answer research questions and analyze the connections between urbanization, urban greenery, and microclimate indicators to mitigate their impact on the environment and public health. Interest in the urban microclimate is growing, with architects, planners, environmentalists, and landscape specialists increasingly focusing on the topic. However, microclimate indicators are still insufficiently integrated into the urban planning process. This study also seeks to explore correlations, balances, and the incorporation of these indicators in urban planning.

The subject of urban development and urbanization is prominent in global literature. For instance, Vinayak et al. (2022) observe that "expanded urban regions transform natural surfaces into urban areas, affecting various physical and biophysical properties, such as evapotranspiration, albedo, emissivity, anthropogenic heat flux, wind speed, and air pollution." These changes can alter both local and regional climates in the long term (Vinayak et al., 2022).

Our collected data, to be analyzed in the results chapter, reveal connections between urbanization, traffic congestion, and urban greenery in affecting carbon dioxide emissions, temperature, and humidity levels. Environmental conditions in Tirana, including rising temperatures, decreasing humidity, and pollution from multiple urbanization sources, are negatively impacting residents' quality of life. To assess whether urban greenery effectively reduces pollutants, we have gathered data on microclimate, greenery, and urbanization as key indicators.

The formation of urban heat islands, influenced by rising local temperatures, is documented by Geo Factsheet (1998): "Recent research on London's heat island suggests that high levels of air pollution reduce daytime temperatures by blocking solar radiation, yet trap heat at night within urban areas" (Geo Factsheet, 1998). Urban areas, particularly during summer, experience higher temperatures than rural areas due to factors like industrial activities, housing, and vehicular emissions that generate heat and pollution. Air pollution in urban areas also impedes the radiation process. Infrastructure materials such as concrete, glass, brick, and asphalt absorb substantial heat and release it slowly at night, impacting the urban microclimate. Additionally, evaporation and transpiration processes are higher in urban areas. Amer et al. (2023) explore the relationships between urban trees, their biomass as carbon stores, and their shading potential.

Research by Buyadi et al. (2013) on the effects of vegetation growth on land surface temperatures in urban areas finds a "strong negative correlation between land surface temperature and urbanization, indicating that vegetation helps reduce temperature" (Buyadi et al., 2013). The role of urban greening in mitigating urban heat islands is receiving increased attention. Vegetation affects microclimate conditions and human comfort by moderating temperature. "Green areas provide ecosystem services, including carbon sequestration, energy savings, and recreational value" (Gómez-Baggethun & Barton, 2013).

The release of carbon dioxide into the environment depends on industrial activities, traffic, and the level of vegetation cover. Reduced urban forests and other factors have increased atmospheric carbon concentrations over time. Fares (2017) notes, "The atmospheric concentration of carbon dioxide has increased dramatically since the start of the industrial revolution. From 280 ppm in 1870, the global average surpassed 400 ppm in 2013" (Fares, 2017).

Major global issues such as global warming, climate change, flooding, droughts, desertification, urban heat islands, and urbanization are affecting the current environment. Addressing these challenges requires collaboration among researchers and urban planners. Takebayashi & Masakazu (2020) define the urban heat island as a phenomenon where urban areas are significantly warmer than surrounding rural areas due to human activities.

International literature acknowledges that climate concerns and mitigation strategies are particularly relevant to existing building stocks. Winker & Rudolph-Cleff (2019) present Germany's approach, emphasizing that "urban development tools in established districts—with competing demands—are increasingly important in urban regeneration and planning". They highlight that for urban areas, "preserving cold-air areas, large open spaces, forested areas, connected parks, green spaces, rivers, open water bodies, artificial water surfaces, and large-scale retention areas are crucial design elements".

LITERATURE REVIEW

In recent years, architects, landscape planners, urban planners, and environmentalists have increasingly focused on studying and publishing about the impact of urbanization on the urban microclimate. Efforts have also been made to conduct comparative tests and create scenarios to identify factors such as land use changes, urban heat waves, and urban heat islands. Additionally, there has been some progress toward drafting specialized protocols. However, a review of the literature reveals disagreements, ambiguity, a lack of interdisciplinary cooperation, and challenges in gathering comprehensive information. Among the key suggestions regarding the urban microclimate is the connection between urbanization patterns and the greening of building facades, which helps mitigate the summer heat load.

METHODS

Our methodology integrates a multidisciplinary set of analytical techniques and data sources to explore the connections between microclimate parameters, urban greening, and urbanization in the city of Tirana. Initially, we acquired geographical data, including administrative boundaries, land use, and structural units, from the State Authority for Geospatial Information (ASIG). This dataset forms the foundation for our spatial and statistical analysis.

The land use dataset provides detailed information on how land is distributed and utilized in different areas, which is crucial for identifying patterns of urbanization, conservation, and resource management. The structural unit's dataset offers insights into the number and types of buildings, as well as parameters like land use coefficients, building density which will be defined and used in later stages of the analysis to assess urban form and development patterns. Additionally, tree data, obtained from the National Agency of Planning Territory (AKPT) and the General Greening Directorate of Tirana Municipality, was integrated into our database. Any missing green space data identified from orthophoto was digitized and added, ensuring a complete representation of Tirana's urban greening.

Our research methodology emphasizes a combined use of spatial and statistical modeling, field measurements, and urban green infrastructure assessment to clarify the intricate relationships between these factors and microclimate dynamics in Tirana. We specifically assessed differences in microclimate indicators such as CO_2 concentration, temperature, and humidity across various urban settings, (including shaded areas, sunny spaces, and regions with varying levels of urban density and green coverage). Air pollution indicators were compared with national standards. Measurements were conducted using a Testo environmental instrument, collecting data at multiple locations while considering different building types, densities, and distances. This configuration accurately reflects the complex urban structure and green space distribution across Tirana.

We employed the Pandas library in Python to conduct correlation analyses between CO_2 concentration, temperature, and humidity in order to clarify their relationship. The data was further analyzed using ArcGIS 10.8, which was utilized to create visualizations and charts, mapping out spatial patterns and connections between land use, urban greening, and microclimate data. The ArcGIS platform is used to generate maps, land-use overlays, and proximity analyses to visually represent spatial patterns in urban greening and building density, while the Pandas library in Python assists in data manipulation and correlation analysis on the tabular data. This combination of tools provides comprehensive insights drawn from both spatial and tabular data sources, facilitating well-informed urban planning and resource management decisions.

By going beyond descriptive analysis, this methodology leverages empirical research, practical field measurements, and data visualization to offer actionable insights. Our ultimate objective is to support urban resilience and sustainability by integrating evidence-based strategies into urban greening initiatives, while mitigating the adverse effects of urban microclimates.

RESULTS AND DISCUSSION

Urbanization and trends of microclimate indicators

In this result the focus will be on the relationship with urbanization. Compared to the year 1990, the city of Tirana now has a population about three times larger and is located on a surface area of 41.8 km2. One of the challenges that the city continues to face is finding ways to mitigate the impacts of rapid and chaotic informal development, without careful spatial planning and disregard for urban planning laws. This development has led to the loss of green spaces and increased air pollution. The indicators of microclimate are crucial in assessing the impact of mistakes on territorial planning, cementing, informal urbanization, traffic, relationships with urban greenery, changes that modify local climates, environmental conditions, and their influence on the quality of life and population health. The worst case of urban informality in the city of Tirana took place during the period of 1992-1997, with the construction of numerous slums (kjoska) in the centre and suburbs of the city, when 33% of the green surfaces were seriously damaged or eliminated (figure 1 and 2). The construction impacted also the Lana River, which was affected by the pollution and lost its function. Furthermore, after the demolition of the slums, thousands of tons of inert material were transported, resulting in significant financial loss.

Figure 1. Constructions along the Lana River 1992-1997

Figure 2. Lana River, 2014

In the publication ALBANIA 2030 Manifesto, after a detailed analysis of development and planning, the authors, architects and urban planners, recommend that "a national spatial plan, it should be connected with other plans on a smaller scale with spatial importance for the country, which elaborate in more detail with sectoral issues such as: infrastructure plans, land use plans, sustainable development, environmental plans, social-economic development plans, etc. (Aliaj, Janku, Allkja, Dhamo, 2014). First of all, from this point of view, enough data that we have analyzed in this article strengthen our opinion that the indicators of the urban microclimate are influenced by urban forms, distances between buildings, building design, infrastructure, land use changes, human activities, density, building materials, which absorb and release the heat of the atmosphere, urban transport, which discharges carbon dioxide as a greenhouse gas with a fundamental impact on global warming. In cities, temperatures are higher, compared to rural areas around them, as the effects of land use change replace the natural cover with layers that absorb solar energy and change the temperature of the environment. Urban greening and its role in the urban microclimate cannot be reduced as a goal in itself, but as a complex, harmonious and multi-purpose relationship with the city, community, public health, relaxation, shading, reduction of environmental pollution and mitigation of climate change. Through direct temperature measurements on March 2024, during midday, at several points on the asphalt on "Barikadave" street, the air temperature was within the limits of 29.1-32.4 degrees Celsius and the air humidity was 29.5%. While at a distance of 100 m below the pines of the flower garden, 25.7-27.8 degrees Celsius and humidity 60.9 -71 %. The same difference is found in this comparison in other points of Tirana measured on the same day. The temperature varies from 16.2 – 18.4 degrees Celsius at the Grand Park of Tirana at midday, regarding to the greenery in this area. The urban microclimate significantly impacts the energy consumption of buildings for cooling during heatwave conditions.

In areas with high density buildings or a little distance between them, and without corridors to allow air circulation, the concentration of CO2 was significantly high. This was particularly observed at “Liqeni i Thate”. Additionally, the temperature ranged from 16.3 to 20.3 degrees Celsius due to the presence of vegetation, while the concentration of CO_2 varied between 367 and 371 ppm (figure 3). However, the measured points where there is a high density of buildings but there are distances between the buildings the temperature varies from 18.4-20.4 degrees Celsius.

In these areas was also the presence of vegetation. At 20.4 degrees Celsius the temperature was measured on the asphalt. In the points where there is a high density of buildings but there are no air circulation corridors, the carbon points vary from 350-383 ppm, the temperature 18-21.1 degrees Celsius and the humidity 42.2-45%. The highest levels of carbon are observed in critical traffic areas, which vary from 470 ppm to 506 ppm. The temperature on the asphalt varies from 22 - 24 degrees Celsius. The humidity ranges from 33.6%- 40.7%. There is a notable correlation between urbanization and microclimate variables.

The study by Chaosu Li, "Urban Building Energy Consumption/Microclimate Tools and Models" (2018), examines the relationship between urbanization and microclimate by introducing models for urban microclimates. The models produce outputs such as energy heat balance generated by buildings and air temperature. They rely on various data inputs related to urban and building design, including number of floors, building materials, reflectivity, cover type, soil condition, heat generation and transfer by buildings, roof material or cover type, as well as meteorological factors such as solar radiation, regional temperature, humidity, and wind velocity (Tanimoto et al., 2003).

A case study was also conducted to assess the microclimatic effects of urbanization in a metropolitan region of India, projecting changes up to the year 2050. This study integrated land use and land cover models for 2018 and 2050, while keeping meteorological conditions consistent (Vinayak B, Lee H, Gedam S, Latha R).

By comparing simulated outcomes to identify potential adverse microclimatic effects arising from future urban development under three different scenarios, the authors indicate that, without implementing a mitigation strategy, urban centers could experience a temperature increase of 4.9–5.5 degrees Celsius by 2050.

However, this increase could be reduced by 1–1.7 degrees Celsius if mitigation strategies are applied. The authors further recommend that, in the future, the integration of various gridded urban parameters such as building height, anthropogenic heat flux, and air pollutants, which affect the local climate will be essential.

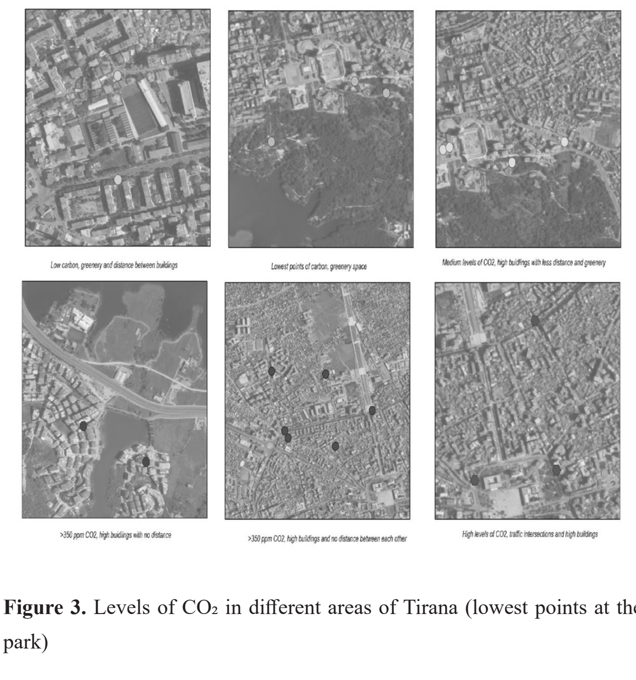

Figure 3. Levels of CO_2 in different areas of Tirana (lowest points at the park)

Air pollution and urbanization factors

However, air quality has improved in comparison to 1990 in several indicators, but it still remains a persistent problem. The main cause of CO_2 emissions is both public and private transportation, the high number of vehicles, the flow of traffic without proper management, and the urbanization typology. The number of critical points, particularly for intersections/interchanges at junctions, major intersections of the city roads, is very high, indicating a high concentration of carbon dioxide emissions. The measurements we conducted in the months of February and March 2024 in the city of Tirana confirm the correlation between carbon emissions, air temperature, and air humidity with traffic flow, land coverage, and urbanization patterns (figure 4).

The data show that in the months of February and March, out of 50 measuring points, in 26 of them the concentration of carbon dioxide is above the allowed standard (350 ppm). The highest concentration is mainly in the center of Tirana, the ring of Tirana (intersection of Don Bosco and Zogu Zi), “Elbasani” street and “Barikadave” street at urban bus stations. While the concentration is the lowest in the Great Park of Tirana, of 297 ppm, due to its urban greenery and lack of cars (figure 3). In other measurements of the concentration of carbon dioxide in Tirana, it has been found that in the summer months, which are characterized by a drastic decrease in rainfall and severe drought, the differences in the concentration of carbon dioxide, temperature and air humidity between the measurement points are greater sensitive and has the highest impacts. So, the measurements at "Tirana International Hotel", shows that the amount of CO_2 is on average 500 ppm; relative humidity 22% and temperature 38 degrees Celsius. (Lushaj, Aliaj, 2018).

The high level of carbon dioxide in the city of Tirana is primarily caused by the large number of resident vehicles, the inflow and outflow of private and public vehicles from other areas, the dominance of oil-powered vehicles, a significant number of old vehicles, chaotic traffic, congestion in the underpass passages and lack of green spaces. At the national level, in 2023, the total number of motor vehicles is 28 % higher than in 2020, of which 81 % are automobiles. The Municipality of Tirana possesses 34.8 % of the total number of vehicles of all types and 31 % of automobiles of country (DSHTRRR,2023). About 80 % of total number are automobiles, over 56% are over 15 years old, and 81 % run on powered by oil contributing to carbon dioxide emissions and other pollutants. In recent years, the Municipality of Tirana has introduced the use of around 1500 electric and another hybrid vehicles.

In Administrative Unit 9, located north of the National Museum, residential spaces lack green surfaces, and the area experiences high traffic flow. This contributes to elevated temperatures (figure 5). Tirana features a diverse range of housing typologies. In Unit 9, which covers approximately 283 hectares, building types are distributed as follows: individual/connected/linear/tower structures occupy 21% of the area; linear/perimeter/tower structures, 52%; perimeter structures, 24%; and tower structures, 3%. These building typologies have a direct impact on microclimate indicators.

At the measurement points on March 14-15, humidity in these areas ranged from 32.9% to 52.9%, while temperatures varied from 17.9 to 22.9 degrees Celsius. It is noteworthy that some points were measured in shaded areas or near trees, while others were taken on asphalt or at intersections. The highest concentration of carbon dioxide (472 ppm) was recorded on the sidewalk behind the museum, attributed to the high volume of car traffic in this area.

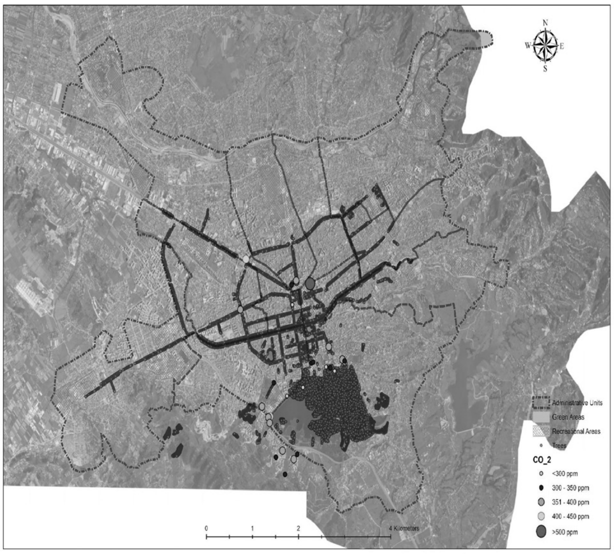

Figure 4. The levels of CO_2 on field measurements

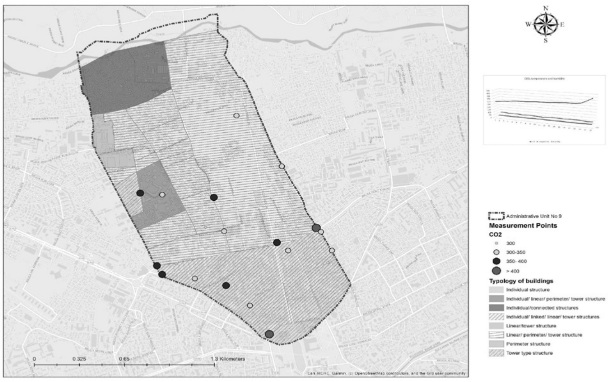

Figure 5. Correlation of high CO_2, building typology and temperature

The correlation coefficient between CO_2 levels and temperature is approximately -0.372, indicating a moderate negative correlation. While correlation coefficient between CO_2 levels and humidity is approximately -0.266, indicating a weak negative correlation. While on in March 2024, on the all location the temperature increases, humidity is low. This suggests that as temperature increases, humidity is low.

Urban Greening and its role in improving microclimate

In the context of the spatial expansion of the city of Tirana and the population growth of around 682,187 thousand inhabitants, the projections of climate change with increasing temperatures and decreasing precipitation levels will also have further impacts on microclimate indicators and the population.

The maximum average air temperature in Tirana in 2020 was 2.6 degrees Celsius higher than the 30-year average from 1961 to 1990, while in 2021 it was +2.3 degrees. Unfortunately, the reports on urban development indicate poor levels of intensity and typology of buildings, as well as a lack of balance between concrete and green spaces. Urban greening and traffic management for reducing greenhouse gas emissions and mitigating environmental temperature receive special attention. In the city of Tirana, throughout the past 33 years, which marked the period of transition, there has been a rapid and chaotic urbanization, accompanied by a reduction in green spaces for residents, ecological corridors, and the release of greenhouse gases into the atmosphere. The built-up area covers 940 hectares from the last data updated. Currently in the Tirana city there is only 3.5 m2 of green space per inhabitant (figure 6). There is a lack of green space referring to build up area.

Urban greening is a key factor for sustainable urban development and as part of urban planning in cities and inhabited centers. Greenery in urban areas, through transpiration, releases water vapor, creating a soil-plant-air relationship that increases air humidity, reduces temperature, and cools the urban environment, improving microclimate and urban city cooling. Based on the measurements taken on March 29, 2024, at two specific points near the "Zogu i Zi", the air humidity was recorded as 34.2% in sunlight and 46.6% in shade. In their publication, the authors state that land use transformation is a common occurrence in cities worldwide (Gaitani et al., 2011), which results in increased intensity and decreased frequency of precipitation, leading to urban flood hazards (Lal et al., 2020) (Upreti M., Kumar A., 2024).

Urban greenery plays a distinct role in public health. In 2019, researchers from the WHO and the University of Colorado discovered that for every 0.1 increase in the normalized vegetation index within a 500 square meter inhabited area, premature mortality decreased by 4%. This is attributed to urban greening, improvement in environmental and living conditions, as well as a reduction in air pollution (Lushaj, Muharremaj, 2018). The greening of European cities has increased by 38% during the past 25 years. Air pollution is associated with heavy traffic and the reduction of green surfaces. In the year 1990, the city of Tirana had an average of 12.5 m2 of green space. From 1991 there is an increasing trend of green spaces being covered with concrete.

The expansion of green areas, including urban forests, parks, gardens, tree planting, rooftop gardens, vertical greening, urban agriculture, and other forms of greening, should remain a significant objective in Tirana's urban greening efforts. Although the Great Park of Tirana's Lake, with its 159 hectares of forested area, is the largest green space in Tirana and regulates the microclimate, Tirana needs to expand urban greening in its public open spaces and in new areas of urban expansion.

At eight critical traffic congestion points, carbon content

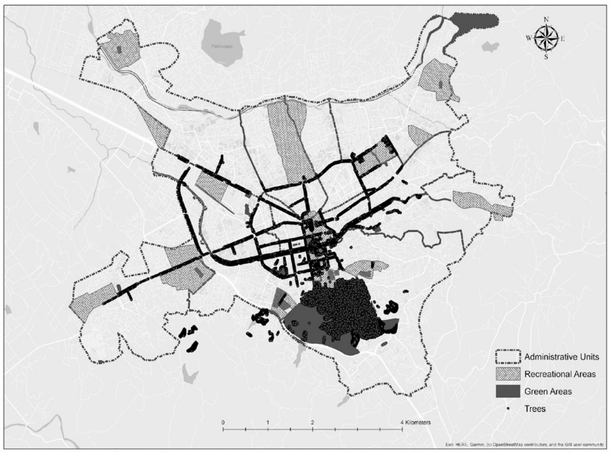

Figure 6. Distribution of green space in the city of Tirana

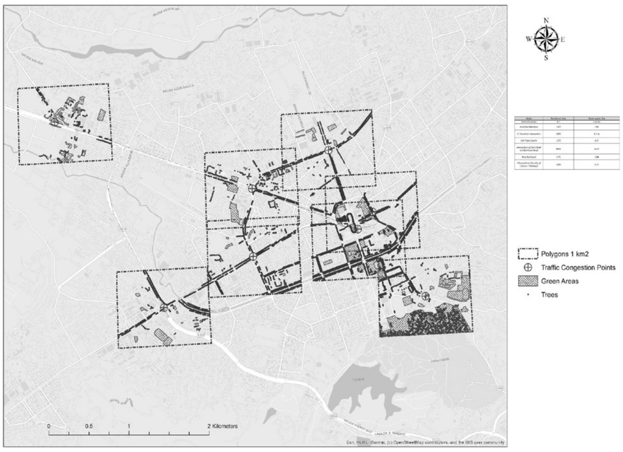

Figure 7. Green spaces around critical traffic congestion points within 1km2 area

ranged from 417 to 507 ppm, accompanied by high temperatures and low air humidity (figure 7). The measurement points included Kamza and Kombinati Overpass, Karl Topia Square, "21 December", the former "Train Station" and the intersection of "Dibra Road" and "Barrikadave" Road. Using GIS, we assessed the amount of vegetation cover for a 1 km² area at each point, which included 36 hectares of green spaces and fruit trees in urban gardens (an average of 4.5 hectares per km²). By leveraging GIS data to measure green surface area and tree density alongside critical environmental factors like carbon content, temperature, and humidity at traffic congestion points, urban planners can gain valuable insights into the efficacy of urban greening initiatives. This data allows decision-makers to identify areas most in need of intervention and prioritize efforts to improve urban microclimates. By strategically implementing green infrastructure, such as increasing green spaces and tree canopy coverage, cities can effectively mitigate pollution, reduce the urban heat island effect, and create healthier, more livable environments for residents.

Inclusion of microclimate indicators in Urban Planning

The challenges related to integrating microclimate knowledge into urban planning over the past decade have been extensively addressed in numerous published works. The inclusion of environmental indicators in urban planning is increasingly seen as essential for designing public spaces, enhancing urban greening, guiding urbanization, and improving quality-of-life parameters. Although environmental aspects of microclimates—such as the effects of urban heat islands, air quality, temperature, humidity, wind, and other microclimate conditions—are acknowledged in studies, their practical use in planning remains limited. This limitation arises from the lack of a unified protocol that facilitates collaboration between designers, architects, environmentalists, meteorologists, and urban planners.

Mills underscores the importance of embedding environmental goals into urban plans across different levels of governance. He emphasizes the need for applied climatology, which would enable urban development decisions to account for the relationship between design choices and climate outcomes. For this integration to succeed, a suitable form of climatological knowledge must be incorporated into urban planning processes (Ravnikar Z, et al., 2023). Although Spain and Slovenia have developed protocols for collecting microclimate data—with a primary focus on assessing roads in relation to microclimate conditions and exploring the potential of the collected data for urban planning—debates, misunderstandings, and limited expansion of these methods persist. In Albania, certain microclimate elements are considered in urban planning, but the integration remains in its early stages.

However, the microclimate is not yet a fully sustainable and controlled system in urban areas through the analysis and implementation of measures aimed at improving the quality of life. When examining other impacts, it is noted that extreme weather conditions can cause microclimates to quickly exceed typical boundaries. For instance, heat waves can significantly raise microclimate temperatures, resulting in detrimental effects (Mislan, 2008). Other studies suggest that "the greening of inner courtyards creates an attractive residential environment" that improves urban microclimates, reduces urban heat islands, and retains water. Additionally, incorporating water features such as playgrounds and fountains in public spaces offers further cooling benefits (Einker M, Rudolph A, 2019).

Globally, to reduce the impacts of climate change and improve urban microclimates, efforts focus on green city initiatives, including greening urban spaces and buildings with green roofs and walls. Sustainable building designs and urban forms aim to mitigate the adverse effects of microclimates.

At the core of green city planning is the goal of cooling - mitigating heat waves and reducing the formation of urban heat islands. Trees and grass play a crucial role in cooling urban areas. Landscape designers should select tree species that absorb more pollution and provide extensive coverage, ideally matching the height of buildings. According to Richter, "Forest ecosystems effectively buffer climate extremes and mitigate climate change effects below the canopy, creating a distinct microclimate with significant temperature differences between ambient air and the area within and below the canopy. Globally, understory temperatures in forests have been found to be, on average, 1.7 ± 0.3 degrees Celsius cooler (mean) and up to 4.1 ± 0.5 degrees Celsius cooler (maximum) than ambient temperatures—greater than the global warming observed over the past century."

Figure 8. Vertical greening of the Tirana building, 2024

Figure 9. Green roof Tirana

What Tirana needs, both now and in the future, is the integration of microclimate indicators in urban planning, greater collaboration among key stakeholders, the expansion of green spaces, and the creation of a consolidated database of essential data. A national-level in-depth study is required, one that unites institutions, environmental and planning agencies, expertise, policymakers, and decision-makers in developing a long-term strategy for the "effects of urban greening." This strategy should aim to achieve EU green space standards per capita. Additionally, policies related to transportation should be reviewed to promote the expansion of alternative transport modes and the gradual reduction of diesel and gasoline vehicles. There should also be standardized inclusion of microclimate indicators in urban planning and design aspects. Involvement from universities is essential for conducting in-depth research on themes like maintaining ventilation corridors, controlling pollutant emission standards from transportation, industry, and services, and promoting alternative energy production.

CONCLUSIONS

Through an analysis of field measurements of carbon dioxide levels, temperature, and air humidity, combined with GIS data on building density, we identified several factors influencing the microclimate in Tirana. These factors include shifts in local climate and environmental conditions and correlations between urban climate, greening, and urbanization.

Significant variations in air humidity, carbon dioxide levels, and temperature were observed across 50 measurement sites in February and March 2024. These discrepancies are influenced by location, traffic congestion, urban density, and the layout of air circulation corridors.Out of 26 measurements, CO_2 concentrations exceed the allowed limit. However, in Tirana's Great Park, CO_2 concentration was measured at 297 ppm, the lowest recorded level, which is within the acceptable range. The city center, particularly areas such as Karl Topia Square, Elbasani Road, Barikadave Road, and the overpasses near major urban road intersections, exhibits the highest levels of CO_2 concentration, temperature, and low air humidity due to vehicle emissions.

Urban green space per capita has significantly declined since 1990 due to the expansion of buildings and infrastructure, a change that substantially affects the city's heat levels. Our correlation analysis yielded meaningful insights into the relationships among temperature, humidity, and CO_2 concentration. Specifically, a moderate negative correlation between CO_2 concentration and temperature suggests that urban activities impact local climate dynamics. Additionally, a slight positive correlation between CO_2 concentration and humidity indicates potential effects on atmospheric moisture. The strong inverse relationship between temperature and humidity emphasizes the delicate balance of these microclimate elements in urban settings.

To cool the city and reduce temperatures, expanding green spaces and maintaining ventilation corridors free from surrounding activities are essential. This goal can be supported by choosing appropriate vegetation, implementing vertical greening and green floors on buildings, managing traffic, and incorporating these factors into urban planning. Adding water features and exploring alternative approaches can also positively affect urban microclimate parameters. Moving forward, microclimate indicators should be incorporated into urban planning standards. Some concerns that require further study will be addressed in future projects.

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