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Urban Heat Islands in Tirana, Albania. Analysis and Potential Solutions

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Abstract. Cities and towns are expanding and thriving as a result of urbanization, which also significantly changes the local climate. One of the most significant phenomena associated with urbanization is the Urban Heat Island (UHI) effect. This phenomenon is increasingly being studied worldwide. The paper aims to investigate the UHI phenomenon in the metropolitan area of Tirana, Albania. It analyses the impact of the UHI on four specific locations in Tirana, its causes and mitigation measures, as well as variations in surface temperature, CO2 emissions, and relative humidity. The regions are measured and observed using a specific instrument such as the Testo 435. Considering the mean surface temperature variations between urban and rural regions ranging from 28.4°C to 33.7 °C, CO2 emissions from 302.9 ppm to 416.2 ppm, and relative humidity from 34.1% to 41.2%, it is found that the UHI impact in Tirana is significant. The lack of green spaces, high building density, urban patterns, building materials used, transport, and energy use are the main contributors to the UHI in central Tirana. Increasing green spaces, using reflective materials, and promoting sustainable urban design are some of the mitigation techniques suggested to reduce the UHI effect in Tirana.

Introduction

The capital of Albania, Tirana, is experiencing the Urban Heat Island (UHI) effect due to significant urbanization. The UHI effect is the phenomenon where temperatures in urban areas are significantly higher than those in the surrounding rural areas [1]. Due to its negative impact on human health [2], energy consumption [3], and the environment, it is important to study the UHI effect on urban tissues in order to find mitigation strategies to minimize this effect.

Ongoing climate change prompts questions and reflections on the systemic status quo of our society to understand its trajectories and assess multiple future scenarios.

By 19 March 2023, the atmospheric CO2 concentration will have reached 420.62 ppm, compared to 280 ppm at pre-industrial levels, with concentrations continuing to rise. In this context, the IPCC (AR5, 2014) offers several possible scenarios for 2100 radiative forcing values (Representative Concentration Pathway or RCP) of +2.6, +4.5, +6.0, and +8.5 W/m2 compared to pre-industrial levels. Under the necessary assumptions, 421 ppm is reached with RCP2.6, 538 ppm with RCP4.5, 670 ppm with RCP6.0, and finally a doubling of current CO2 ppm to as much as 936 ppm in the RCP8.5 scenario.

This would result in significant temperature changes in the most prominent European cities over the 30-year period 2020-2050. Considering Tirana, Albania, as a case study, the maximum temperature of the warmest month is likely to increase by 3.5 °C, resulting in an average annual temperature change of 1.9 °C [4]. Tirana will experience the same temperature as the city of San Antonio, Texas, USA, currently experiences (ibid). In addition, 77% of the world's cities will have to live with climates that currently exist but at different latitudes, while 33% will have to live with entirely new climates (ibid).

According to Spano et al. (2020), climate change impacts in Italy will cost -8% of GDP per capita by 2100, in the range of +2 to +5 °C temperature increase. They will affect 56% of the population, exposing cities to heat waves and more intense rainfall. It will lead to increased health risks for citizens, with the onset of cardiovascular and respiratory problems, especially in the elderly, and will also affect the safety of infrastructure and services [5].

Cities are warmer than rural areas as a result of the urban heat island effect [6]. According to Hardy et al., around 50-60% of the world's population lives in cities [7]. Thus, the majority of the world's population is affected by the UHI phenomenon. The reduction of vegetation, the density of our cities, and hard and heat-absorbing surfaces are the main sources of the heat island effect [8]. The urban heat island increases energy consumption in summer, increases the concentration of harmful pollutants, increases CO_2 emissions, reduces indoor and outdoor thermal comfort, and affects mortality and health outcomes [9]. Various studies have shown a reduction in outdoor comfort as a result of the increase in temperature. The main interventions related to this issue to improve outdoor comfort include areas such as vegetation, water, building form, and materials.

Mahmutaj et al. (2013), in their analysis of temperature trends in Tirana from 1971 to 2000, found that the urban temperature increased by 0.03 °C per year, which was higher than the temperature increase in rural areas. The study underlines that the expansion of urban areas and the construction of new buildings were the main drivers of the UHI in Tirana. Energy consumption for air conditioning and vehicle traffic also contributed significantly to the UHI effect [10].

In light of the above, this paper aims to understand the current situation in Tirana, Albania, by assessing the contribution of public spaces in its neighborhoods to potential Urban Heat Islands (UHI). Measurements using detectors will be carried out on sidewalks in selected public areas and then placed around each other. The selected areas for measurement will be equipped with courtyards located in the inner and outer city to undermine comparisons of measured values. Mitigating and adaptive solutions will then be proposed through strategies and actions (e.g. paving the most sealed areas and planting green infrastructure). Measurements will be taken on several types of pavements in each case, on green spaces, pavements, and roads, in order to draw conclusions. This paper aims to further expand and update the topic, building on previous contributions by other authors in the field, such as Dervishi, Lakaj, and Vathi (2012), Panariti, Maliqari and Tashi (2015), Picari and Dervishi (2019) and Xhexhi (2023), in line with the Vulnerability Assessment and Adaptation Action Plan for Tirana (2015) [11].

The findings presented in the paper will be useful to support the upcoming monitoring and risk mapping of urban areas affected by flash floods, dewatering of public and private areas, and rainwater harvesting buffers. This insight into four selected neighborhoods in Tirana will also provide suggestions on which of them are most at risk, as a result of investigations conducted through interdisciplinary readings. These will target and suggest mitigation and adaptation measures to be implemented on an ongoing basis through a learning-by-doing approach. This approach is in line with the UN Sustainable Development Goals no. 3 “Ensure healthy lives and promote well-being for all at all ages”, no. 7 “Ensure access to affordable, reliable, sustainable and modern energy for all”, no. 8 “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”, no. 10 “Reduce inequalities within and between countries”, no. 11 “Make cities and human settlements inclusive, safe, resilient and sustainable”, and no. 13 “Take urgent action to combat climate change and its impacts” [12].

Research Aims. The authors aim to demonstrate that integrated approaches in the fields of architecture and urbanism, carried out by combining tools such as ground truthing during field surveys and software simulations, are useful in identifying ongoing trends in urban contexts.

Specifically, the research aims to detect quantitatively and then analyze and discuss qualitatively:

- the presence and extent of urban heat islands in metropolitan areas, specifically in Tirana, Albania, selected as a case study,
- the variations in temperature (°C), carbon dioxide concentration (CO_2), and relative humidity (%) measured on the ground on three types of pavements in pre-selected areas within the city of Tirana, which occurred over a given time period,

- some of the environmental variables composing the microclimate (i.e. temperature, relative humidity) of these pre-selected areas in order to understand recurring problems and suggest local mitigation approaches.

Materials and Methods

Study areas. The four study areas selected by the authors are all located in Tirana, Albania, whose metropolitan area had a population of 925,268 on 1 January 2023 [13]. In terms of geography, it has an altitude of 125 m above sea level and geographical coordinates of 41.3275° N and 19.8187° E. The four case studies are located in different neighborhoods, the first of which is POLIS University at 12, Rruga Bylis, Kashar (41. 352760, 19.750523), the second is the Garden City complex on Rruga Kastriotet, Kamza (41.343635, 19.778984), the third is on Jordan Misja Street (41.336376, 19.810689) and the fourth is on Kavaja Street (41.327844, 19.815855) (Figure 1).

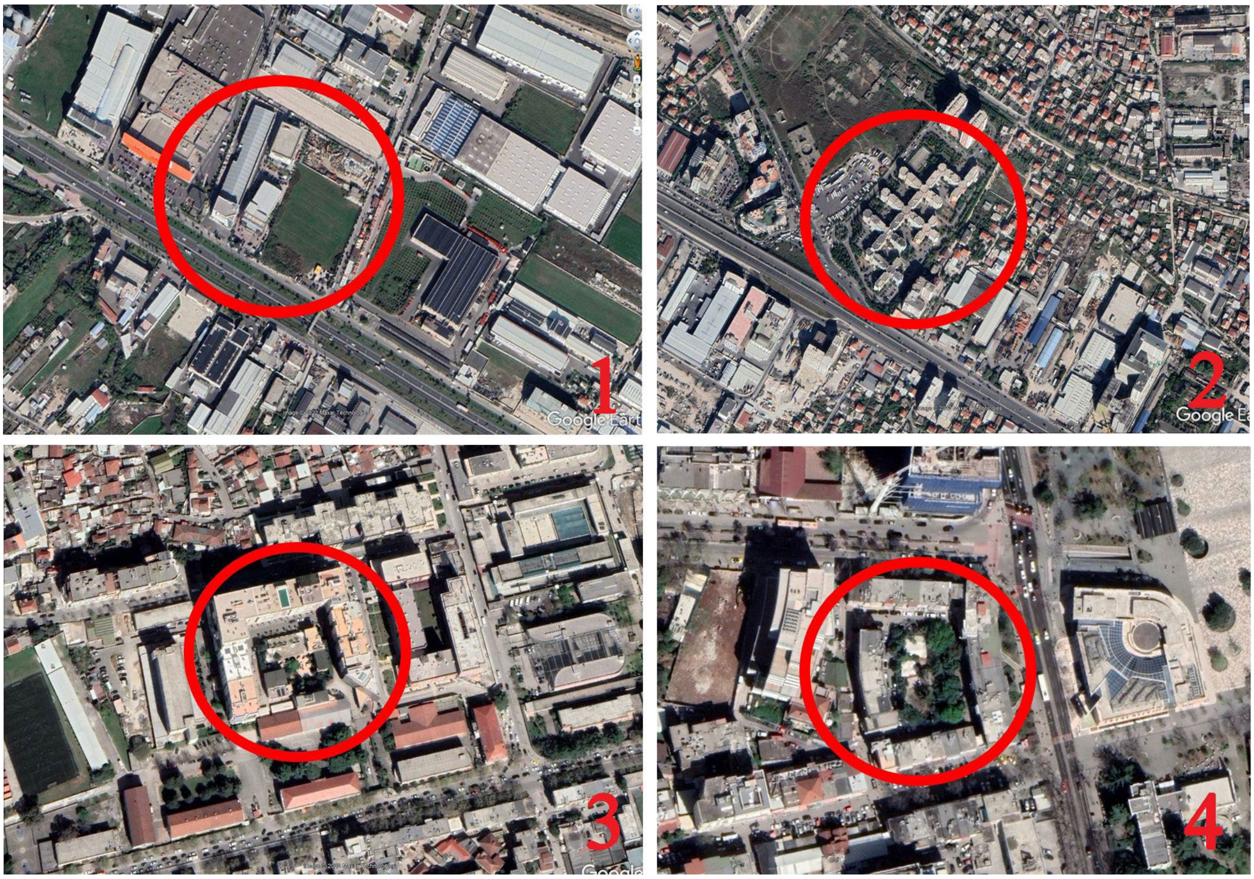

Fig. 1. The study areas in Tirana, Albania, are as follows: 1) POLIS University, Rruga Bylis 12, Kashar, 2) Garden City complex, Rruga Kastriotet, Kamza, 3) Jordan Misja Street, and 4) Kavaja Street. (Source: Google Street Map. Authors' elaboration).

Environmental detectors. The device used for the measurement is the Testo 435, manufactured by the German company Testo SE & Co. KGaA. The Testo 435 is a multi-functional indoor and outdoor air quality meter that performs a variety of different measurements, including air temperature, air flow, volumetric flow rate, humidity, lux, ambient CO_2, etc. (Figure 2).

In this study, one of the probes is used to measure CO_2 emissions into the atmosphere. The IAQ probe (order no. 0632 1535) is particularly suitable for monitoring air quality control. This probe can be used to measure CO_2, temperature, relative humidity, and absolute pressure simultaneously. This paper focuses only on the measurement of CO_2, outdoor temperature, and outdoor relative humidity in the specially selected neighborhoods of Tirana, Albania.

Fig. 2. The Testo 435 detector. (Source: Authors.)

The probe has a temperature range of 0-50 °C with an accuracy of +/- 0.3 °C, a humidity range of 0-100% RH with an accuracy of +/- 2% RH and a CO_2 range of 0-10,000 ppm CO_2 with an accuracy of 50 ppm CO_2 or 2% of mv [14].

The evaluation grid. The evaluation grid provides three possible measurements for each of the pavements considered (i.e. asphalt in public roads, self-locking tiles in footpaths, and public greenery), namely soil temperature (°C), CO_2 (ppm) and relative humidity (%). A table was used for each of the study areas shown in Figure 1 for each of the four rounds of measurements taken. Table 1 was produced by the authors using the Table command in Microsoft Word.

Table 1. The evaluation grid used for each round of field measurements. (Authors' elaboration).

<table>
<tr><td colspan="6">Location no. x (insert a number)
Replace here with the name and/or location</td></tr>
<tr><td>Day
dd/mm/2023</td><td colspan="3">Temperature on the ground
(°C)</td><td>CO₂
(Ppm)</td><td>Relative humidity
(%)</td></tr>
<tr><td></td><td>Asphalt</td><td>Sidewalk</td><td>Greenery</td><td></td><td></td></tr>
<tr><td>01</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>02</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>03</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

The four rounds of evaluation measurements. The purpose of the mentioned four rounds of field-based measurements was to determine the presence and extent of one or more Urban Heat Islands (UHIs) in Tirana, comparing the different data obtained in the four areas selected as case studies.

The first round was conducted on February 23, 2023, in the four selected areas. The weather conditions at the beginning of the session were 16 °C (H=17 °C, L=3 °C), cloudy, precipitation expected 1%, average humidity 56%, and wind 3 km/h. At the end of the session, they were 16 °C, primarily sunny, with rainfall expected at 1%, average humidity at 55%, and wind at 14 km/h. Measurements were taken on three different surfaces, namely asphalt, sidewalk, and greenery, using the Testo 435 detector (Figure 3).

Fig. 3. The sample of surfaces analyzed with the detector. From left to right, asphalt, self-locking concrete pavers, and greenery. (Source: Authors).

In the first and third rounds, the measurements were affected by the long time used by the authors to obtain the measurements, which amounted to a total of 151 minutes for the first and 180 minutes for the second and fourth areas. Only in the first round, was used only one detector for the measurements.

To obtain more accurate results, the second, third, and fourth rounds were carried out using two detectors instead of a single one, allowing the authors to undertake independently the field measurements. It also allowed the two authors to perform the measurements at the same time and therefore with greater precision for later comparison purposes. Moreover, this helped in reducing the total exposure time to an average of 63 minutes in the second and fourth rounds of measurements.

The second round was conducted in the same areas on March 23, 2023. The weather conditions at the beginning of the session were 21 °C (H=17 °C, L=3 °C), mostly sunny, with precipitation expected at 0%, average humidity at 37%, and wind at 11 km/h. At the end of the session, they were 21 °C (H=22 °C, L=6 °C), primarily sunny, with rainfall expected at 0%, average humidity at 35%, and wind at 14 km/h. Measurements were taken on three different surfaces, namely asphalt, sidewalk, and greenery, using the Testo 435 detector.

The third round was conducted on April 24, 2023, in the same selected areas. The weather conditions at the beginning of the session were 22 °C (H=22 °C, L=12 °C), cloudy, precipitation expected 8%, average humidity 32%, and wind 10 km/h. At the end of the session, they were 23 °C (H=23 °C, L=12 °C), mostly cloudy, with rainfall expected at 14%, average humidity at 39%, and wind at 10 km/h. Measurements were taken on three different surfaces, namely asphalt, sidewalk, and greenery, using the Testo 435 detector.

The fourth and last round was conducted on May 29, 2023, in the same selected areas. The weather conditions at the beginning of the session were 27 °C (H=27 °C, L=15 °C), mostly sunny, with precipitation expected at 75%, average humidity at 47%, and wind at 11 km/h. At the end of the session, they were 28 °C (H=28 °C, L=15 °C), partly cloudy, with rainfall expected at 74%, average humidity at 40%, and wind at 8 km/h. Measurements were taken on three different surfaces, namely asphalt, sidewalk, and greenery, using the Testo 435 detector.

The relative records found in the four measurement rounds are shown in Table 2 below.

Table 2. The detailed findings of the four rounds of measurements and the average values per each location and type of pavement. (Authors' elaboration).

Measurements results													
		Location no.1 Polis University			**Location no.2** Garden City Complex			**Location no.3** Jordan Misja Street			**Location no.4** Kavaja Street		
		Asphalt	Sidewalk	Greenery	Asphalt	Sidewalk	Greenery	Asphalt	Sidewalk	Greenery	Asphalt	Sidewalk	Greenery
Measurement no.1	Temperature	[21°C]	[20.5°C]	[19.1°C]	[21.4°C]	[20.5°C]	[20°C]	[20.5°C]	[20.7°C]	[18.3°C]	[18°C]	[17.5°C]	[15.7°C]
	CO_2	[380 Ppm]	[351 Ppm]	[344 Ppm]	[359 Ppm]	[363 Ppm]	[360 Ppm]	[358 Ppm]	[356 Ppm]	[352 Ppm]	[330 Ppm]	[343 Ppm]	[328 Ppm]
	Relative Humidity	[51.2%]	[55%]	[59%]	[46.3%]	[50.5%]	[60%]	[46.6%]	[46.8%]	[57.2%]	[54.2%]	[57%]	[67.5%]
Time interval and weather condition 23/02/2023		13:13-13:26 (partly cloudy/ cloudy)			13:58-14:10 (partly cloudy/ cloudy)			14:26-14:38 (cloudy)			14:54-15:04 (partly cloudy)		
Measurement no.2	Temperature	[31.8°C]	[31.7°C]	[30.4°C]	[30.1°C]	[34.3°C]	[32.4°C]	[41.5°C]	[40.3°C]	[36.5°C]	[36.2°C]	[42.5°C]	[28.1°C]
	CO_2	[306 Ppm]	[290 Ppm]	[275 Ppm]	[278 Ppm]	[276 Ppm]	[267 Ppm]	[503 Ppm]	[502 Ppm]	[494 Ppm]	[537 Ppm]	[526 Ppm]	[441 Ppm]
	Relative Humidity	[24%]	[23.8%]	[30.4%]	[25.6%]	[25.5%]	[43.3%]	[18.2%]	[20.5%]	[38.4%]	[19.5%]	[18.5%]	[47.5%]
Time interval and weather condition 23/03/2023		13:35-13:50 (mostly sunny)			12:37-12:57 (mostly sunny)			12:30-12:50 (mostly sunny)			13:35-13:50 (mostly sunny)		
Measurement no.3	Temperature	[22.8°C]	[22.5°C]	[22.3°C]	[33.5°C]	[30.8°C]	[30.2°C]	[25.8°C]	[28°C]	[24.3°C]	[26.4°C]	[26.3°C]	[22.2°C]
	CO_2	[290 Ppm]	[288 Ppm]	[289 Ppm]	[262 Ppm]	[285 Ppm]	[302 Ppm]	[265 Ppm]	[274 Ppm]	[273 Ppm]	[285 Ppm]	[281 Ppm]	[297 Ppm]
	Relative Humidity	[45.2%]	[49.4%]	[60.1%]	[23.8%]	[31.2%]	[42.8%]	[34%]	[31%]	[39.6%]	[39.1%]	[39.5%]	[60.9%]
Time interval and weather condition 24/04/2023		15:10-15:25 (mostly cloudy)			12:55-13:10 (cloudy)			13:35-13:50 (cloudy)			14:15-14:30 (cloudy)		
Measurement no.4	Temperature	[40.4°C]	[39.5°C]	[39.1°C]	[44.8°C]	[46.8°C]	[49.5°C]	[53.1°C]	[50.2°C]	[45.9°C]	[45.3°C]	[43.6°C]	[41.9°C]
	CO_2	[299 Ppm]	[301 Ppm]	[300 Ppm]	[293 Ppm]	[301 Ppm]	[289 Ppm]	[535 Ppm]	[560 Ppm]	[523 Ppm]	[484 Ppm]	[497 Ppm]	[475 Ppm]
	Relative Humidity	[25.7%]	[26.3%]	[37.1%]	[22.9%]	[21.5%]	[32.4%]	[19.8%]	[19.3%]	[38.3%]	[22.2%]	[27.4%]	[41%]
Time interval and weather condition 29/05/2023		14:26-14:45 (mostly sunny/partly cloudy)			13:38-13:57 (mostly sunny/partly cloudy)			13:50-14:05 (mostly sunny/partly cloudy)			14:30-14:45 (mostly sunny/partly cloudy)		
Average	**Temperature**	[29°C]	[28.5°C]	[27.7°C]	[32.5°C]	[33.1°C]	[33°C]	[35.2°C]	[34.8°C]	[31.2°C]	[31.5°C]	[32.5°C]	[26.9°C]
	CO_2	[318.7 Ppm]	[307.5 Ppm]	[300.7 Ppm]	[298 Ppm]	[306.3 Ppm]	[304.5 Ppm]	[415.2 Ppm]	[423 Ppm]	[410.5 Ppm]	[409 Ppm]	[411.7 Ppm]	[385.2 Ppm]
	Relative Humidity	[36.5%]	[38.6%]	[46.6%]	[29.6%]	[32.1%]	[44.6%]	[29.6%]	[29.4%]	[43.4%]	[33.7%]	[35.6%]	[54.2%]

Results

Based on the record reported in Table 2, it is clearly visible that the average temperature rises as one approaches the city center of Tirana, mainly due to public activities, less permeable construction materials, lower wind speed, higher urban density, and lack of green areas, among others. In general, the main streets are the ones that provide more heat due to asphalt, direct sun exposure, highly absorbing materials such as asphalt, and lack of vegetation.

Fig. 4. The average values per each location including all types of pavements. (Authors' elaboration.)

In Table 2 and Figure 4, it is observed that location no.3 has the highest values of the measured and average temperature on asphalt and sidewalk, meanwhile, location no.2 has the peak value of measured and average temperature on greenery. Compared to location no.1, the temperature differences are approximately 4 °C. Furthermore, the lowest measured and mean temperature on asphalt and sidewalk are represented by location no.1. The most polluted areas in terms of CO_2 emissions are location no.4 and location no.3 with a difference of approximately 100 ppm compared to location no.1 and 2. According to the measured and average values of relative humidity location no.1 has the highest values on asphalt and sidewalk, meanwhile location no.4 has the highest values on greenery. Meanwhile, the lowest measured values of relative humidity including all types of pavements are represented by location no.3.

Table 3. The mean values per each location including all types of pavements. (Authors' elaboration).

	Location no.1 Polis University	**Location no.2** Garden City complex	**Location no.3** Jordan Misja Street	**Location no.4** Kavaja Street
Temperature (Total mean value)	[28.4 °C]	[32.8 °C]	[33.7 °C]	[30.3 °C]
CO_2 (Total mean value)	[308.9 Ppm]	[302.9 Ppm]	[416.2 Ppm]	[401.9 Ppm]
Relative humidity (Total mean value)	[40.5%]	[35.4%]	[34.1%]	[41.2%]

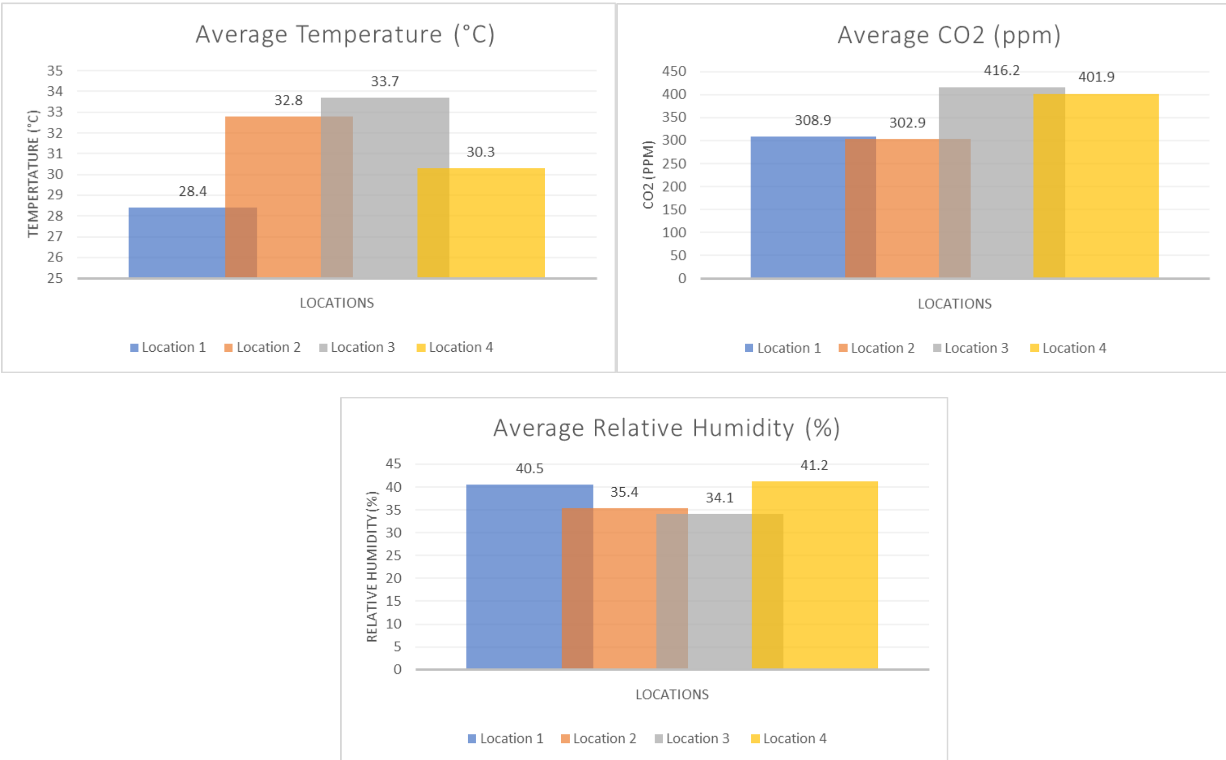

Fig. 5. The overall average values per each location including all types of pavements. (Authors' elaboration).

According to the overall temperature values including all types of pavements, location no.3 has the highest value, as reported in Table 3 and Figure 5. Compared to location no.1 the temperature difference is 5.3 °C, which is relevant. It is important to underline that location no.4 (a central area) due to temperature as a result of positioning the device in an area with more greenery, the values are lower than in other areas. As a consequence, this has reduced the overall average value of the measured temperature of the area. The most polluted areas in terms of CO_2 emissions are locations no.3 and 4. The winner of this category is location no.2 with a mean value of 302.9 ppm. This is due to the distance of the area to the main streets. It is observed that the overall relative humidity is higher in locations no.4 and 1. This value increases a lot again in location no.4, as a result of the chosen area of the measurements, which was very green, and shadows were present. It is noticeable and understandable that location no.3 which had the highest values of the temperature has the lowest value of relative humidity of 34.1%.

Discussion

Comparing the current research with other national and international studies. According to Xhexhi (2023), urban design and form are the results of a complicated interaction of many strains and factors, including social, economic, political, strategic, transportation, regional regulations, aesthetic considerations, and many more. In general, urban densities, orientations, street networks, and shapes are associated with climate change, besides geography. Additionally, the microclimatic conditions of outdoor areas are significantly influenced by the density of urban buildings. Each type of outdoor space depends on its relationship with its surroundings. It is crucial to emphasize that the temperature in both indoor and outdoor areas will be lower if there is a low ratio between the size of the structure and the width of the spaces. Tirana, as part of the Mediterranean coastal zone, has an average annual temperature of 15.3 °C. In Tirana's city center, there are regions with a lot of pollution due to a higher percentage of shops, settlements, and traffic. Such areas contribute to the creation of the heat island phenomenon. Communities might be impacted by heat islands by contributing to increased summer energy consumption, cooling expenses, greenhouse gas emissions, air pollution, water quality, mortality, and heat-related illness. The role of vegetation is sometimes critical, creating microclimates in the downtown area. Vegetation can reduce wind speed, create cooler microclimates, regulate humidity, and lower temperatures. In the actual study, it is observed that the measured temperature is lower in grasslands, meanwhile, the relative humidity is higher. The temperature can be reduced by only one single tree up to 3 °C. It has been observed that trees have a bigger impact on humidity than on temperature. A possible approach for reducing the heat island effect in metropolitan areas is the implementation of green belts. In general, the relative humidity in the Mediterranean region is constant and is influenced by regional elements. Nicosia has an average humidity rating of 55%, Gibraltar has a value of 74%, whereas Tirana has a value of 52.1%. On the other hand, the role of building materials can determine the temperature range and fluctuations of a particular area. For instance, the albedo of the vegetation is low. In general, the values are between 5% and 30% of grassland and coniferous forest. Meanwhile, when reflecting the light at a low angle, water has an albedo of up to 95%. Increasing albedo and vegetation can effectively reduce surface and near-ground air temperatures. Vegetation also reduces the CO_2 released into the atmosphere. It is observed that young, fast-growing, and healthy trees perform better in reducing CO_2. Trees in urban areas are 15 times more valuable than those in rural areas in reducing and limiting CO_2. The heat island effect will be amplified in cities with little vegetation because of pollution and temperature rise. The absence of greenery mostly in some of the areas taken into consideration in this study causes temperature and CO_2 rise. The role of water surfaces which have an albedo of up to 95% in all areas is missing, so the majority of the light is absorbed by the materials causing temperature rise. It is observed that the relative humidity is higher due to vegetation and grasslands [15, 16].

According to Dervishi et al. (2012), to evaluate interior and outdoor thermal comfort, surface materials, climatic data, and urban geometry are essential. The author considers four different areas in the city of Tirana, which have different characteristics and different locations among each other, as was also done by the present research. Likewise, the areas were chosen in the city center and the suburban area. The temperature measurements were made for each area and each day during June, July, and August, differently from the current research that was carried out during February, March, April, and May. The highest temperature is recorded in the city center area and the lowest temperature is recorded in the suburban area with a maximum difference of 9 °C. This difference is greater than that found in the present research, about 5 °C. Dervishi et al. also explain the impact of the UHI in enclosed urban areas, the importance of the H/W ratio of buildings, and their orientation. According to their study, the need for vegetation prevails concerning water and other needs of the inhabitants. Differently from the current research, Dervishi et al. consider the importance of building materials as an essential future of the UHI phenomenon, considering their reflectivity and absorption capacity. The effect of surface material is related to CO_2 emissions, reflective properties of materials, etc. Both researchers agree on the fact that the UHI effect is more present in polluted areas. It is observed that CO_2 emissions are higher in the asphalt areas than in the concrete areas. Moreover, concrete releases about 8% less CO_2 than asphalt pavement, while the current research shows almost similar values [17].

Picari and Dervishi (2019) analyze the UHI phenomena in Tirana, Albania, and develop some strategies to mitigate the UHI effect to reduce the temperature in the city center. They consider three locations in the city of Tirana, one lesser than the current research. The zone located next to the artificial lake results in having the highest humidity level due to the water surface and, for this reason, it was discarded when the authors were in the identification process for identifying the four sites in Tirana. However, in the Sami Frasheri area, these levels are significantly greater at night and in the early morning, while the current research only focuses on daytime measurements. The data have been collected during three months of summer, extracted from the weather station placed on the site, while the current research, has opted for months in the late winter-early summer for the rounds of measurements. The highest temperatures were recorded in the Prokop Myzeqari zone. Once the three zones were compared, the Prokop Myzeqari zone had the lowest humidity. In addition, Picari and Dervishi note that the wind speed decreases in heavily built zones and at ground level. Large open expanses and open corridor roadways have high wind speeds. In regions with more humidity as well as stronger winds, the air temperature is lower. In the main street, the temperatures seem to be minor because of the wind corridors and shady trees. In addition, the areas exposed to the sun have the highest temperatures. The temperature in the surrounding zone can vary due to different materials such as asphalt or light concrete pavement used in sidewalks and green areas. Due to the fact that light concrete pavement reflects more light than black asphalt, it absorbs less heat than the other one [18].

Panariti, Maliqari, and Tashi (2015) analyze the urban thermal comfort in Durrës, Albania, promenade, instead of Tirana. According to their findings, surface heat islands (SHIs) are critically present in the afternoon, while the current research is focused only on a given time frame. The heat radiation in promenades is decreased through the use of various materials, green spaces, and water surfaces, while these evaluations are not in the scope of this paper. The incorporation of random urban textures has a significant impact on outdoor thermal comfort. The promenade is wholly exposed to solar radiation. On the other hand, the sea breeze influences the air temperature, differently from the case study of Tirana. In three distinct parts of the promenade composed of various materials, measurements of the air's temperature, wind speed, relative humidity, dew point, and thermal radiation were made, while the current research focuses on four areas. The results show the importance and necessity of shading elements on the promenade, as in the case study of Tirana. Panariti, Maliqari, and Tashi found that grass, green vases, and wet tiles are found to be up to 10 °C cooler than concrete and granite tiles. Concrete tiles are 4 °C warmer than granite tiles, and wood texture is 11 °C cooler than granite and concrete tiles. The emitted temperature of the green vases and the grass was 8.9-10 °C each, and the wooden texture was 10 °C. Moreover, in summer, some of the urban textures such as granite tiles, concrete tiles, and concrete vases are 2-6 °C hotter than the air temperature [19]. By contrast, evaluations regarding the application of different materials are not in the scope of this paper, which limits to suggest of some hints to face the UHI effects.

Another research by Dervishi et al. (2018) indicated that during the summer, there might be a temperature differential of up to 8 °C between urban and rural locations of Tirana. The percentage of impermeable surfaces in Tirana, which was adversely connected with green spaces, was also directly related to the UHI impact. By reflecting solar radiation, reflective materials like white roofs can be used to reduce the UHI impact [20]. Similarly, Brestovci et al. (2019) discovered that throughout the summer, Tirana had temperatures that were 2 to 4 °C higher than those in the rural districts nearby. The study discovered that adding 10% more green space might lower the UHI impact by 1 to 2 °C [21]. Conversely, the current research does not extend the survey to the rural locations but focuses on the urban metropolitan area of Tirana, Albania, and does not go into details regarding specific solutions to mitigate the UHI effects.

Regarding potential mitigation actions that can be considered, other researchers have proposed mitigation and adaptation approaches in Albania and other European countries. In brief, Mahmutaj et al. (2013) proposed the introduction of green elements and green roofs as tools for countering the microclimate disbalances due to the UHIs phenomena in Albania [10]. Similarly, Aimar (2023) suggests the potential planting of additional green elements to complete the existing but decayed urban green infrastructure system, as well as after the pavement removal process in the public spaces located in the city of Asti, Piedmont, Italy [22]. Lastly, Battisti et al. (2023) suggest the adoption of Green Forestry in urban areas as a tool part of urban nature-based solutions with the aim to improve ecosystem services to improve people's well-being in terms of air quality and health in general [23].

Transferability of the current study into the African context.

Metropolitan heat and air pollution in urban areas have an unbreakable link and contribute to increasing unfavorable health effects for city inhabitants. The relationship between these three aspects within African transport sector developments gives numerous urban design mitigation techniques to increase human health and well-being. In SSA (Sub-Saharan Africa), the urbanization process has resulted in changes to urban biophysical characteristics such as building constructions, intense mobility and transportation corridors, and paved surfaces. Because of their low reflectivity, these surfaces are impermeable to solar radiation and absorb it, resulting in 'heat islands' with somewhat higher temperatures than the surrounding suburban and rural regions. The physical characteristics of the urban built environment, such as height, compactness, and organization, impact UHI in African cities.

Nowadays, regarding the issue, research remains insufficient. Despite having a greater green space-to-paved surface ratio, studies have shown that the UHI effect still exists in African cities. UHI can produce heat waves and a declining human thermal comfort in extreme circumstances. Some of the mitigation strategies to minimize the UHI effect are urban green spaces (UGS) and cool Infrastructure (greenery, walls, roofs, and pavement); construction design and material (high radiation materials; and pollution absorber materials); governmental policies; decarbonizing vehicles; and monitoring the mobility corridors. These concepts should be consolidated by urban planners in land use planning, urban design, greening, and environmental heat reduction for current and new urban projects [24].

According to Marcotullio et al. (2021), in the year 2100, heat waves of more than 42 °C might affect 300 million Africans living in cities. Approximately 27% of individuals exposed (under the age of 5 years and over 64 years old) may be heat sensitive. UHI might increase exposure to 950 million, and 38.7% of the population is expected to be vulnerable. In the worst-case scenario, 2 billion urban Africans might be subjected to such temperature rises [25].

Conclusions

The UHI effect in Tirana is a serious problem that has an adverse effect on people's health, energy use, and the environment. This issue has to be resolved at this moment. The absence of green space, excessive building density, mobility, the usage of construction materials in urban patterns, and energy use all contribute to the UHI impact in Tirana. Increased green space, the use of reflecting surfaces, and the promotion of sustainable urban design are just a few of the proposed mitigating measures.

To investigate the efficacy of these mitigation techniques in the Tirana setting, additional research is required. Some of the mitigation strategies in order to reduce UHI effect in the city of Tirana could be the implementation of additional urban green spaces, water surfaces, green roofs, green facades, low solar absorption materials on pavements, facades, and streets, cool infrastructure, pollution absorber materials, electric or hydrogen mobility in order to reduce CO_2 emissions (at the moment in Tirana 0.5% of the total amount of the vehicles are electric ones), and maximizing renewable energy sources, especially from the sun, earth (geothermal energy) and wind.

Among the potential developments of this research, further studies of Urban Heat Islands (UHIs) using software such as the urban climate modeling tool ENVI-met and land surface temperature records collected by Layer since 1970 may support further mid-scale assessments in urban areas. The latter will inform future research and policy efforts aimed at reducing the UHI effect in Tirana and other urban areas facing similar challenges.

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