The impact of urbanization and climate change on urban temperatures: a systematic analyse for Tirana city

Albana HASIMI
Institute of Geosciences, Polytechnic University of Tirana, Albania
a.hasimi@geo.edu.al
ORCID: 0009-0005-9406-9707

Blerina PAPAJANI
Faculty of Natural Sciences, University "Aleksandër Xhuvani", Elbasan, Albania

Gazmir ÇELA
Institute of Geosciences, Polytechnic University of Tirana, Albania

Elvin ÇOMO
Institute of Geosciences, Polytechnic University of Tirana, Albania

Florinda TUGA
Institute of Geosciences, Polytechnic University of Tirana, Albania

Mirela DVORANI
Institute of Geosciences, Polytechnic University of Tirana, Albania

Abstract

Some 3.5 billion people reside in urban areas, according to the WMO. The city population is growing, and it's far projected that via way of means of 2050 approximately 66% of the populace could be residing in towns and concrete areas. This increment is expected to happen not only through the increasing number of megacities, but also large and medium-sized cities with the largest urban growth. The situation changed dramatically in the twentieth century, as the rate of urban population growth increased significantly also in the Tirana city at the last decades. A statistical methodology is used to perform the required calculations and analyses related to temperatures above 35°C in meteorological data for the period 2010-2020. Application of the Statistical Methodology in the Field of Meteorology has wide applicability in the study of extreme temperature events and can help in: Forecasting heatwaves and analysing climate patterns for different periods; Assessing the impact of high temperatures on health and ecosystems, and monitoring extreme temperature events; Creating policies and risk management strategies to address the potential consequences of extreme heat on daily life, agriculture, and other sectors.

The analysis of the temperature changes revealed that the urbanization will strongly affect maximal temperature. The maximum temperature changes will be noticeable throughout the year. However, during winter and spring these differences will be particularly large and the increases could be double the increase due to global warming. Results indicate that the changes were mostly due to increased heat capacity of urban structures and reduced evaporation in the city environment. It was found that, in the future, summer weather will spread to early autumn, and winter weather will move to early spring, in Tirana

Keywords: *urban resilience; statistical methodology; maximum temperature; climate parameters; Tirana city.*

Introduction

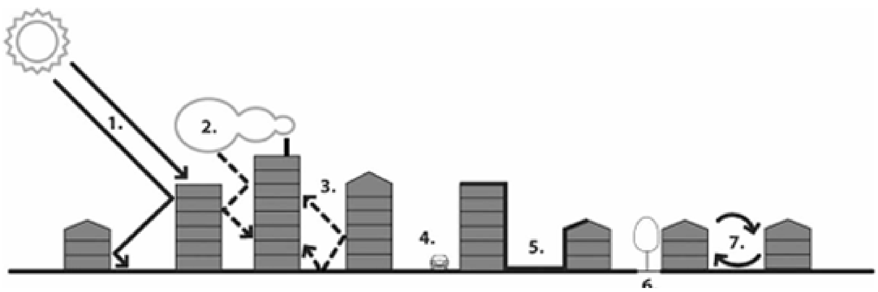
The Sustainable Development Goal (SDG) 11 focuses on urban resilience, climate and environment sustainability, and disaster risk management. In response to the New Urban Agenda, WMO established a cross-cutting urban focus initiative through Integrated Urban Hydrometeorological, Climate, and Environmental Services for urban resilience and sustainable development. The main goal is to develop urban multi-hazard early warning systems, Integrated Urban GHG Information System (IG3IS - urban), and climate services, with the focus on the impact-based forecast and risk-based warnings. Integrated Urban Services is an emerging multidisciplinary holistic approach, where requirements are unformalized and research and development are still in the development stage (WMO, n.d.).

Uncontrolled urbanization has caused many irreversible effects on the global biosphere, including environmental degradation, land insecurity, slum growth, water and sanitation issues, increased air pollution, land insecurity, etc. However, within appropriate limits, has several beneficial consequences, including technical and infrastructure improvements, high-quality educational and medical facilities, more significant transportation and communication, and better living standards (Humbal et al., 2023).

Climate change and urbanization are the two major drivers that can alter vegetation growth processes in the urban environment. However, the effects of these two drivers on the continuous vegetation dynamics in the urban environments are not well understood, especially at a high spatial resolution. (Li et al., 2020).

The relationship between climate and city is reciprocal: the climate influences the ways in which the city space is being used and the climatic performance and needs of buildings. In its turn, the city influences its climate. On the large scale the city as a whole modifies the regional climate conditions, which results in differences between the city and its surrounding (rural) area in cloud cover, precipitation, solar irradiation, air temperature and wind speed (Kleerekoper et al., 2012). Some of the causes, as shown in Figure 1, include absorption of short-wave radiation, air pollution that absorbs and re-emits longwave radiation, obstruction of the sky by buildings reducing longwave radiative heat loss, anthropogenic heat from combustion processes, increased heat storage by building materials with high thermal admittance, reduced evaporation due to waterproofed surfaces and less vegetation, and decreased turbulent heat transport from reduced wind speed.

FIGURE 1: Causes urban heat islands(Kleerekoper et al., 2012).



This study is the first of its kind, in terms of using Albanian meteorological measurement data. Was investigated the impacts of climate change on the urban heat island (UHI) and the number of very hot (maximum temperature >35°C). Downscaling models based on the simple systematic statistical technique were developed for each calendar month for projecting the number of very hot days in Rinas, Tirana (Hasimi & Çomo, 2022).

Materials and Methods

Analyses and Calculations Performed

The used database is from Rinas meteorological measurements and is open data. All statistical analyses were performed using an algorithm built in Python.

The meteorological data of Rinas station, was filtering before to conduct several calculations and in-depth analyses to identify and analyse the periods of extreme heat for each year of the decade under review:

a) Duration of Temperatures Above 35°C in Rinas: The total duration of the period was calculated as the time interval from the first to the last day with temperatures above 35°C, for each year.
b) Maximum Duration of Continuous Period: The method of grouping and identifying continuous periods with uninterrupted days where the temperature exceeded 35°C was used. The longest continuous period with temperatures above 35°C was calculated, and the days that constituted this uninterrupted period were identified.
c) Number of Cases with 2 or 3 Consecutive Days above 35°C: This analysis was used to identify periods with 2 or 3 consecutive days of temperatures above 35°C, and the number of such periods was calculated for each year.
d) Analysis of the Sum of Progressive Temperatures above 35°C: For each year, the sum of temperatures exceeding 35°C was calculated, providing an overview of the total heat accumulated during periods with temperatures above 35°C.

1. Summary of Analyses for Each Year: For each year, we performed:

The total duration from the first to the last day.

The maximum duration of the period without interruption with temperatures above 35°C.

The number of periods with 2 or 3 consecutive days above 35°C.

The sum of progressive temperatures for each year.

2. Analysis for Each Month of the Year: We also created an analysis to show the number of days with temperatures above 35°C for each month of the year.

Discussion and Conclusions

The Institute of Statistics (INSTAT) estimated the population of the municipality of Tirana at 598,176, with a unit density of 9,313/km², according to the 2023 census (*2023 Albanian Census*, 2024). However, according to the 2011 census, for the first time, the urban population exceeded the rural population. The resident population in urban areas was 53.5 percent, while 46.5 percent of the population lived in rural areas (*Census-of-Population-and-Housing*, n.d.). This significant demographic change is closely linked to the transformation of the city (fig 2). Table 1 presents data on population changes

TABLE 1: Population changes of Tirana city

Year	Population	± % of population
1989	238 057	+ 26.0%
2001	341 453	+ 43.4%
2011	418 495	+ 22.6%
2023	389 323	− 7.0%

Observed meteorological data from Rinas station were used to calculate the long-term temperature trends above 35 °C. These observations were also used to evaluate the model performance. This was done by calculating monthly, 3-month and each year for 10-year averages and to compare with the norma temperatures acording Klimate Atlas of Albania (Grup, 1984)

FIGURE 2: Satelit image of Tirana City 2010 and 2020

FIGURE 3: Duration of Temperatures above 35 °C

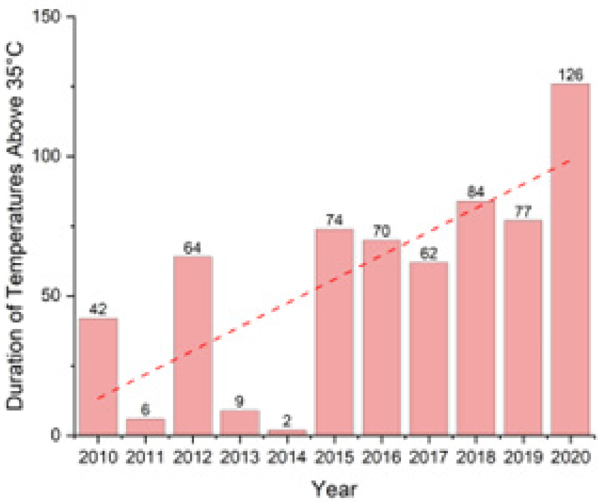


Figure 3 graphically illustrates the number of days with maximum temperatures exceeding 35°C. The dotted line clearly shows the upward trend. From Climate of Albania, for the Rinas meteorological station, we have some data on the climate of Albania, but not statistically analyzed as presented in our study. (Grup, 1975)

When making the comparison, the fundamental change in the microclimate of the city of Tirana becomes evident, partly as a result of the urban transformations it has undergone in the last 10 years. The city now has fewer green spaces and more tall buildings.

TABLE 2: The start and the end date of days above 35°C temperatures during 2010-2020 on Rinas

Year	Start Date	End Date	Days Above 35°c	Duration (Days)	Max Streak	2 Days Streaks
2010	16/07	27/08	3	42	1	0
2011	20/08	26/08	5	6	3	2
2012	23/06	26/08	24	64	6	6
2013	31/07	08/09	8	9	6	2
2014	08/12	14/08	3	2	3	1
2015	07/07	19/09	40	74	15	7
2016	17/06	26/08	17	70	3	4
2017	25/06	26/08	33	62	13	5
2018	06/08	31/08	15	84	6	3
2019	15/06	31/08	25	77	7	4
2020	14/05	17/09	37	126	9	10

During heat waves, temperatures in cities can build up day by day when there is no cooling wind or sufficient green spaces to provide relief. As shown in Table 2, there is a significant year-by-year increase in the number of days with maximum temperatures exceeding 35°C. However, what is even more remarkable is that the duration of these hot days is progressively extending, making heat waves more impactful for the city of Tirana (Hasimi & Çomo, 2022).

For the decade under review, the record stands until 2020, which had the highest number of days with temperatures exceeding 35°C. These high temperatures were recorded as early as May—an unusual occurrence for the Mediterranean climate, according to historical records (Çela* et al., 2025). Additionally, September marked the final month of the extremely hot season, with a maximum temperature of 35°C.

TABLE 3: Number of days per month with temperatures above 35°C

Year month	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
May	1										3
June			1				4	3	1	7	
July			8	1		19	7	13	2	7	12
August	2	5	15	7	3	15	6	17	12	11	14
September						6					8

It appears that there is a shift in temperature patterns, with August now being the month with the highest number of days over 35°C, instead of July, as historical data suggests for Rinas meteorological station. Several factors could explain this shift: Over time, climate change has been shifting weather patterns globally. This might have caused temperature extremes, including heatwaves, to move to different months. It's possible that the heat intensity and frequency of high temperatures are increasing in August.

Also, local changes in Tirana City: Changes in land use, urbanization, or even changes in local atmospheric patterns could contribute to the shift. For instance, urban heat islands or altered wind currents could be making August warmer than in the past.

Another key indicator analysed in this study is the duration of consecutive days with maximum temperatures exceeding 35°C, which directly impacts the quality of life in the city. These results are shown in Table 1. Even for this indicator, the most significant year is 2020, with 10 events lasting up to a maximum of 9 days. Such meteorological conditions have a broader impact on the economy, energy demand, human health, and other sectors.

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