Heat Islands in Zadar and Rugvica

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Summary

Since we have been actively participating in the GLOBE campaign Urban Heat Island Effect by measuring the surface temperature of different surfaces at various locations for several years, we wanted to investigate the differences in surface temperatures of asphalt and grass. The long-term cooperation between the Ante Kuzmanić Medical School Zadar and the Rugvica Elementary School encouraged us to do research together. The Ante Kuzmanić Medical School in Zadar is located in coastal Croatia, and the Rugvica Elementary School in continental Croatia. We were also interested in the existence of heat islands, since Zadar is a city area, and Rugvica is a rural area (with an increasing transformation of space, which is manifested in the increasing construction of residential buildings and the expansion of the industrial zone), we were interested in whether there are differences in surface soil temperatures and air temperatures between rural and urban areas.

By processing and analyzing the available data, we noticed that the amplitude of measured surface temperatures on the asphalt surface is higher in Rugvica than in Zadar, and thus confirmed our first hypothesis. The values of surface temperatures of the soil on the asphalt surface are higher in the urban area, referring to the city of Zadar, and the values of the surface temperature on the grass surface are also higher in the urban area, Zadar than in Rugvica. From the analysis of the available air temperature data, we confirmed our hypothesis that the air temperature will be higher in an urban area than in a rural area.

Introduction

Since we have been actively participating in the GLOBE campaign Urban Heat Island Effect for several years, measuring surface temperatures of different surfaces at various locations, we wanted to investigate the temperature differences between asphalt and grass. The long-standing cooperation between the Ante Kuzmanić Medical School in Zadar and the Rugvica Elementary School encouraged us to conduct joint research. The Ante Kuzmanić Medical School in Zadar is located in coastal Croatia, while Rugvica Elementary School is in continental Croatia. We were also interested in the presence of heat islands since Zadar is an urban area, whereas Rugvica is a rural area (with increasing spatial transformation evident in the growing construction of residential buildings and the expansion of the industrial zone).

Urban Heat Islands (UHI) is a phenomenon best described as the occurrence where certain geographic areas (e.g., a city) have higher air temperatures than surrounding areas (e.g., rural areas). Assuming that the Sun's heat and light reach all surfaces in the same way, the difference in temperature between urban and less developed rural areas is linked to the heat capacity of surfaces in a given area [3]. UHI is a microclimatic

phenomenon that occurs in urban environments and manifests itself through elevated temperatures compared to surrounding undeveloped, i.e., green areas. Due to the UHI effect, city residents are exposed to longer periods of higher air temperatures compared to residents of rural areas [2].

Research Questions, Research Objectives, and Hypotheses

The aim of the project was to investigate differences in surface temperatures between Zadar (a coastal city) and Rugvica (a continental rural area), analyze the impact of urbanization on the formation of heat islands in both settlements, and compare air temperatures in Zadar and Rugvica with the air temperatures in their surrounding areas.

Research Questions:

1. Is the difference between maximum and minimum surface temperatures on asphalt greater in Zadar or in Rugvica?

2. Are surface soil temperatures higher in urban or rural areas?

3. Is the air temperature higher in urban or rural areas?

Hypotheses:

1. A greater difference in the maximum and minimum surface temperature of the asphalt surface is in Rugvica.

2. The values of soil surface temperatures will be higher in the urban area than in the rural area.

3. In an urban area, the air temperature will be higher than in a rural area.

Research methods

We compared measurements across different seasons (summer, winter, spring, autumn) to observe seasonal variations in surface temperatures, air temperatures and urban heat island phenomena. The measurement period is from 1.3.2024 to. 1.3. 2025. The measurements were carried out on different surfaces (asphalt and grass) near schools (Figure 1, Figure 2). We also compared the air temperature data at the GLOBE stations in Zadar and Rugvica and compared them with the air temperature data of the surrounding areas from the GLOBE stations in Preko and Zagreb. We compared the surface temperatures in Zadar and Rugvica with the surface temperatures of the surrounding areas in Preko and Zagreb. We measured the surface temperature with an infrared thermometer according to the GLOBE protocols for surface temperature once a week, during the day, around solar noon.

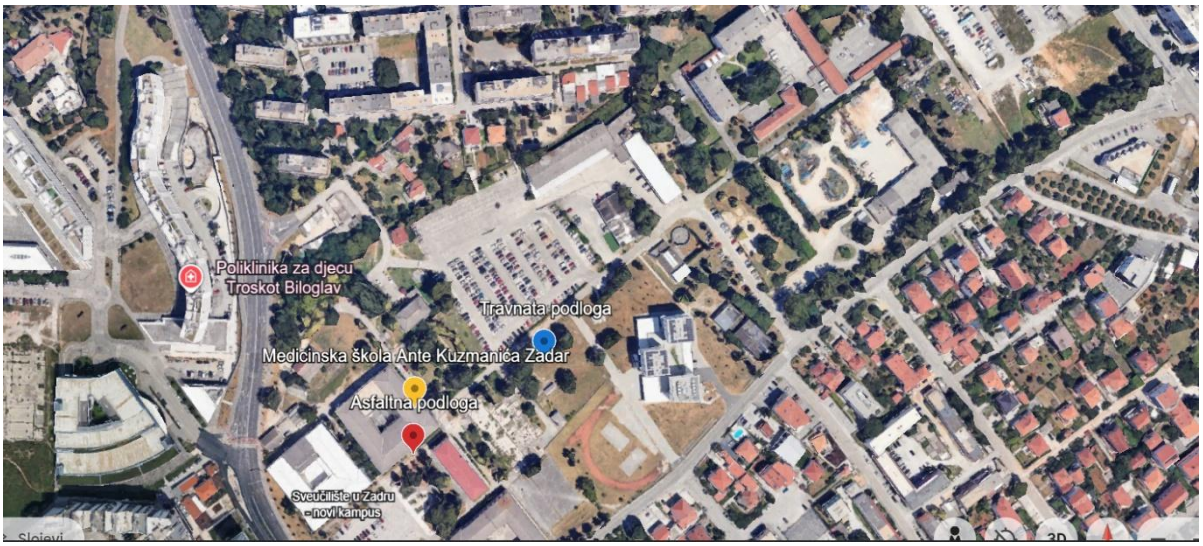

Figure 1. Display of selected measuring stations at Secondary Medical School Ante Kuzmanić Zadar (Source: GoogleEarth , 28.2.2025.)

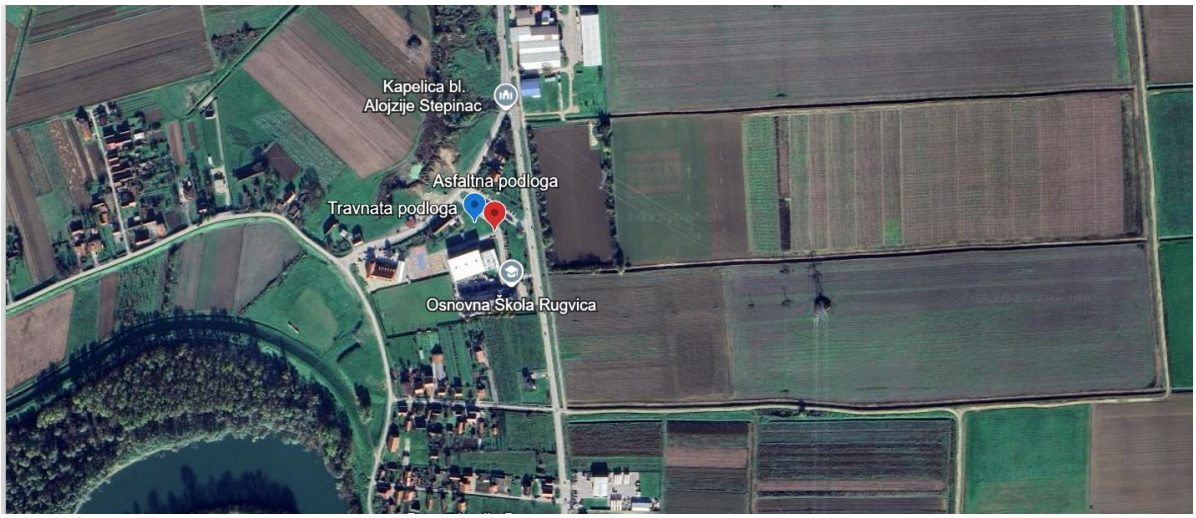

Figure 2. Display of selected measuring stations at Rugvica Elementary School (Source: GoogleEarth , 28.2.2025.)

Data Presentation and Analysis

From the graphical representation of the data measured at the Ante Kuzmanić Medical School location, it can be observed that the surface temperature of the asphalt pavement is higher than the surface temperature of the grassy surface (Figure 3). In the graphical representation of the data measured at the Rugvica Elementary School location, it was observed that the surface temperature of the asphalt pavement is higher than that of the grass (Figure 4).

The surface temperature data of the asphalt pavement for the Rugvica monitoring station were measured from March 1, 2024, to March 1, 2025. The lowest surface temperature was recorded on November 29 and was –10.1 °C, with the surface being wet. The highest surface temperature was recorded on June 5 and was 41.4 °C, with the surface being dry. At the Rugvica monitoring station, there were days when students observed and measured the surface temperature of the snow cover, and the surface temperature was –2.2 °C.

Data on the temperature of the asphalt surface at the weather station of the Ante Kuzmanić Medical School in Zadar, measured from March 1, 2024, to March 1, 2025, show the following results: the lowest surface temperature was recorded on January 15 and was 1.8°C, with the surface dry. The highest surface temperature was measured on June 18 and was 47.4°C, with the surface also dry. During the measurement period at the weather station in Rugvica, three surface temperatures with negative values were recorded on the asphalt surface, whereas at the weather station in Zadar, no negative surface temperature values of the asphalt surface were recorded.

Surface temperature measurement data on grassy ground in Rugvica show the following results: the lowest surface temperature was recorded on November 29 and was –3.5°C, with the surface being wet. The highest surface temperature was measured on June 5 and was 31.1°C, with the surface being dry.

Surface temperature measurement data on grassy ground in Zadar show the following results: the lowest surface temperature was recorded on January 15 and was 2.6°C, with the ground being dry. The highest surface temperature was recorded on June 11 and was 36.9°C, with the ground also being dry.

During the mentioned period, one negative surface temperature value was recorded at the measurement station in Rugvica on grassy ground, while no negative values were recorded at the measurement station in Zadar.

From this data, it is evident that the surface temperature values on asphalt and grassy surfaces are higher in Zadar than in Rugvica, and the lowest surface temperature values were recorded in Rugvica.

Table 1 Display of maximum and minimum surface temperature of asphalt and grass surface at measuring stations in Rugvica and Zadar

Measuring station	Maximum temperature of the grass surface	Minimum temperature of the grass surface	Maximum temperature of the asphalt sutface	Minimum temperature of the asphalt surface
Rugvica	31,1 °C (5.6.)	-3,5 °C (29.11.)	41,4 °C (5.6.)	-10,1 °C (29.11.)
Zadar	36,9 °C (11.6.)	2,6 °C (15.1.)	47,4 °C (18.6.)	1,8 °C (15.1)

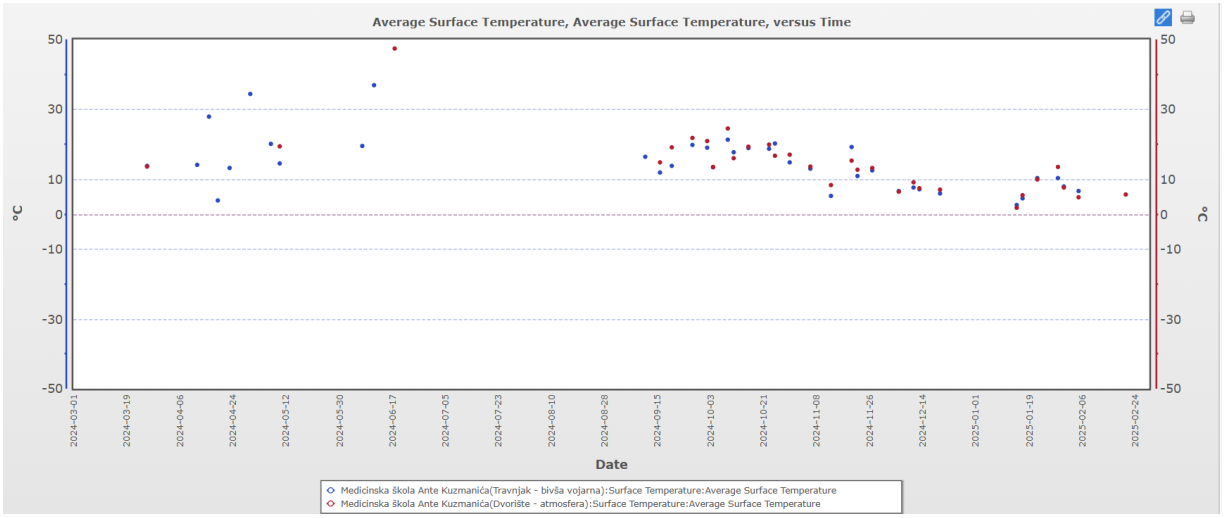

Figure 3. Display of surface temperatures of grass and asphalt surfaces at selected locations of the Ante Kuzmanić Medical School Zadar

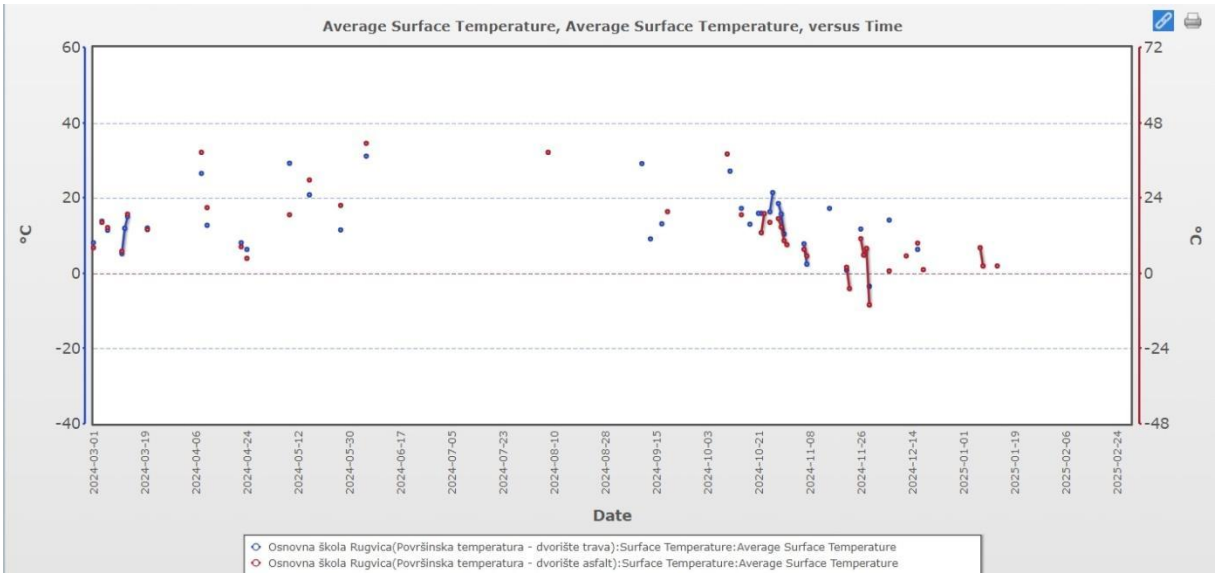

Figure 4. Display of surface temperatures of grass and asphalt surfaces at selected locations of the Elementary school Rugvica

The daily air temperature values measured at solar noon at the GLOBE stations of Rugvica Elementary School and Ante Kuzmanić Medical School in Zadar show that the values are higher in Zadar than in Rugvica.

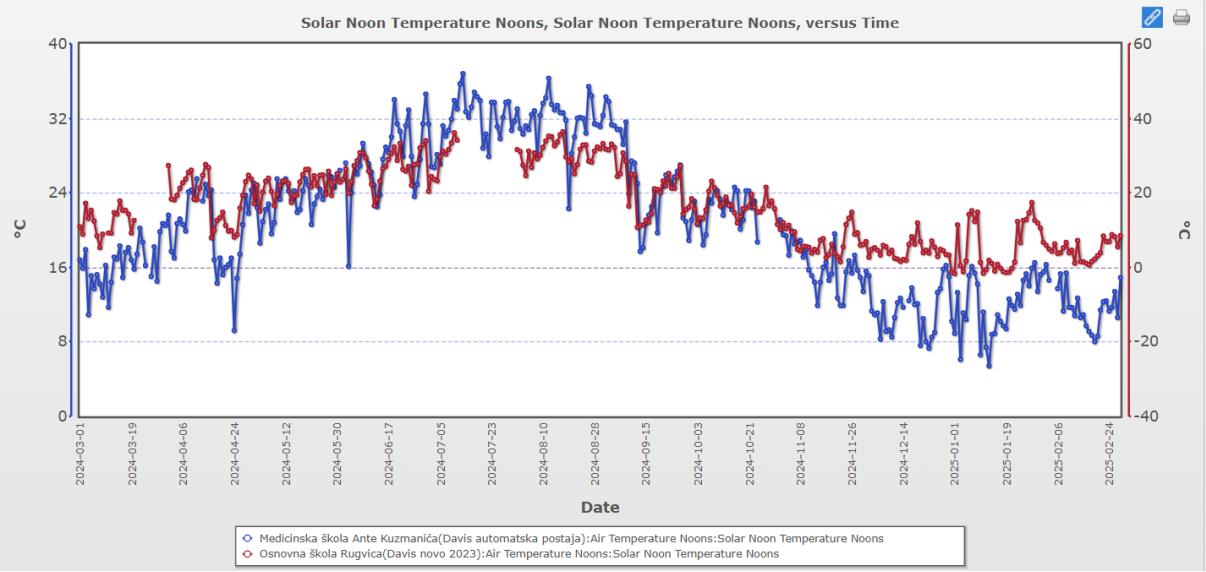

Figure 5. Comparison of air temperature measured at solar noon with GLOBE automatic measuring stations in the Rugvica Elementary School and the Secondary Medical School Ante Kuzmanić in Zadar

To better understand the occurrence of urban heat islands, we compared air temperatures in urban and rural areas. In this case, we compared air temperatures at solar noon in the area of Zadar and the nearby town of Preko on the island of Ugljan (Figure 6). The air temperature values were taken from GLOBE automatic weather stations. From the chart (Figure 6), it can be seen that air temperature values are higher in the Zadar area. We compared air temperature data for Rugvica with air temperature data from the GLOBE weather station in Lučko (Figure 7). From the chart (Figure 7), it is evident that, for the most part, air temperature values in Lučko are higher than those in Rugvica.

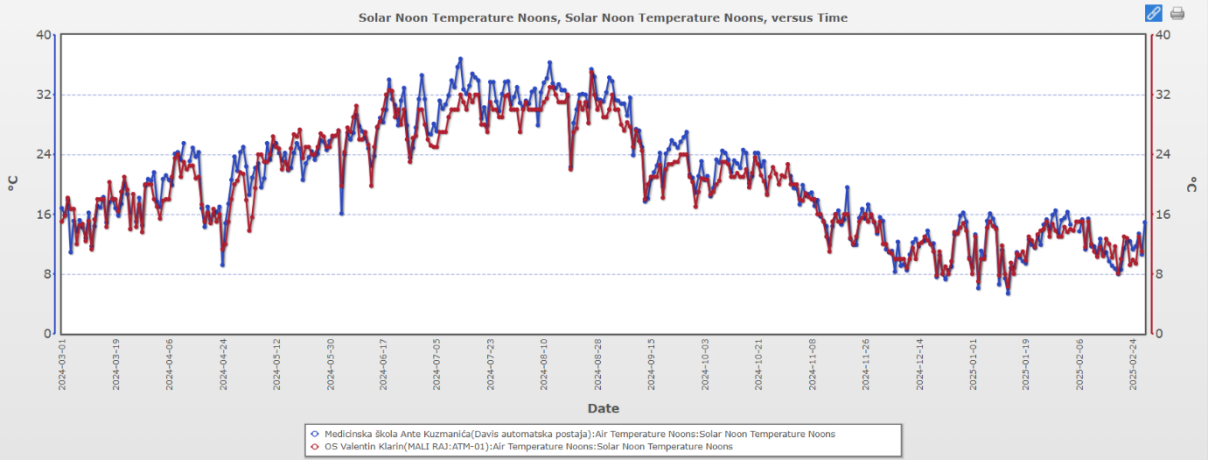

Figure 6. Comparison of air temperature measured at solar noon with GLOBE automatic measuring stations in the Secondary Medical School Ante Kuzmanić Zadar and Elementary School Valentin Klarin, Preko

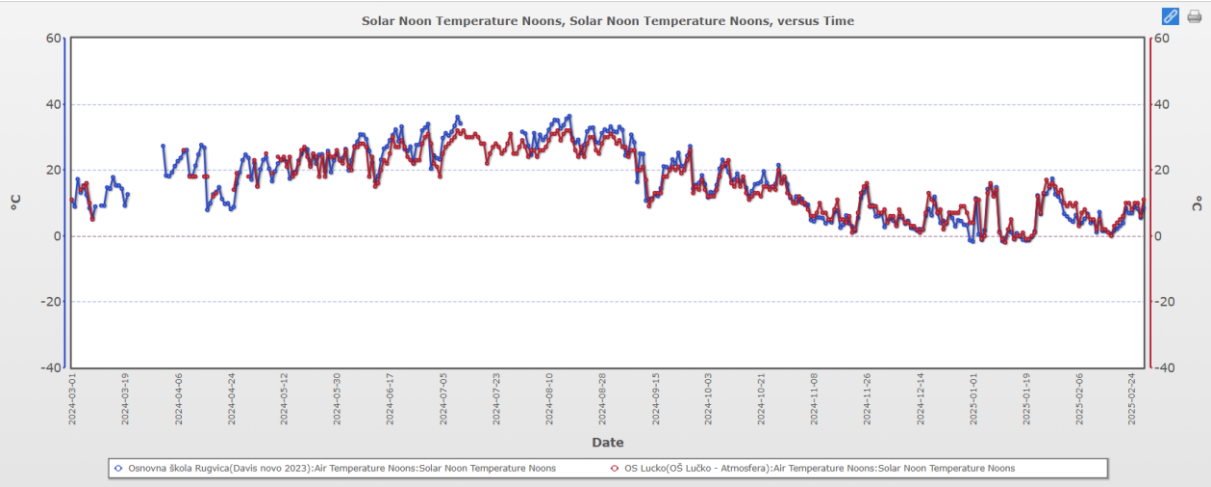

Figure 7 Comparison of air temperature measured at solar noon with GLOBE automatic measuring stations in Rugvica Elementary School and Lučko Elementary School

Comparing the surface temperature values at the measuring stations in Preko and Zadar, we noticed that the average values in Preko are higher than those recorded in Zadar (Figure 8).

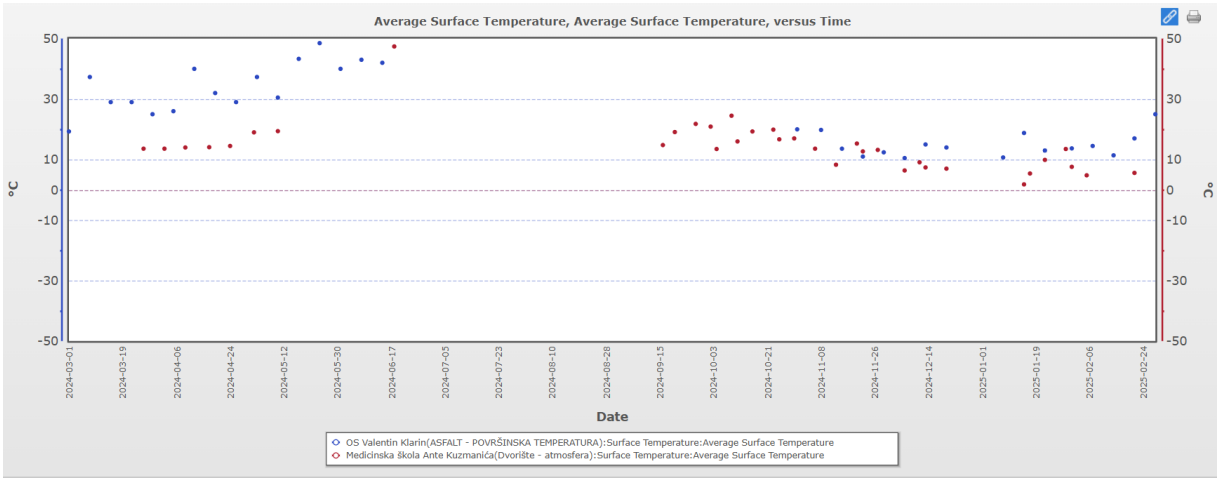

Figure 8 Comparison of asphalt surface temperature at measuring stations in Preko (island of Ugljan) and Zadar

Figure 8. View of the selected area of the municipality of Rugvica (Source: Google maps)

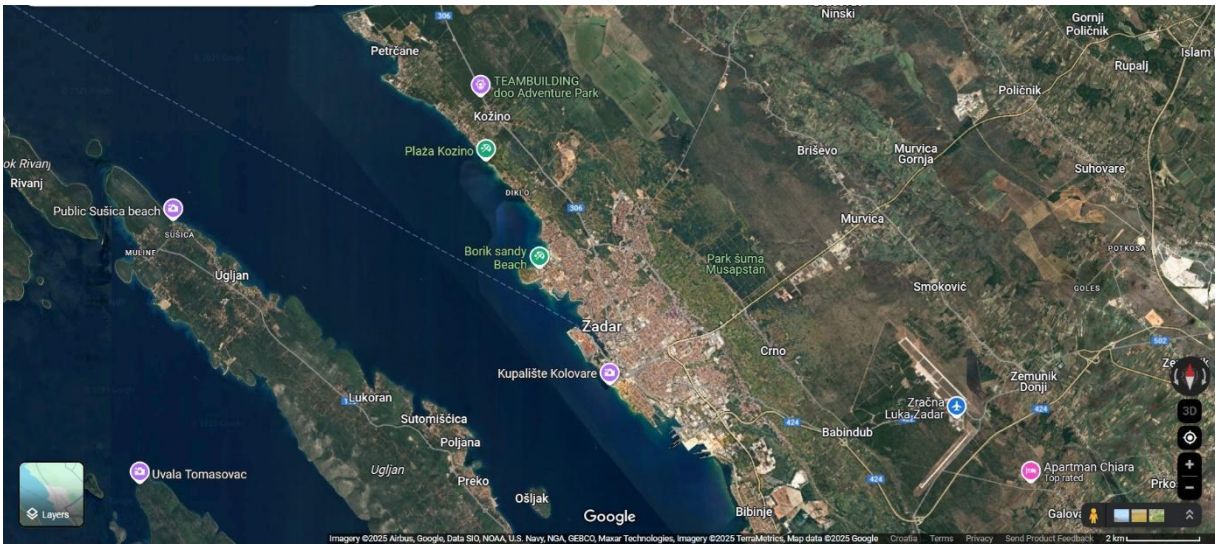

Figure 9. View of the selected area of the city of Zadar (Source: Google maps)

As the basic spatial data for mapping UHI, it is possible to use the vegetation and soil type map available in the form of the Fundamental Topographic Database (TTB), which was created according to the CROTIS methodology and is under the responsibility of the State Geodetic Administration. These data are available upon request and mapped at a scale of 1:10,000, which is currently the only data of this type and level of detail available for the entire territory of the Republic of Croatia. Using satellite measurements, it would be possible to map TTB categories with UHI effect categories. By overlaying land cover and land use layers according to TTB (Table 1) with solar radiation calculations and using GIS tools for spatial analysis, we identified areas with potential Urban Heat Island occurrence [2]. Analysis of available satellite images of both locations, Zadar and Rugvica, shows that a higher level of urbanization, marked in red, predominates in the Zadar area. Green areas, marked in green tones on satellite images, predominate in the area of Rugvica.

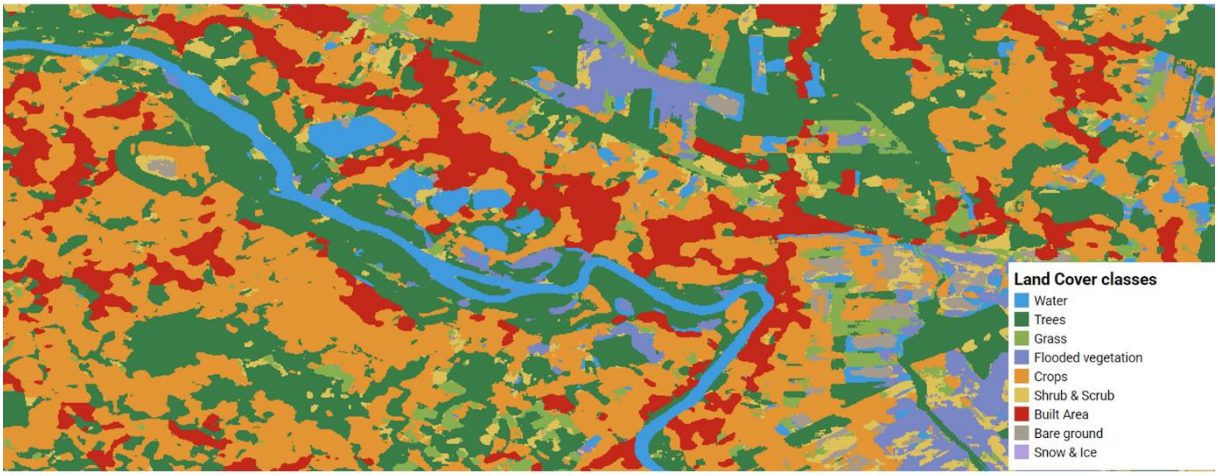

Figure 9. Satellite image of the land cover of the area of the municipality of Rugvica (Source: Imagery Compare - Tool for Satellite Imagery Comparison of EarthMap.org)

Figure 10. Satellite image of the land cover of the area of the city of Zadar (Source: Imagery Compare - Tool for Satellite Imagery Comparison of EarthMap.org)

Among the students of our schools, we conducted a workshop ("Heat in the neighborhood, how to measure and act?") on measuring surface temperature on different surfaces. After the workshop, the students created an action plan and recommendations on how to reduce the effects of heat islands in the form of a poster. They presented the posters to other students at our schools as well as on our website and Facebook pages to raise awareness in the local community. The workshops and presentations were carried out during Green Week in April. Additionally, the students of Rugvica Elementary School conducted a surface temperature measurement workshop at the Rugvica Kindergarten, where the children concluded that it is necessary to plant many more trees in their park to lower the surface temperatures.

Image 11 Poster of students of the Ante Kuzmanić Medical School in Zadar, action plan for the mitigation of heat islands

Figure 12 and 13 Workshop of pupils of the Rugvica Elementary School in the Kindergarten in Rugvica

Figure 14 and 15 Display of surface temperature measurements on different substrates at the location of the Ante Kuzmanić Medical School in Zadar

Discussion and Conclusions

By processing and analyzing the available data, we concluded that the amplitude of measured surface temperatures on the asphalt pavement is higher in Rugvica than in Zadar. In Rugvica, it was 51.5 °C, while in Zadar it was 45.6 °C, thus confirming our first hypothesis.

Comparing surface temperature values at the measuring stations in Preko and Zadar, it is evident that the average surface temperature values in Preko are higher than those measured in Zadar.

Surface temperature values of the ground on asphalt pavement are higher in the urban area, referring to the city of Zadar, and surface temperature values on grass surfaces are also higher in the urban area, Zadar, than in Rugvica.

From the analysis of the available air temperature data, we confirmed our hypothesis that the air temperature would be higher in urban areas than in rural areas. Urban

surfaces, such as industrial zones, are characterized by a high proportion of asphalt, concrete, metal, and other artificial materials and a low proportion of greenery. In addition, heat emissions from industrial processes further increase the health risk (urban heat islands generally pose a health risk to the elderly, children, people with chronic illnesses, and those who work outdoors) in these areas. These are usually the parts of the city with the highest temperatures and need to be carefully analyzed because a large number of citizens work and live in them [2].

On grassy, natural surfaces, due to high exposure to solar radiation, temperatures are often similar to or even higher than in urban areas. Moreover, throughout the year they are not continuously covered with greenery, but consist of bare soil, which contributes to the increase in temperatures [2].

After conducting the analysis and processing the data and drawing conclusions, the students created an action plan during Green Week in April, which was presented to the school students and the local community. In this way, our project gained greater significance, and we were able to reach the awareness of the local community at least to some extent.

In order to mitigate the effects of UHI (Urban Heat Island), it is important to implement measures in spatial planning and construction processes and utilize available instruments: building orientation and their mutual relationships to form cooling corridors, more detailed specification of the typology, proportions, and shapes of buildings in the context of thermal insulation efficiency, use of high energy-efficiency materials as well as colors and material types to reduce UHI effects, implementation of solutions inspired by nature (e.g., green roofs and façades) in parts of settlements with higher building density, increasing the share of green areas and canopy coverage, development of diverse public green spaces, as well as their interconnection into a green infrastructure system by prescribing special measures for areas with specific restrictions. These available instruments enable a comprehensive approach to mitigating negative effects. When preparing spatial plans (or their amendments and supplements), the land use needs to be adjusted to adapt the purpose to the climatic context and, according to implementation rules, define measures for the most critical parts of the settlement, which are those where the existence of UTO has been identified and mapped [2].

Literary Sources

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