

submitted: 03.02.2026.

<https://doi.org/10.62683/ZRGAF41.6>

corrected: 11.05.2026.

Research paper

accepted: 18.05.2026.

## URBAN MORPHOLOGY INDICATORS FOR MICRO-SCALE URBAN HEAT ISLAND VULNERABILITY ASSESSMENT – LESSONS FROM THE BE READY PROJECT

Jelena Đekić<sup>1</sup>, Ljiljana Vasilevska<sup>2</sup>

### Abstract

*Rapid urbanization has significantly altered urban morphology, intensifying the urban heat island (UHI) effect and increasing thermal stress in cities. Previous studies have demonstrated that urban morphology plays a crucial role in UHI formation, especially at the micro-scale. This study examines the feasibility of assessing UHI sensitivity at the micro-scale through key urban morphology indicators – building coverage ratio (BCR), floor area ratio (FAR), and street canyon aspect ratio (SCR) – using the City of Niš (Serbia) as a case study. The methodology used in this research was developed within the framework of the Be Ready project. The results indicate that publicly available satellite datasets are not adequate for micro-scale UHI assessment due to limitations in data precision, data timeliness, and the nature of the data itself, which requires additional analytical computation. With respect to data availability at the city or municipal level, there are no systematically monitored or georeferenced datasets of urban morphology indicators. Consequently, the values of the selected indicators can be determined only through analytical calculations and field surveys, which is highly time-consuming and limits the practical applicability of these indicators in urban planning practice. The study highlights the need for improved, up-to-date urban morphology datasets to support the effective UHI risk assessment and climate-resilient urban planning.*

**Key words:** Urban Heat Islands, Urban Morphology, Micro-Scale, City of Niš, Be Ready Project

---

<sup>1</sup> PhD, Assistant Professor, Faculty of Civil Engineering and Architecture, University of Niš, Serbia, [jelena.djekic@gaf.ni.ac.rs](mailto:jelena.djekic@gaf.ni.ac.rs), ORCID 0009-0007-8408-4297

<sup>2</sup> PhD, Full Professor, Faculty of Civil Engineering and Architecture, University of Niš, Serbia, [ljiljana.vasilevska@gaf.ni.ac.rs](mailto:ljiljana.vasilevska@gaf.ni.ac.rs), ORCID 0000-0002-6836-0139

## 1. INTRODUCTION

Today, cities accommodate more than half of the world's population. Accelerated urban growth has significantly altered urban morphology, leading to the replacement of natural, permeable surfaces with artificial, impermeable ones and to increased emissions of heat and pollutants. Urban areas exhibit higher temperatures than surrounding natural areas due to elevated energy emissions, heat accumulation from anthropogenic activities, and heat transfer from various sources - a phenomenon known as the urban heat island (UHI) effect [1-3]. The UHI effect occurs when impervious surfaces in cities retain and emit more heat, resulting in higher temperatures compared to adjacent non-urban areas [3].

The constant expansion of cities leads to the intensification of the urban heat island effect, resulting in various harmful impacts, such as increased energy consumption, elevated pollution levels, and adverse effects on population health and quality of life. With increasingly pronounced climate change, the effects of urban heat islands are spreading beyond city centers to include industrial areas, suburban commercial zones, and even rural settlements.

The formation of urban heat islands is influenced by numerous factors, including climatic and geographical conditions; the expansion of built-up areas that replace natural surfaces with artificial ones that accumulate heat; the characteristics of materials and surfaces; urban morphology, which affects airflow; and human activities. The consequences of altered morphology and disrupted natural airflow on air pollution and UHI formation are particularly pronounced in cities located in valleys due to limited air circulation [4].

Studies on UHI have shown a clear link between urban morphology and UHI intensity, indicating that urban morphology plays a crucial role in the formation and development of the UHI effect, particularly at the micro-scale [2]. Urban morphology encompasses various aspects, such as urban structure types, landscape patterns, and settlement density, which are key factors in the formation and evolution of the UHI effect [5].

Accordingly, in addition to land-use patterns and surface characteristics, three-dimensional features of the built environment are considered, including building height, building shape, spacing between buildings, street canyons, and the sky view factor. Some factors show a positive correlation with the UHI effect (e.g., floor area ratio (FAR) and diversity of building shapes (DBS)), while others have been found to be negatively correlated with UHI (e.g., building height (BH) and sky view factor (SVF)) [2,6]. There is also seasonal variation in the influence of individual factors throughout the year [2].

FAR exhibits a positive correlation with UHI throughout the entire year – areas characterized by lower FAR demonstrate a moderating effect on UHI intensity, whereas increased development density contributes to the amplification of the UHI effect [2]. However, the positive correlation between FAR and UHI is most pronounced during the spring and midsummer seasons. Similarly, the influence of DBS is strongest during the summer months [2]. Street canyons affect wind movement, direction, and speed, thereby influencing air quality and ambient air temperature. Wind speed, as well as the accumulation of solar radiation, is also influenced by street orientation. Different street widths and building heights within

street canyons affect the ability of building envelopes to absorb and release solar heat. North–south-oriented streets can store up to 30% of midday solar energy, which is released at night when temperatures decrease [7]. Building shape also plays a role in modifying wind speed and solar radiation shading [8]. Some studies indicate that building height can be significant due to its ability to provide shading during the summer period [2, 8].

To mitigate the negative effects of UHI, particularly those affecting human health, it is essential to conduct risk and vulnerability assessments of cities. Risk assessment involves the identification and analysis of factors influencing UHI formation, while vulnerability assessment includes identifying at-risk population groups, infrastructure vulnerability, and the preparedness and adaptive capacity of cities and municipalities to respond to urban heat islands.

The Be Ready project develops a common methodology for assessing vulnerability and risk related to the Urban Heat Island (UHI) effect at the city level, with the aim of strengthening urban resilience in the Danube Region. A major output of the project is an open-access online vulnerability assessment toolkit that will enable cities to conduct guided UHI risk assessments and support evidence-based planning. The project also contributes to the development of a joint strategic framework for climate adaptation, prevention, and harm reduction.

The city of Niš is one of the partner cities participating in the project and actively contributes to testing and applying the proposed methodology. Since urban morphology represents one of the most influential factors in UHI formation, particularly at the micro-scale, this study focuses on these elements. Using Niš as a case study, the research evaluates the applicability of open-source and field-collected urban morphology data for assessing UHI risk at the micro-scale.

## 2. METHODOLOGY

The assessment of sensitivity to the Urban Heat Island (UHI) effect involves the overlay of a large number of spatial and thematic layers relevant to the formation and intensity of UHI. The analysis can be conducted at different spatial scales, ranging from the macro scale – the city-wide level – used to identify areas most affected by UHI effects, to the micro-scale, which enables a detailed examination of local variations and specific urban configurations. In contemporary research, UHI assessment is increasingly performed at the micro-scale, as it allows for a more precise understanding of the cause–effect relationships between urban characteristics and the UHI phenomenon [9, 10].

The risk and vulnerability assessment methodology applied in this study is based on the approach developed within the Be Ready project<sup>3</sup>, which provides four analytical tools for conducting UHI vulnerability assessments at the municipal or city level. These tools include: (1) exposure of buildings and surroundings, (2) sensitivity of equipment and material, (3) identification of risk groups among urban residents, and (4) the level of preparedness and adaptive capacity of cities and municipalities. Within the assessment of exposure of buildings and surroundings, the following major urban criteria are examined: urban morphology/urban form, vegetation, surface permeability, human activities, and urban climate.

---

<sup>3</sup> <https://interreg-danube.eu/projects/be-ready>

This study focuses on indicators related to urban form, including the building coverage ratio (BCR), floor area ratio (FAR), and the street canyon aspect ratio (SCR), and their assessment at the micro level. The analysis of data required for assessing the UHI effect included the use of open-source datasets, primarily satellite data from the Copernicus program<sup>4</sup>, and available state and city-level spatial and statistical data including: Digitalni atlas klime Srbije (Digital Climate Atlas of Serbia)<sup>5</sup>, GeoSrbija<sup>6</sup>, GIS Niš<sup>7</sup>. For the purpose of micro-scale indicator calculation, the subject area was divided into sub-units. The indicators were calculated separately for each sub-unit, as well as for the whole area. Considering the relationship between individual indicators and the UHI effect, the comparison of the obtained values among sub-units reveal the area with the highest risk of UHI formation.

The data obtained at the micro-scale, when integrated with other datasets related to exposure, the sensitivity of materials and equipment, and risk groups among urban residents, enable a comprehensive assessment of sensitivity and vulnerability to the UHI effect. This integrated approach allows for precise identification and mapping of priority zones and provides a robust basis for defining targeted mitigation and adaptation measures within the framework of climate-resilient urban planning.

### 3. STUDY AREA

#### 3.1. Macro-location: City of Niš

Niš is the third-largest city in Serbia and one of the oldest urban settlements in the Balkans. Located in the southeastern part of the country, approximately 237 km from Belgrade, it lies between 43°15' and 43°30' north latitude and 21°49' and 22°13' east longitude. The city is situated within the Nišava Valley, at the confluence of the Nišava and South Morava rivers, and is bordered by the slopes of Svrljiške planine, Suva Planina, and Jastrebac. It has a temperate continental climate characterized by warm summers and moderately cold winters [11].

As an important university, industrial, economic, and cultural center, Niš has significant national and regional importance. Its strategic transport position is reinforced by Constantine the Great Airport, the second-largest airport in Serbia, and by its location along Pan-European Corridor X, making it a significant road, rail, and air transport hub. The city also has notable tourism potential, supported by a rich historical legacy, diverse urban heritage, and valuable natural resources.

Due to its geographical setting, Niš is particularly vulnerable to the Urban Heat Island effect. The surrounding mountain ranges limit air circulation and reduce natural ventilation, contributing to heat accumulation in densely built urban areas, especially during warm and stable weather conditions. Unlike cities located in open plains, where stronger airflow facilitates heat dispersion, Niš experiences limited natural cooling, although local winds such as Košava may occasionally provide temporary relief. A high number of sunny days further intensifies thermal stress

---

<sup>4</sup> <https://www.copernicus.eu/en>

<sup>5</sup> <https://atlas-klime.eko.gov.rs/lat/map?dataType=mod&visualization=pro&area=regions>

<sup>6</sup> <https://a3.geosrbija.rs/>

<sup>7</sup> <https://gis.ni.rs/smartPortal/gunisPublic>

through increased solar radiation absorption, while cloudy and windy periods contribute to partial cooling.

Climate observations over the past decade indicate rising average temperatures and increasingly variable precipitation patterns. July remains the warmest month, with an average air temperature of approximately 22.5 °C, while January averages around 0.6 °C. Compared with the 1961–1990 reference period, mean monthly temperatures for 1981–2010 increased by more than 1 °C during summer months. In July, the average temperature rose from 21.3 °C to 22.5 °C, and in August from 21.1 °C to 22.3 °C. Additionally, the number of tropical days in the reference periods increased from 10.8 to 15 days in July and from 12.9 to 17 days in August. Winters remain cold, with January average air temperature approximately 0.6°C [11]. These trends align with broader regional climate patterns, suggesting a shift towards warmer conditions with irregular precipitation patterns.

### 3.2. Micro-location: Central city zone of the City of Niš

For the UHI assessment at the micro-scale, the central city zone of the city of Niš was selected as the pilot zone. The study area includes: the main pedestrian zone, comprising the central city square – King Milan Square and part of Obrenovićeveva Street; part of Voždova Street, one of the city's primary streets; and the adjacent mixed-use blocks (Fig. 1). This zone was chosen because it represents a densely built-up area, with a high population density and a large share of paved surfaces, which are key prerequisites for the occurrence of UHI and the possible negative effects it brings with it [6]. Previous studies of paving surface temperatures and thermal comfort at King Milan Square have shown that, during the summer period, the temperature of paved surfaces is approximately 20 °C higher than that of grassy areas, which contributes to an increase in air temperature and affects the thermal comfort of users [13,14]. The study area is divided into seven subunits according to their characteristics: A, B, C, D – mixed-use blocks; E – central city square; F – pedestrian street; and G – streets (Fig. 2).



Figure 1. Micro-location position and boundaries, source: Authors, [6]



Figure 2. Layout of subunits within the micro-location, source: Authors, [6]

## 4. RESULTS AND DISCUSSION

### 4.1. Building coverage ratio

Building Coverage Ratio (BCR) is an urban planning and construction metric that indicates the proportion of a site or plot occupied by buildings. In other words, it shows the relationship between the building footprint and the total area of the parcel.

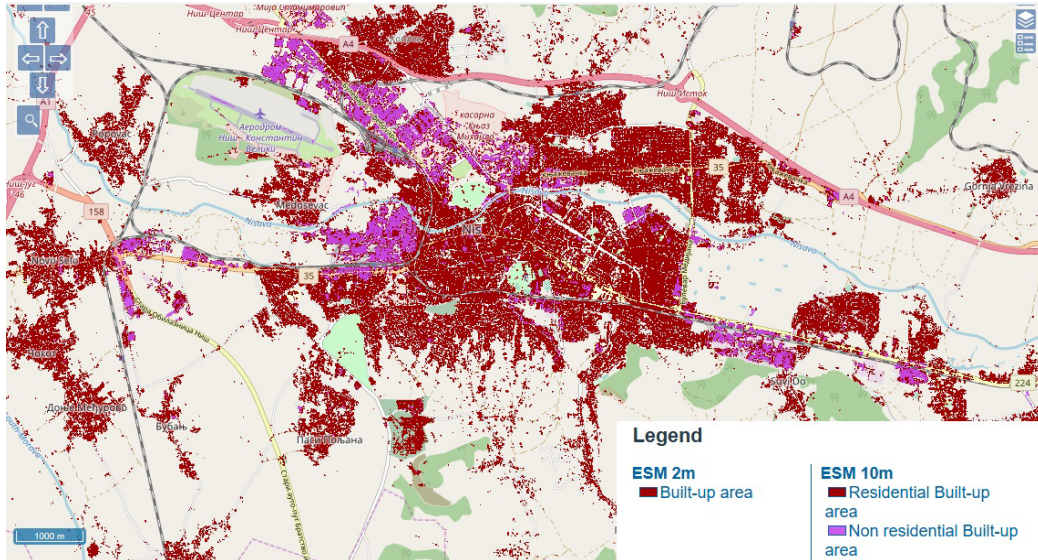


Figure 3: European Settlement Map, source: <https://human-settlement.emergency.copernicus.eu/ESMVisualisation.php#>

Maps showing BCR values are not available online. However, the European Settlement Map provides built-up area data at the city level (Figure 3). According to this map, the pilot area is characterized as a predominantly residential zone within a densely built urban fabric.

Table 1. Current BCR values for the selected pilot zone

Sub-unit	BCR (net value)
A	83.44%
B	59.72%
C	65.90%
D	64.41%
E	-
F	-
G	-

Source of data: Authors, [6]

The BCR value for the entire pilot area, including streets and the main city square, is 36.65% (gross value).

The highest BCR value (83.44%) occurs in sub-unit A, which comprises numerous small, nearly fully built-up cadastral plots. The pilot zone also contains large undeveloped areas, including the central city square, the main city road, and the pedestrian street, resulting in a much lower overall BCR for the zone (36.65%)

compared to individual sub-units. Consequently, the average BCR of the sub-units (68.37%) can be considered a more representative measure [6].

BCR values are specified in the city's urban plans – both Plans of General Regulation (PGR) and Plans of Detailed Regulation (PDR) – but these values refer to future, planned development. According to the Plan of General Regulation of the City Municipality of Medijana, the pilot zone is classified as a “business-residential zone,” for which the plan allows a maximum BCR of 60–70%, depending on the size of individual plots.

Current Building Coverage Ratio (BCR) is calculated as follows:

$$BCR = \sum B / P * 100 \quad (1)$$

*BCR – building cover ratio,  $\sum B$  = sum of buildings' areas,  $P$  – area of the plot*

Building area and area of the plot for each plot were obtained by measuring from Geosrbija and GIS Niš maps.

BCR values for sub-units (A, B, C, and D) are expressed as net values, representing the ratio of the total building footprint area within each sub-unit to the net area of that sub-unit. In contrast, the total BCR for the pilot zone is expressed as a gross value, calculated as the ratio of the total building footprint area to the gross area of the entire pilot site.



Figure 4: Building coverage – subunits A, B, C and D, source: Authors based on GIS Niš, [6]

The analysis of the available open-access Copernicus data [15], which include satellite Earth Observation and in-situ (non-space) data, as well as open-access data from municipal authorities, indicates that there are no sufficiently precise data to assess the UHI sensitivity at the micro-scale.

Copernicus maps contain significant data, such as residential and non-residential built-up area (Fig. 3), built-up surface and built-up volume (Fig.5), for assessing the UHI sensitivity at the macro scale, but the level of detail, i.e., the data resolution, is not sufficient for a UHI assessment at the micro scale.

Neither the City nor the City municipality possesses a usable georeferenced spatial assessment or mapping of building coverage ratio that can be directly processed in GIS at the grid level. The available data provide surface area information only at the level of the city municipality. Likewise, population census data and other open-source datasets are not available in grid- or spatial cell-based formats. This significantly constrains indicator analysis, as well as its practical application in urban planning for identifying and assessing urban heat island (UHI) effects.

At present, the indicator value can only be derived through analytical calculation using data collected separately from GeoSrbija and GISNiš (Fig. 4), often supplemented by direct observation. This process is time-consuming and raises concerns regarding the efficiency and practical applicability of the indicator in urban planning [6].

#### 4.2. Floor area ratio (FAR)

Floor Area Ratio (FAR) – also referred to as Floor Space Ratio (FSR), Floor Space Index (FSI), site ratio, or plot ratio – is an urban planning indicator that describes the intensity of land development by expressing the relationship between the total gross floor area of buildings and the total area of the plot on which they are located. Higher FAR values indicate a greater development intensity, allowing for more extensive building volume on a given site. Figure 5 presents the built-up volume of buildings in the area of the City of Niš.

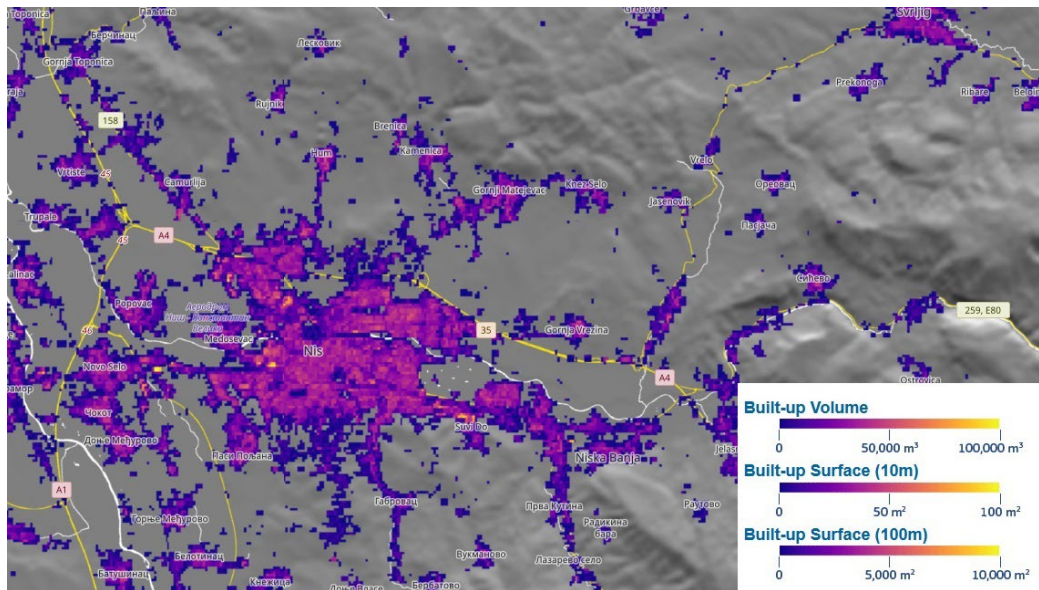


Figure 5: Built-up volume of buildings – city level, source: <https://human-settlement.emergency.copernicus.eu/visualisation.php#>

Table 2. Current FAR values for the selected pilot zone

Sub-unit	FAR (net value)
A	2.52
B	2.48
C	1.94
D	2.88
E	-
F	-
G	-

Source of data: Authors, [6]

The floor area ratio (FAR) of the pilot zone is 1.39, calculated as a gross value. The highest FAR value is recorded in sub-unit D, which comprises both low-rise single-family housing and high-rise multi-family residential buildings ranging from

seven to thirteen stories. In contrast, the lowest FAR value is observed in sub-unit C, characterized predominantly by low-rise single-family and multi-family buildings.

FAR values are specified in the city's urban planning documents – PGRs and PDRs, however, these values apply to future planned development rather than existing conditions. According to the Plan of General Regulation of the City Municipality of Medijana, the pilot zone is classified as a “business-residential zone,” for which the maximum permitted FAR ranges from 2.4 to 4.2, depending on plot size [6].

Current Floor Area Ratio (FAR) is calculated as follow:

$$FAR = \sum F / P \quad (2)$$

*FAR* - floor area ratio,  $\sum F$  - total floor area of buildings, *P* - area of the plot

FAR values for sub-units (A, B, C, and D) are expressed as net values, calculated as the ratio of the total floor area within each sub-unit to its net surface area. In contrast, the overall FAR for the pilot site is expressed as a gross value, representing the ratio of the total floor area to the gross surface area of the entire pilot site.

As mentioned in the previous section, the data available from global Copernicus maps are not sufficiently detailed for micro-scale analysis. The available data relate to built-up area and volume, but not to FAR. At the city and municipal levels, there is no systematic monitoring of indicators related to urban morphology (BCR, FAR, etc.), so the value of the indicator can only be determined through analytical calculations, as was the case with the previously analyzed indicators.

### 4.3. Street canyon aspect ratio

Street canyon is a narrow street with tall buildings along the street on both sides of it. It can be measured as an aspect ratio of average building height along the street and street width.

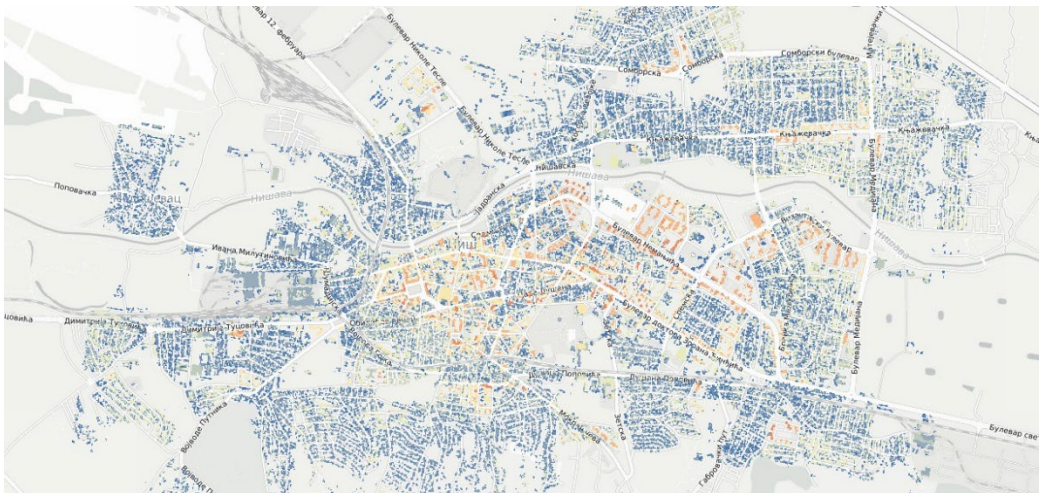


Figure 6: Building height – city level, source: <https://land.copernicus.eu/en/map-viewer?dataset=9b64a56b49f74f458aa401ad7809af16>

The pilot site features buildings of varying heights and typologies. In areas where continuous rows of buildings on opposite sides of the street form street canyons, the building-to-street height-to-width ratio (H/W) ranges from 0.8 to 1.3. The highest ratio

( $H/W = 1.3$ ) is observed in the northern section of Balkanska Street, which borders sub-unit A on the western side. However, the presence of substantial high greenery along Balkanska Street helps mitigate the effects of the street canyon. On other streets, the  $H/W$  ratio remains below 1.

Street canyon effects are minimal in areas dominated by detached single-family houses – namely, the perimeter edges of sub-units C and D – as well as in the central city square.

The street canyon aspect ratio is calculated as follows:

$$SCR = H / W \quad (3)$$

*SCR - street canyon aspect ratio, H - building height, W street width*

The  $H/W$  ratios were calculated using the following data:

- street widths, measured from GeoSrbija [16] and GIS Niš maps [17],
- building heights, determined through field observations and analytical calculations, based on the number of floors multiplied by the average floor height.

For asymmetric street canyons, the average building height on both sides of the street was used in the calculation. The results of the analysis are presented graphically in Figure 7.

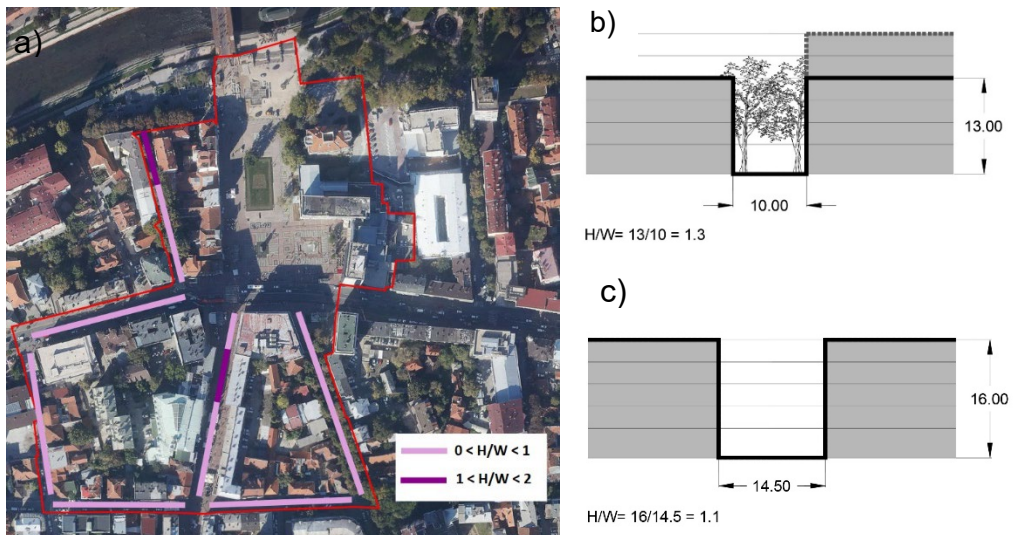


Figure 7: a) Street canyon aspect ratio – pilot zone; b), c) Cross sections of the street canyons in Balkanska and Nade Tomić street respectively, source: Authors, [6].

Open-access data available from Copernicus include building height data at a 10 m resolution from 2012 (Fig. 6), which are useful for macro-scale UHI assessment. Given the map resolution, these data may be useful for micro-scale UHI analysis; however, because they date from 2012, their validity is limited in light of the intensive construction activity in the central urban core.

As with the previous indicators, no data on building height and street width are available at the city or municipal level. The indicator value can be determined only through field observation and analytical processing of data that must be separately collected from available sources - GeoSrbija and GIS Niš [16,17], and from observational findings (Fig.7). This approach is time-consuming and raises concerns

regarding the efficiency and practical applicability of the indicator in urban planning for the detection and assessment of UHI effects.

## 5. CONCLUSION

Previous research has demonstrated that urban morphology elements play a significant role in the formation of urban heat islands (UHI), particularly at the micro-scale. The objective of this study was to examine the feasibility of assessing the impact of urban morphology on UHI vulnerability at the micro-scale. The analysis focused on available open-access satellite data, data accessible at the city and municipal levels, and methodologies for calculating key urban morphology indicators, including the building coverage ratio (BCR), floor area ratio (FAR), and street canyon aspect ratio (SCR).

The results indicate that publicly available satellite data either lack the spatial resolution or are not sufficiently up to date to support micro-scale UHI assessment. Moreover, no publicly available datasets for any of the analyzed indicators exist at the city or municipal level. Consequently, the calculation of urban morphology indicators at the micro-scale relies exclusively on field surveys and analytical processing, which is highly demanding and time-consuming.

In the context of increasingly pronounced climate change, it is essential to identify UHI-related risks and vulnerable population groups, as well as to implement adaptation measures aimed at mitigating negative impacts. For effective UHI risk assessment, both at the city scale and particularly at the micro-locations identified as high-risk areas, continuous monitoring of urban morphology parameters is required, along with the integration of these parameters into urban planning in order to support the reduction of UHI effects.

Therefore, the establishment of systematically monitored, georeferenced urban morphology datasets at the municipal level should be considered a prerequisite for reliable micro-scale UHI risk assessment. Without such data, the practical application of micro-scale indicators in urban planning remains limited, despite their recognized importance in addressing climate-related urban risks.

The Be Ready project proposed a methodology for assessing urban vulnerability and the capacity of cities to respond to the risks associated with urban heat island (UHI) formation. Beyond the indicators discussed in this study, the methodology incorporates a comprehensive set of additional indicators. Taken together, they provide a holistic assessment of an area's vulnerability and form the basis for developing strategies to mitigate UHI impacts.

Due to its valley location and high built-up density, Niš is particularly vulnerable to urban heat island (UHI) effects. Establishing systematic monitoring of urban morphology, together with the expansion of green areas, improved ventilation, and the use of reflective materials, represents essential steps toward climate-resilient urban development.

## ACKNOWLEDGMENTS

This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, under the Agreement on

Financing the Scientific Research Work of Teaching Staff at the Faculty of Civil Engineering and Architecture, University of Niš - Registration number: 451-03-34/2026-03/200095 dated 05/02/2026.

Sustainable Development Goals: Sustainable Cities and Communities

## REFERENCES

- [1] Liu Biao, Guo Xian, Jiang Jie: **How urban morphology relates to the urban heat island effect: A multi-indicator study.** *Sustainability*, Vol. 15, No. 14, Article 10787, 2023.
- [2] Ramachandra T. V., Rana Rajesh Singh, Vinay S., Aithal Bharath H.: **Urban heat island linkages with the landscape morphology.** *Scientific Reports*, Vol. 15, No. 1, Article 24485, 2025.
- [3] Li Guodong, Zhang Xi, Mirzaei Parham A., Zhang Junhua, Zhao Zisheng: **Urban heat island effect of a typical valley city in China: Responds to the global warming and rapid urbanization.** *Sustainable Cities and Society*, Vol. 38, 736–745, 2018.
- [4] Tran Duy X., Pla Filberto, Latorre-Carmona Pedro, Myint Soe W., Caetano Mario, Kieu Hoan V.: **Characterizing the relationship between land use land cover change and land surface temperature.** *ISPRS Journal of Photogrammetry and Remote Sensing*, Vol. 124, 119–132, 2017.
- [5] Obeidat Bushra, Qasem Areen, Abed Amal R., Alali Razan Omar & Alnusairat Saba: **Toward climate-responsive zoning: microscale simulation of building coverage ratio effects on outdoor thermal comfort in a semi-arid city.** *Architectural Engineering and Design Management*, 1–23, 2025.
- [6] Vasilevska Ljiljana, Blagojević Borislava, Vasov Miomir, Đekić Jelena, Milanović Danijela, Đokić Nikola, Trajković Slaviša: **Urban heat islands vulnerability and risk assessment: Methodology with guide for application and tools.** *BeReady – UrBan hEat islands REsilience, prepAreDness and mitigation strategy*, Interreg Danube Region Programme, June 2024, <https://interreg-danube.eu/projects/be-ready/library>;  
[https://www.ni.rs/wp-content/uploads/2025/05/UHI\\_assessment\\_Nis\\_Serbia.pdf](https://www.ni.rs/wp-content/uploads/2025/05/UHI_assessment_Nis_Serbia.pdf)
- [7] Dinić Branković Milena, Igić Milica, Đekić Jelena, Mitković Mihailo: **Impact of post-socialist vertical extensions of buildings on outdoor microclimate in collective housing areas: A study of Niš**, Serbia. *Energy and Buildings*, Vol. 265, Article 112081, 2022. <https://doi.org/10.1016/j.enbuild.2022.112081>
- [8] Ellena Marta, Melis Giulia, Zengarini Nicolás, Di Gangi Eduardo, Ricciardi Guglielmo, Mercogliano Paola, Costa Giuseppe: **Micro-scale UHI risk assessment on the heat-health nexus within cities by looking at socio-economic factors and built environment characteristics: The Turin case study (Italy).** *Urban Climate*, 49, 101514, 2023.
- [9] Sayad B., Helmi Mansour Rifaat, Osra Oumr Adnan, Abed Ahmad Mohammed, Alhubashi Haytham Hussain: **Microscale investigation of urban heat island (UHI) in Annaba City: Unveiling factors and mitigation strategies.** *Sustainability*, 16(2), 747, 2024.
- [10] **Plan razvoja grada Niša za period od 2021. do 2027. godine.** *Official List of the City of Niš*, no. 36/2021. Available on: [https://www.eupropisi.com/dokumenti/NI\\_036\\_2021\\_003.pdf](https://www.eupropisi.com/dokumenti/NI_036_2021_003.pdf)
- [11] [https://www.hidmet.gov.rs/latin/meteorologija/stanica\\_sr.php?moss\\_id=13388](https://www.hidmet.gov.rs/latin/meteorologija/stanica_sr.php?moss_id=13388) (22.01.2026.)
- [12] Djekic Jelena, Djukic Aleksandra, Vukmirovic Milena, Djekic Petar, Dinic Brankovic Milena: **Thermal Comfort of Pedestrian Spaces and the Influence**

**of Pavement Materials on Warming Up During Summer.** *Energy and Buildings*, 159, 474-485, 2017.

- [13] Đekić Jelena, Mitković Petar, Dinić-Branković Milena, Igić Milica, Đekić Petar., Mitković Mihailo: **The study of effects of greenery on temperature reduction in urban areas.** *Thermal Science*, Vol. 22, Suppl. 4, 988–1000, 2018.
- [14] Bogdanović Protić Ivana, Vasilevska Ljiljana, Petrović Nemanja: **Blue–Green Infrastructure Strategies for Improvement of Outdoor Thermal Comfort in Post-Socialist High-Rise Residential Areas: A Case Study of Niš, Serbia.** *Sustainability*, 17(23), 10876, 2025.
- [15] <https://www.copernicus.eu/en>
- [16] <https://a3.geosrbija.rs/>
- [17] <https://gis.ni.rs/smartPortal/gunisPublic>

