LIGHT POLLUTION AND SUSTAINABLE TOURISM: A CASE STUDY OF THE LOCAL COMMUNITY TRG OSLOBOĐENJA – CENTAR, SARAJEVO, BOSNIA AND HERZEGOVINA

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Abstract: The analysis of light pollution levels is crucial for understanding its impacts on the environment, human health and urban development, as well as for developing strategies and technologies to mitigate its negative effects. The International Dark-Sky Association (IDA) defines light pollution as any harmful phenomenon caused by artificial lighting, including skyglow, glare, light trespass and overillumination. Light pollution disrupts ecosystems, influences animal behavior and threatens human health. In urban areas, it can also reduce the attractiveness of tourist destinations, diminishing the clearity of the night sky. This research focuses on the geovisualization and measurement of light pollution at a selected micro-location – Trg oslobođenja - Centar, a local community in Sarajevo (Bosnia and Herzegovina). The primary aims of this study are to conduct precise measurements and geovisualization of light pollution levels, analyze their relationship with tourism activities and formulate strategies for sustainable tourism development. The proposed measures emphasize balancing tourism growth with the need to preserve the environment and the aesthetic value of the space. Research findings offer valuable insights into a critical aspect of tourism planning and provide a solid foundation for future comparative studies, both within Sarajevo and in broader contexts.

Keywords: light pollution, sustainability, geovisualisation, Sarajevo.

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INTRODUCTION

Light pollution, defined by the International Dark-Sky Association (IDA) as any harmful phenomenon caused by artificial lighting, such as skyglow, glare, light trespass and over-illumination, has become a pressing global issue (URL 1). This type of pollution not only disrupts ecosystems and human health but also contributes to energy waste and carbon emissions, with approximately 30% of global artificial lighting remaining unused (URL 2). In urban areas, light pollution significantly diminishes the visibility of the night sky, thereby reducing the aesthetic and experiential appeal of tourist destinations. This phenomenon poses a series of challenges, such as balancing urban growth and tourism development with the preservation of environmental and cultural heritage (Baloch et al, 2022). The local community of Trg Oslobođenja – Centar in Sarajevo, one of the most urbanized areas of the City of Sarajevo, which serves as the administrative, political, economic and educational center of the country, is presumed to be particularly vulnerable to the effects of light pollution due to its dense concentration of streetlights, illuminated advertisements, public events and commercial lighting. These sources collectively contribute to the overillumination of the area, raising important questions about the environmental and social sustainability of tourism development in such contexts (Baloch et al, 2022). As a significant tourism hub, rich in cultural and historical resources, this local community serves as an representative case study to explore the relationship between light pollution and sustainable tourism.

The importance of analyzing light pollution lies in its multidimensional impact on urban ecosystems, human well-being and tourism dynamics (Aguilera, Gonzalez, 2023). Artificial lighting interferes with the nighttime behavior of animals, impacts human sleep patterns and causes considerable economic losses due to energy inefficiency (Czarnecka et al, 2022). On the other hand, for tourism-driven localities, light pollution could negative affect the assets that attract visitors, such as clear night skies and the preservation of authentic urban aesthetics (Gallaway, 2010; Rodrigues et al., 2014). Rodrigues et al. (2014) state that light pollution in heavily illuminated areas has a range of impacts on tourists, affecting various aspects of their experiences and perceptions. It can diminish the aesthetic impression of destinations by obscuring the natural beauty of the night sky, a feature many tourists seek (Gallaway, 2010). Additionally, excessive artificial lighting can interfere with sleep quality, particularly for visitors staying in accommodations near bright, bustling areas (Wang et al, 2023; URL 5). From a practical perspective, light pollution can also raise concerns about safety, as overly bright or improperly directed lighting may cause glare or reduce visibility (URL, 6, 7). At the same time it can influence environmental awareness, encouraging tourists to reflect on the ecological impacts of artificial lighting (Jägerbrand, Bouroussis, 2021; Himschoot, 2024).

Considering the aforementioned topics and challenges, it becomes evident that a systematic and comprehensive study is needed, primarily aimed at determining the intensity of light pollution and identifying key zones with the highest levels of illumination and pollution. Expanding on the primary research question, further inquiries should explore how this form of pollution affects the sustainability of local tourism development. The main focus of this paper is the geovisualization and measurement of light pollution and daylight illumination in the local community of Trg Oslobođenja – Centar, with the aim of understanding their relationship with sustainable tourism development. The study is structured around several main objectives:

- to conduct detailed measurements of illumination and light pollution levels within the area to obtain precise data on its intensity and distribution;
- to identify the primary sources of light pollution in this local community, including street lighting, advertisements and commercial activities;
- geovisualisation using GIS software to create spatial representations that enhance the understanding of pollution dynamics;

Together, these objectives form a sistematic framework for assessing light pollution and its implications for sustainable urban and tourism planning. In addition to the measurements conducted in the evening hours (8:00 pm), measurements of light levels were also carried out in the morning hours to determine the degree of illumination. It is important to emphasize that the following work builds upon prior research that investigated noise pollution in the same geographical area, forming part of a broader effort to analyze urban environmental challenges in selected local community. By focusing on light pollution, this research expands the understanding of pollution's impact on urban sustainability, offering insights into how artificial lighting interacts with tourism activities. This research seeks to propose practical measures that balance the need for tourism growth with environmental preservation and the enhancement of visitor experiences.The findings of this study contribute to an important and underexplored area of urban and tourism planning, particularly in the context of Sarajevo and Bosnia and Herzegovina. Furthermore, it provide a foundation for comparative studies within other local communities, offering opportunities to identify broader patterns and develop targeted strategies to mitigate light pollution. By addressing these challenges, this research highlights the critical role of environmental management in ensuring the long-term sustainability of tourism hubs in urban areas.

LITERATURE REVIEW

Light pollution has been increasingly recognized as a significant environmental issue, attracting attention in various geographical and interdisciplinary studies. Research in this area employs diverse methodological approaches from geography, particularly geoecological studies and urban planning, as well as psychology, to assess and address the

impacts of artificial lighting. The role of geography and geographic software, such as GIS, has proven crucial not only in the detection and visualization of light pollution but also in its integration with analyses of other urban pollutants, such as noise (Votsi et al, 2017). This emphasizes the growing importance of geospatial tools in understanding and mitigating the effects of pollution in urban and suburban contexts. Today, numerous resources provide geovizualized data that allow for comparative analysis of light pollution levels, including interactive light pollution maps (URL 3, 4,).

In recent studies advanced modeling techniques and remotely sensed imagery are used to analyze light pollution, particularly in urban and suburban areas (Chalkias, 2006; Lamphar, 2020; Li et al., 2020). Authors of these studies highlight the potential of combining satellite data with GIS to map and monitor the spatial distribution of light pollution. On a global scale, research has demonstrated a concerning trend, with satellite observations indicating a 49% increase in emissions between 1992 and 2017 (Sanchez de Miguel et al., 2021). In Europe, light pollution research has focused on three primary themes: the impact on ecosystem functioning and trophic interactions, socio-economic aspects of darkness protection and the advancement of measurement methods (Widmer et al., 2022). These studies provide a foundation for understanding the complex interplay between artificial lighting and environmental, economicand technological systems. Widmer et al. (2022) provide an overview of studies examining the relationship between light pollution and human health, encompassing approximately 20 studies conducted on substantial sample sizes. The findings from these studies make significant contributions to medicine, emphasizing the critical health implications of light pollution and the urgent need to address it as a pressing environmental and public health issue. European countries are increasingly addressing light pollution through legal frameworks, strategies and technical standards (Green Public Procurement Criteria for Street Lighting and Traffic Signals, 2018; Zero Pollution Action Plan, 2021). According to the documents, the measures encompass legislation, voluntary guidelines, awareness campaigns, research projects and the promotion of dark-sky areas. However, while European research has advanced in these areas, gaps remain in local-level assessments and regulations, particularly in Southeast Europe.

In the context of Bosnia and Herzegovina, research on light pollution, including studies conducted between 2013 and 2021, has provided valuable insights into the national trends and spatial distribution of this issue. These studies analyze changes in light pollution levels across different regions of the country and examine the impact on dark sky areas (Žiberna, et al., 2019; Žiberna et al., 2022). The findings emphasize the potential for establishing 'Dark Sky' protected parks through targeted measures for artificial lighting limitation, stating the importance of preserving areas with minimal light pollution for both ecological and tourism benefits. Such efforts align with broader global trends and highlight the necessity of integrating light pollution management into environmental and spatial planning in Bosnia and Herzegovina. Besides these studies it is important to mention the deficit in research at the local community level. This contrasts with the more extensive literature addressing other

forms of pollution, such as air and noise pollution in Sarajevo (Ćetković et al., 2023; Hasanović, 2023). According to Žunić (2024), research analyzing pollutants in Sarajevo concluded that light pollution significantly disrupts migratory bird behavior, affecting their navigation and stopover patterns. The research highlights how tourism-driven light pollution, combined with noise pollution and some other factors, may explain the unusual settlement of seagulls in urban areas like Sarajevo. This phenomenon underscores the intersection of environmental pollutants and wildlife conservation challenges, particularly in regions experiencing rapid tourism expansion. The scarcity of localized studies on light pollution presents an opportunity for new research in order to contribute to a deeper understanding of its impacts on urban sustainability.

These global and regional findings emphasize the importance of advancing research at both macro and micro levels to address the challenges posed by light pollution. By increasing the potential of geographic tools and interdisciplinary approaches, future studies could enhance the precision of measurements, develop targeted mitigation strategies and inform sustainable urban and tourism planning.

STUDY AREA

The local community of Trg Oslobođenja – Centar is located in the central part of Sarajevo and represents one of the most urbanized areas in Bosnia and Herzegovina. Its small spatial coverage, with a total area of 0.542 km² and a population of 3,148 (Federal Bureau for Statistics, 2016), indicates a high population density (among highest in the country). This community has a highly dynamic urban character, particularly in terms of tertiary activities and dense urban structures (Marić et al, 2024). The area includes key streets and squares that are functionally significant for the local population and form Sarajevo's cultural and commercial center. Consequently, there are significant daily population fluctuations in the streets within the study area, such as Branilaca Sarajeva, Dalmatinska, Ferhadija, Gimnazijska, Gajev Trg, Kaptol, Kulovića, Muhameda Kantardžića, Mula Mustafe Bašeskije, Obala Kulina Bana, Maršala Tita and Ćemaluša (Figure 1). The morphological and functional diversity of the selected area, together with intensive urbanization, high population density, diverse economic activities (which require high levels of illumination) and the presence of certain park areas (with very low illumination), makes this community an interesting location for measuring illumination and light pollution. Its central position in Sarajevo provides a relevant context for analyzing urban pollution and exploring opportunities to implement sustainable measures aimed at improving the sustainable forms of tourism.

It has already been noted that this local community was selected as a case study for a series of research projects, starting with noise pollution, followed by light pollution and subsequently comparative analyses with other local communities characterized by lower levels of urbanization and more peripheral locations. Trg Oslobođenja – Centar also plays

an important role in Sarajevo's tourism landscape, serving as an area for events, festivals and public gatherings that attract both local residents and international visitors. The area's intense street lighting and illuminated landmarks contribute to creating a lively and welcoming atmosphere for tourists, enhancing their overall experience. However, these features also significantly contribute to light pollution, raising questions about the balance between tourism development and environmental sustainability.

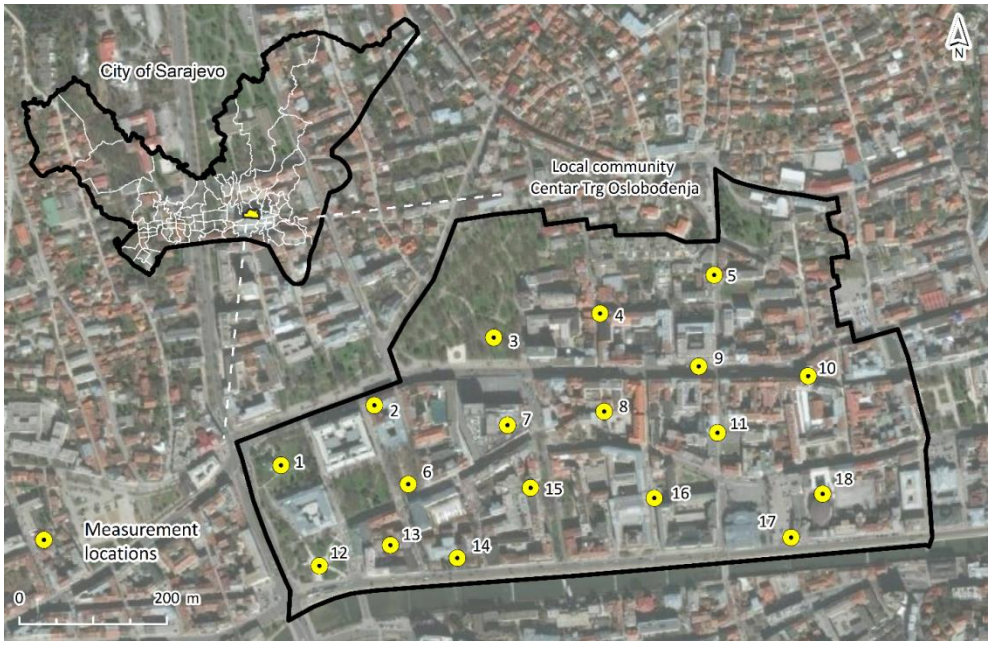

Fig. 1. Measurement locations within study area
Source: authors

Cultural events, which are hosted within and around this area, require extensive lighting infrastructure to ensure safety and create an engaging ambiance. The diverse tourism activities in Trg Oslobođenja and its surroundings make it an attractive destination, offering cultural, religious and business tourism, supported by apartments, hotels and conference centers that serve to visitors year-round. These social characteristics, including significant tourism potential and active tourism development, state the importance of the selected study area in Sarajevo's tourism sector while highlighting the challenges of managing its environmental footprint.

METHODOLOGY

The research applied set of methods, comprising analysis, synthesis, field research, statistical analysis and GIS techniques. In the first research phase, literature and cartographic materials were collected to define the subject and objectives of the study, as well as the research area itself. This phase also included a review of methodological approaches applied in previous studies, as well as the scientific equipment used for these types of research.

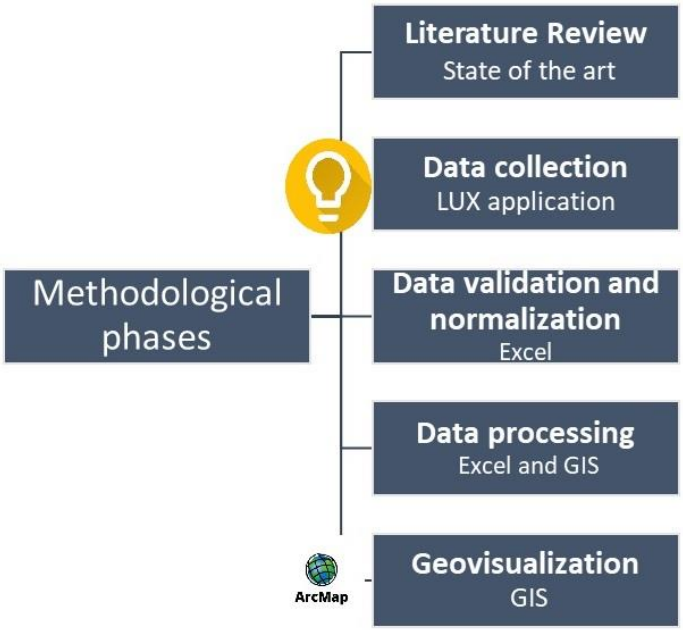

Fig. 2. The research methodological process

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For field research, the mobile application **'Lux Light Meter Pro'**[28] was used, which enables relatively precise measurements of light pollution levels (expressed in lux, lx), given the use of mobile devices. The application was chosen for its reliability and compatibility with the research requirements, including the ability to collect accurate, time-stamped data. Data was

[28] Reviews for the mentioned application indicate very high user ratings compared to other applications with the same function - https://play.google.com/store/apps/details?id=com.doggoapps.luxlight&hl=en&pli=1 (accessed in April 4, 2024).

gathered at a total of 18 locations within the local community of Trg Oslobođenja – Centar, aiming to capture key points (from the perspective of functional and morphological differentiation) that represent the entire area within the defined community boundaries (Figure 1). Locations were selected near street lighting, public facilities and green spaces to allow for comparisons of pollution levels across different parts of the area and under varying conditions.

Data collection was conducted from *March 30 to April 5, 2024*. Measurements were taken twice a day: in the morning (08:00 am) to capture daylight illumination levels, and in the evening (08:00 pm) to measure different levels of light pollution. This methodology enables the analysis of changes in the intensity of light pollution depending on the time of day and specific urban conditions (weather). The final output of the research process are thematic maps of light levels/illumination and light pollution at night, which represent the spatial distribution of this type of pollution within the local community of Trg Oslobođenja – Centar. This form of visualization provides significant insights into the spatial patterns of illumination and light pollution, allowing the identification of high-intensity zones, which is very important for planning of mitigation measures and the development of strategies for the sustainable tourism of the area.

RESULTS

Analyzing the collected statistical data (database) and thematic cartographic visualizations revealed that light pollution directly correlates with the morphological and functional differentiation of the area. Daylight cannot be classified as light pollution. Measurements, database creation and geovizualization of illumination during the morning hours (08:00 am), focusing on natural daylight, were conducted for comparative analysis with artificial night illumination. The goal was to determine the natural and anthropogenic factors influencing this type of pollution.

The comparative analysis identified significant differences between natural daylight and nocturnal light pollution levels (as expected), but it also established a link between the factors influencing daytime illumination and night-time pollution. Among detected factors, cloud cover stands out as having a significant effect on illumination, impacting the transformation of sunlight as it passes through the atmosphere to reach the Earth's surface. The highest average morning daylight levels were recorded at *8,883.6 lux* during clear and sunny days, while the lowest average values were *2,569.1 lux* during overcast and partly cloudy days.

Cloud cover also significantly affects night-time illumination. The highest average light levels at 8:00 pm were *17.9 lux* during clear nights, while the lowest were approximately *10 lux* on cloudy nights. In addition to cloud cover, the openness of the space to natural light sources (the morphology of the area) plays a crucial role in both daylight illumination and

light pollution. Even without artificial light sources, the most illuminated areas at night are those that are morphologically open to natural light. However, the morphological predisposition of an area (such as land cover contributing to its openness to natural light) is significantly enhanced during nighttime by the functional differentiation of the space. This includes services, illuminated advertisements and light emitted from vehicles, which together amplify the effects of light pollution.

The map (Figures 3, 4) illustrates the distribution of light illumination levels in the local community of Trg Oslobođenja-Centar during mornings on weekdays and weekends. The highest daily illumination (Figures 3, 4) is found in areas with the most open spaces, wide streets and squares that allow maximum passage of natural light. Additionally, extra artificial light from street lighting and commercial establishments contributes to the overall high level of illumination. On the outskirts, where daily light pollution is minimal, natural daylight is limited and artificial light sources are scarce. These areas may include residential neighborhoods with few open spaces or regions with dense tree cover that obstructs sunlight. It is important to note that cloud cover had a significant impact on the daytime measurement results.

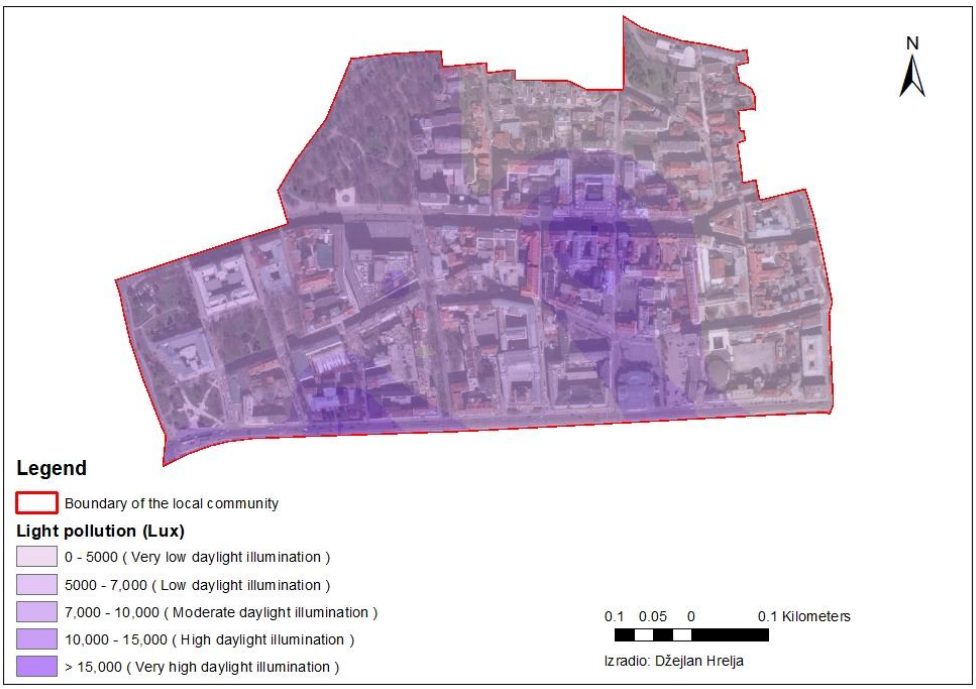

Fig. 3. Map of Illumination in the Morning Hours on a Weekday (Trg Oslobođenja - Centar)

The highest average morning illumination (08:00 am) during weekdays was approximately *9,000 lux* on clear and sunny days, while the lowest was around 4,000 lux on cloudy days.

The maximum recorded values during this measurement period (morphologically open spaces) were *14,097.9 lux*, while the minimum recorded values (morphologically enclosed spaces) during the same period were *3,093.5 lux*. Maximum daylight values were measured on clear days, while the minimum values were recorded during periods of significant cloud cover.

On weekends, with one day being clear and sunny and the other cloudy, similar measurement results were observed as on weekdays. The highest average morning illumination (08:00 am) during weekends exceeded *10,000 lux* on clear and sunny days, while the lowest was around *2,569.1 lux* on cloudy days. The maximum recorded values during this measurement period (morphologically open spaces) were *41,250.5 lux*, while the minimum recorded values (morphologically enclosed spaces) were *1,786.8 lux*.

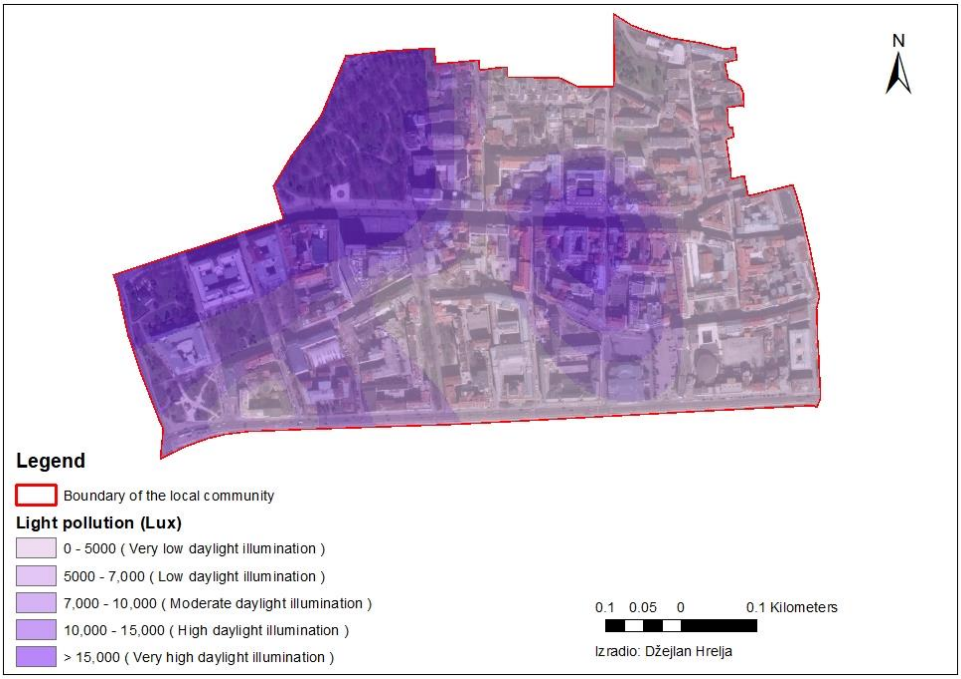

Fig. 4. Map of Illumination in the Morning Hours on a Weekend (Trg Oslobođenja - Centar)

Maximum daylight values were measured on sunny days, while the minimum values were observed during periods of significant cloud cover and in morphologically enclosed areas (Figure 4).

Measurements of light pollution during nighttime hours (8:00 pm) and the geovisualization of spatial data reveal that pollution levels depend on both natural and anthropogenic factors. This conclusion is supported by the fact that the areas with the highest concentrations of

daylight also exhibit the highest levels of nighttime light pollution. A natural factor influencing these levels is cloud cover. Among the anthropogenic factors, the morphological and physical characteristics of the area, along with its functional differentiation, play a significant role in determining the extent of light pollution.

High levels of light pollution arise from the dense presence of artificial light sources, such as intense street lighting, heavily illuminated commercial areas and busy traffic. These are universal sources of light pollution, identified in studies conducted in other urban areas (Gaston et al, 2013). Areas with the lowest levels of light pollution are located on the outskirts of the local community, where there are very few or no sources of artificial light, which may include parks, green spaces or residential areas with minimal lighting. These zones are typically associated with urban cores where commercial and residential activities overlap. Moderate light pollution levels are present in transitional zones, such as areas between highly urbanized sectors and more peripheral or open spaces. These areas may have reduced but still active lighting, such as residential streets or secondary roads (Figures 5, 6).

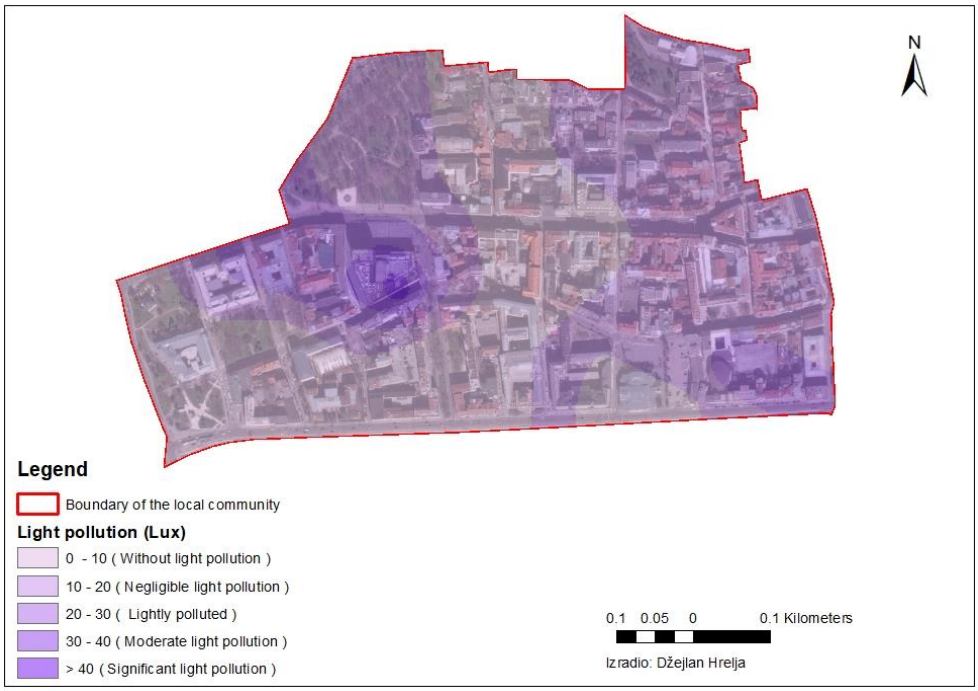

Fig. 5. Map of Light Pollution in the Evening Hours on a Weekday (Trg Oslobođenja - Centar)

The highest average concentration of light pollution at 8:00 pm on weekdays was *17.9 lux* during clear nights, while the lowest was approximately *9.9 lux* during cloudy nights. The maximum recorded values during this measurement period (in morphologically open spaces) were *21.1 lux*, whereas the minimum recorded values (in morphologically enclosed spaces)

were *4.2 lux*. The maximum light pollution levels were observed on clear nights in areas that are morphologically open and have a high concentration of service functions, while the minimum levels were recorded during periods of significant nighttime cloud cover in morphologically enclosed spaces without service functions.

During the nighttime measurement periods on weekends, the highest average concentration of light pollution was over *12.2 lux* on a clear night, while on the second day of the weekend (during a cloudy night), it was *10.7 lux*. The maximum recorded values during this period (in morphologically open spaces) were *17.7 lux*, whereas the minimum recorded value (in morphologically enclosed spaces) was *7.6 lux*. The maximum levels of light pollution on weekends were recorded in morphologically open areas with prominent service functions during clear nights, while the minimum levels were measured in areas with opposite spatial and functional characteristics (Figure 6).

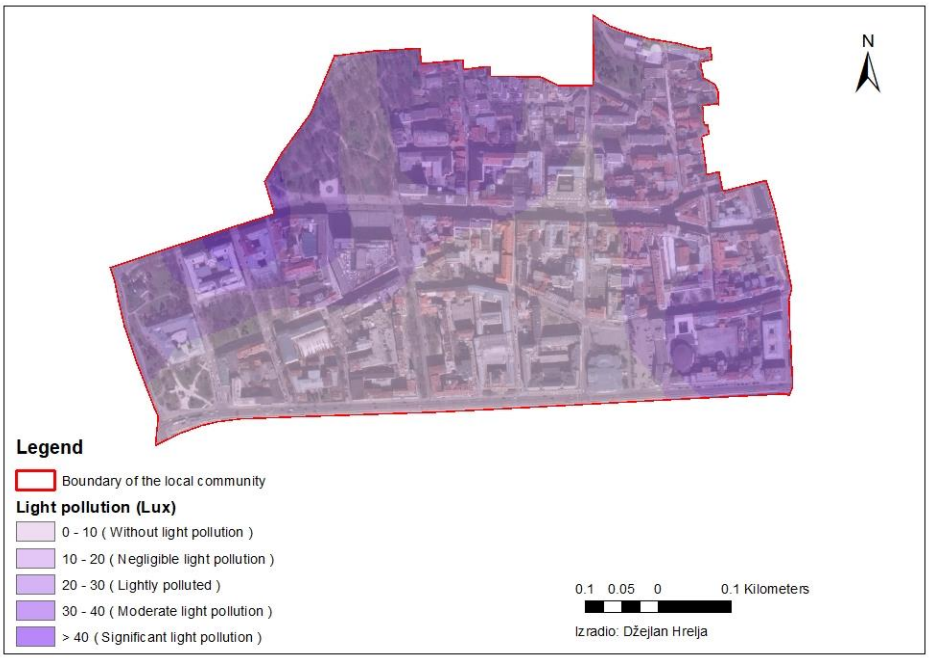

Fig. 6. Map of Light Pollution in the Evening Hours on a Weekend (Trg Oslobođenja - Centar)

A comparative analysis of statistical and geovisualized data on light pollution during evening hours (8:00 pm) on weekdays and weekends revealed no significant differences in the intensity or spatial extent of this type of pollution.
Slightly higher levels of light pollution (within certain lux categories) were observed on weekends, coinciding with increased activity by both local residents and international visitors (Table 1).

Tab. 1. Light Pollution in the evening hours (Trg Oslobođenja – Centar)

Category	(LUX)	Weekday		Weekends	
		%	km^2	%	km^2
1	<10	34.27	0.186	36.65	0.188
2	10- 20	49.74	0.27	42.33	0.23
3	20 - 30	14.6	0.079	14.04	0.066
4	30 - 40	1.19	0.006	6.96	0.028
5	>40	0.2	0.001	0.02	0.030

Source: authors

The local population predominantly uses private vehicles, accounting for approximately 70-80% of all movement (Ministry of Transport of Sarajevo Canton, 2014, 2023), which contributes to light pollution through vehicle lighting. However, this source of illumination does not create substantial differences between weekdays and weekends. Consequently, it can be concluded that the key factors influencing light pollution levels are natural (cloud cover and spatial morphology) and anthropogenic (functional diversification and land cover characteristics).

DISCUSSION

The analysis of light pollution in the Trg Oslobođenja-Centar area reveals significant spatial patterns and disparities. Areas with the highest concentrations of natural daylight also exhibit the highest levels of nighttime light pollution, revealing overlapping spatial patterns shaped by both physical and anthropogenic factors. Among the physical-geographical factors influencing the measured values, cloud cover stands out (Sciezor, 2020). During clear days and nights, higher illumination levels are recorded, while cloudy conditions lead to reduced light levels, stating the dynamic role of natural weather conditions in light pollution measurements (Liu et al, 2020). The morphological characteristics (openness or enclosure of spaces) and functional differentiation of the area (e.g., presence of service functions and commercial lighting) play a significant role in light pollution levels (Pan, Du, 2020). Open spaces with high service activity exhibit the highest levels, while enclosed spaces with fewer functions show significantly lower levels. Zones with the highest levels of illumination and night pollution are predominantly located along traffic routes (same as for noise pollution) particularly near main streets, where intense street lighting is necessary for traffic and

pedestrian safety. The commercial areas, including shopping centers, restaurants and cafes significantly contribute to increased pollution levels due to large illuminated advertisements and extended operating hours. Zones with the lowest levels of light pollution are predominantly enclosed green spaces and areas with limited traffic activity, such as parks. These areas provide important shelters from urban illumination, stressing the value of preserving such spaces in highly urbanized environments (Candolin, 2024). Considering the fact that light pollution plays a significant role in habitat transformation and altering ecosystem functions, areas with minimal or no light pollution may hold greater biodiversity-related tourism appeal. For example, in regions illuminated solely by natural light, there is the possibility of observing nocturnal organisms, such as fireflies, which are absent in areas burdened by this form of pollution.

The contributing factors to light pollution are multiple, but three important elements stand out:

- cloudy weather and intense lighting along traffic routes, combined with inadequate lighting infrastructure that unnecessarily disperses significant amounts of artificial light, are primary reasons contributing to pollution.
- large light advertisements on buildings and commercial establishments further increase pollution, especially in the central urban zones.
- unnecessary and redundant lighting along pedestrian paths, particularly in areas with low foot traffic.

Addressing light pollution in this area requires a deatiled approach. The adoption of energy-efficient lighting systems, such as LED lights with adaptive brightness, could significantly reduce energy consumption and light spill (Gentile, 2022; URL 8), with lighting fixtures directed at a 90-degree angle relative to the surface. Another solution is the installation of sensors to turn artificial lighting on and off during time periods when illumination is needed or not needed. On the other hand, implementing dark-sky policies, which aim to reduce unnecessary lighting while preserving visibility and safety, could play a pivotal role in mitigating pollution levels (Žiberna et al, 2022). Raising awareness among local businesses, government bodies and tourists is also crucial, particularly regarding the environmental and aesthetic consequences of light pollution (Rodrigues, Loureiro, 2024).

In some cases, artificial lighting can also serve as a part of the tourism offering. It is well-known that Paris, aside from other reasons (such as being a center of culture, education and philosophy during the Enlightenment), earned its nickname "The City of Light" due to the establishment of street lighting that illuminated pathways for its citizens and visitors. Similarly, to improve general living conditions and enhance tourism attractiveness, Sarajevo established the Park of Light, known for its light effects and illumination. Additionally, the Sarajevo Festival of Light was created to utilize artificial light sources as a tourist attraction.

The project, which includes light installations at the National Museum of Bosnia and Herzegovina, aims to revitalize the Museum as a 'must-see' Sarajevo attraction and create a new, sustainable tourism product (Tourism Development Strategy of Sarajevo Canton, 2024). Similarly, some countries highlight natural illumination as a key tourist attraction. For instance, the Northern Lights are marketed as a global phenomenon and one of the seven natural wonders of the world in Norwegian tourism. Norway has embraced the Northern Lights as its most important attraction, enriching it with various complementary activities (Deben, 2022).

However, there are numerous examples worldwide where light does not contribute to the tourism appeal of an area. For example, the DarkSky Association, in its International Principles on Astrotourism Development, highlights that dark nights are a disappearing tourism resource (URL 9). Additionally, there are numerous examples of the negative impact of tourism and tourist traffic on increasing the effects of light pollution, indirectly affecting ecosystem functioning (Cho et al., 2014; Sung, 2022).

While the methodology used in this study provided valuable insights, there is need for improvement in future research. One significant step would be to calibrate the collected data, ensuring higher precision in measurements (the use of more sophisticated devices for measuring light pollution such as *Konica Minolta T-10A Lux Meter or Extech LT300 Light Meter*, which could also validate the measurements obtained through the application) (URL 10). Future studies could also overlay light pollution models with residential zones and key sources of artificial lighting, comparing these layers with tourist movements and the intensity of site visitation. This approach would allow researchers to understand how light pollution intersects with urban functions, residential living conditions and tourism activities. Additionally, assessing the impact of light pollution on the quality of life for both residents and tourists would provide a more holistic understanding of its consequences (Falchi et al, 2011; Candolin, 2024).

Future research should incorporate qualitative methods, such as surveys or interviews with tourists and local residents to better understand their perceptions and experiences regarding light pollution. Such studies would reveal the subjective dimensions of this issue, including its impact on tourist satisfaction, well-being, and the attractiveness of urban destinations. Combining these insights with quantitative data would create a significant framework for researching light pollution in urban and tourist destination areas like Sarajevo (Trg Oslobođenja-Centar).

CONCLUSION

This research is based on the process of measuring and geovisualizing daylight and nighttime light pollution, with a focus on spatial distribution in local community Trg Oslobođenja-Centar, Sarajevo. The findings show that both physical-geographical factors, like cloud

cover along with the morphological characteristics of the area (land cover) and the functional diversification of the space, human-made influences such as bright streetlights, commercial lighting and traffic, strongly affect the levels and distribution of light pollution. Open areas with active commercial use have the highest pollution levels. As a popular area for tourists and tourism activities, Trg Oslobođenja-Centar faces challenges in managing lighting needs while promoting sustainable tourism. Light pollution affects not only the environment and appearance of the area but also how tourists experience and perceive the destination.

As highlighted in the study, in some cases, light (both artificial and natural) serves as a tourist attraction and contributes to increased tourist traffic. On the other hand, dark nights are becoming an increasingly threatened tourism resource for specific types of tourism, such as astrotourism. Additionally, high levels of illumination reduce biodiversity, indirectly diminishing the attractiveness of tourist destinations. Furthermore, tourism itself is often cited as a significant factor contributing to light pollution due to the use of tourism services, which unnecessarily consume electricity and produce excessive levels of artificial light. In the tourism industry, to ensure economic efficiency and promote responsible, sustainable practices, various methods are being explored to reduce electricity consumption and light pollution. One such example is the installation of sensors for turning artificial light sources on and off, as well as the use of key cards for locking/unlocking hotel units, which interrupt the power supply in rooms or apartments, thereby reducing energy consumption and light pollution.

Using energy-efficient lighting, dark-sky practices and educating businesses and visitors could help reduce the impact of light pollution and support sustainable tourism. The study also highlights the need to combine numerical data with personal feedback from tourists and residents to better understand how light pollution affects urban living and tourism. This type of research is significant in geography as it connects spatial patterns of light pollution with human activities and environmental impacts. It provides insights for urban planning, sustainable development and the mitigation of pollution in rapidly growing urban areas such as Sarajevo.

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