

CLIMATE CHANGE, CULTURAL HERITAGE AND THE PLANNING OF SUSTAINABLE TOURISM: THE CASE OF STEĆCI IN SARAJEVO CANTON

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Abstract: The long-term monitoring of climate in Sarajevo Canton, primarily based on temperature and precipitation data from the Sarajevo–Bjelave meteorological station (1888–2024), provides a solid foundation for assessing climate variability and change. While the overall trend reflects gradual warming and relatively stable annual precipitation, alterations in seasonal patterns have contributed to an increased occurrence of floods, droughts, landslides and wildfires. These processes threaten not only the natural environment but also the preservation of cultural heritage, particularly necropolises of stećci, which represent an integral component of the Canton's historical landscape. As these medieval monuments are recognized as a unique cultural asset and a key driver for the development of special-interest tourism, their exposure to climate impacts directly influences long-term strategies for sustainable tourism. By integrating spatial models of climate-related hazards with the distribution of stećci, this research enhances understanding of how climate change affects both cultural heritage and tourism development. It underlines the importance of adaptive spatial planning that reconciles heritage conservation with the sustainable use of cultural resources.

Keywords: climate change, stećci, sustainable tourism, cultural heritage, Sarajevo Canton

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INTRODUCTION

Climate is defined as the average state of the atmosphere at a given location over a specific period of time (considering both average and extreme deviations). Climate monitoring is usually based on series of climate data covering a 30-year time span (Drešković, N., Hrelja, E., 2025c; Drešković, N., 2011; Drešković, N., 2003; Šegota, T., Filipčić, A., 1996). The heterogeneity of the Earth's surface relief and the extremely high complexity of general atmospheric circulation are the main reasons for the existence of significant differences between the climates of individual parts of the world.

This situation is expressed to such an extent that, theoretically speaking, it can be said that “almost every square kilometer of the Earth's surface has its own climate” (Drešković, N., 2011; Šegota, T., 1996). Earth's climate has been changing since the formation of the planet approximately 4.5 billion years ago, influenced by natural and social factors with varying intensities (Popović, D., Vuković, A., 2019). During this long period, the climate oscillated between warm periods and ice ages. Such cycles have always lasted tens of thousands or even millions of years; however, over the last 150 years, as a result of intensive industrialization, temperatures have been rising faster than ever before. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as “any change in climate over time, whether due to natural variability or as a result of human activity.” The United Nations define climate change as long-term changes in temperatures and weather patterns. The recent increase in temperature is particularly pronounced in the Northern Hemisphere and can be attributed with high confidence to human activities.

Human influence on climate is manifested through various forms of activities and actions. This includes the clearing of forested areas (deforestation) and the expansion of agricultural and urbanized land. Through the consumption of fossil fuels (in energy production, transport, agriculture, etc.), humans contribute to increasing concentrations of carbon dioxide (CO₂) and other gases in the atmosphere, thereby enhancing the greenhouse effect and consequently global warming. Among the most important gases naturally present in the atmosphere that absorb long-wave terrestrial radiation and are therefore referred to as greenhouse gases are water vapor and carbon dioxide (CO₂), followed by methane (CH₄), nitrous oxide (N₂O) and ozone (O₃). Despite defined international obligations, the concentration of carbon dioxide (CO₂) in the atmosphere continues to rise and, according to World Meteorological Organization data, reached a record level in 2019 (almost 150% higher than in 1750) (Hrelja, E., Drešković, N., 2025). The

main consequence of climate change is an increase in the Earth's global temperature.

According to meteorological measurements, temperatures have increased by 1.1 °C compared to the pre-industrial period. There are certain regional differences in temperature increase; thus, air temperatures in Europe have risen even more (2.12–2.19 °C) compared to the global average for the same period.

Furthermore, according to climate change scenarios, it can be stated that without drastic reductions in global greenhouse gas emissions, the 2 °C threshold will be exceeded before 2050 (Hrelja, E., Drešković, N., 2025). During the period of meteorological monitoring at weather stations (for the analyzed time series of 136 years), Bosnia and Herzegovina has recorded an increase in air temperature slightly higher than the global average and slightly lower than the European average (Drešković, Hrelja, 2025a).

Climate change has a significant impact on natural processes, social and economic activities (including impacts on cultural and historical heritage—specifically, medieval tombstones known as *Stećci*), with pronounced regional differences. Regional differences in climate change impacts depend on changes in basic climate elements as well as other physical-geographical and socio-geographical characteristics of an area. Accordingly, in the context of climate change and its effects, regions are distinguished by reduced summer sea ice cover and permafrost thawing (Arctic); reduced snow cover, decreased ice cover on lakes and rivers and increased winter and spring river discharge (Northern Europe); increased magnitude and frequency of floods (Northwestern Europe); high temperatures and droughts (Central and Eastern Europe); reduced precipitation and rising temperatures accompanied by forest fires (Mediterranean region); fewer days with snow and reduced snow amounts (mountain areas); and urban areas characterized by high temperatures, air and water pollution and increasingly frequent floods. In line with regional characteristics of climate change effects, Bosnia and Herzegovina records rising temperatures and a slight (almost uniform) increase in precipitation. The negative effects of climate change are particularly intense in areas that are naturally predisposed (due to geological structure, relief, climatic, hydrographic, pedological and vegetation characteristics) or anthropogenically predisposed (Drešković, Hrelja, 2025b).

STUDY AREA

Sarajevo Canton is located in the central part of Bosnia and Herzegovina and represents the main administrative, functional and transport core of the country. It covers 1,276.9 km² and includes nine municipalities (Stari Grad, Centar, Novo Sarajevo, Novi Grad, Ilidža, Hadžići, Vogošća, Ilijaš and Trnovo), with Sarajevo City comprising the four central municipalities. According to the final results of the 2013 Census, Sarajevo Canton had a total population of 413,593 inhabitants, making it the most demographically concentrated canton in the Federation of Bosnia and Herzegovina (Federalni zavod za statistiku Bosne i Hercegovine, 2016). The canton's pronounced vertical dissection is reflected in an average elevation of about 1,000 m, ranging from approximately 430 - 480 m in the western lowlands to 2,066 m at the highest mountain peaks (Bjelašnica) in the southwest. This marked hypsometric gradient is essential for interpreting spatial contrasts in climate, ecosystems and land use, which, in turn, frame both exposure and sensitivity of outdoor cultural heritage sites (including stećci) and the seasonal patterning of tourism demand.

The geological structure of Sarajevo Canton is complex, shaped by tectonic processes typical of the Dinarides. Mesozoic formations, particularly carbonate rocks, are widespread, while Quaternary deposits dominate valley floors and major fluvial corridors (Ekonomski institut Sarajevo, 2024). Carbonate lithology is especially relevant for stećci, which are predominantly carved from limestone, making them inherently sensitive to weathering processes. These processes are further intensified by climate variability, notably freeze-thaw cycling, changing moisture regimes and pollution-related chemical alteration, particularly in urban and industrial basins. In this context, lithological characteristics define a baseline level of material vulnerability that must be interpreted in conjunction with climate signals, environmental pressures and site-specific management practices, as emphasized in UNESCO's approach to climate change impacts on World Heritage properties (UNESCO World Heritage Committee, 2018).

Geomorphologically, the canton consists of the Sarajevo intramontane basin (Sarajevo Polje and the Sarajevo Valley), surrounded by mountainous rims - Bjelašnica and Igman to the southwest, Trebević to the southeast and east and a lower mountain belt to the northeast. This basin-rim structure generates pronounced local contrasts in exposure, accessibility and microclimatic conditions. In particular, the enclosed valley topography is directly linked to frequent temperature inversions and winter stagnation episodes, which suppress air circulation and promote the accumulation of pollutants and moisture near the ground surface (Mašić et al.,

2016). These conditions shape both environmental stressors (air pollution, moisture retention) and visitor comfort, factors that can influence the attractiveness of tourism and long-term preservation of cultural landscapes and open-air heritage assets.

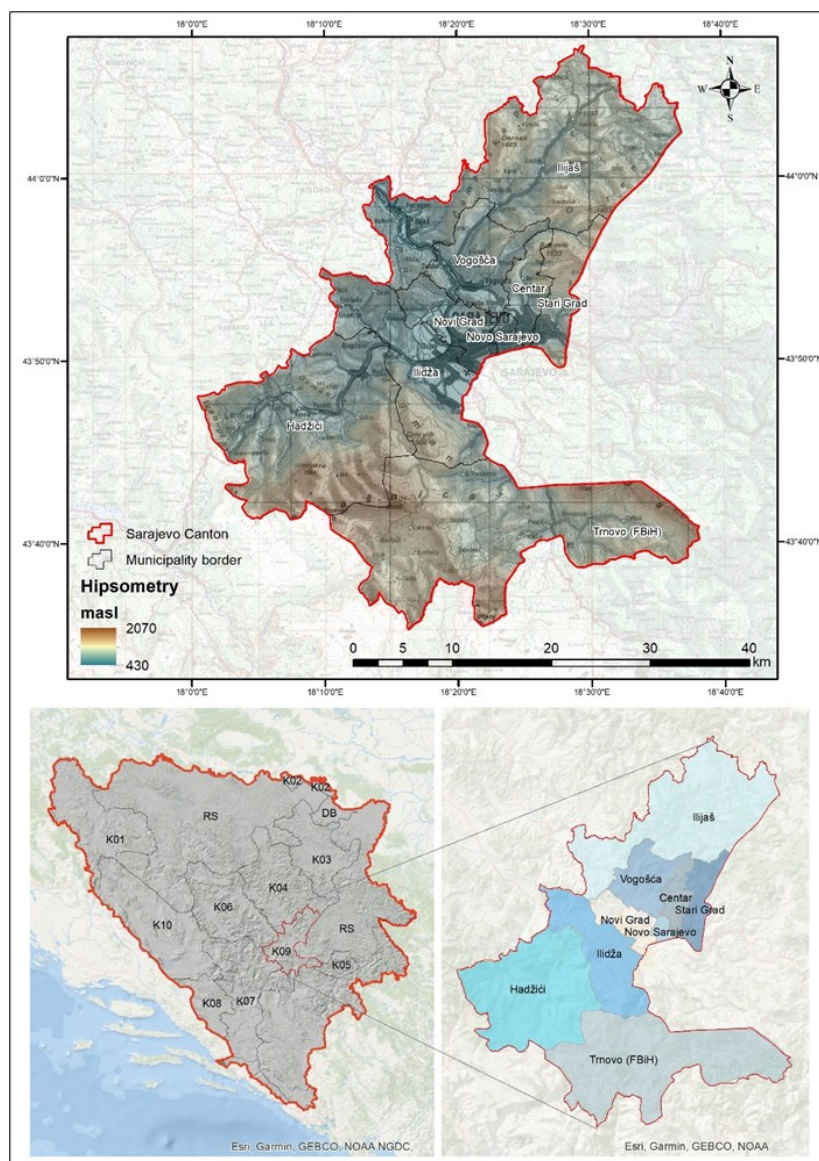


Fig. 1. Hypsometry of Sarajevo Canton with municipal boundaries, illustrating the elevation gradient from the Sarajevo Valley to the surrounding mountain areas and the basin-rim relief structure.

Source: Authors' own elaboration based on GIS analysis using Esri basemaps, topographic maps (Military Geographical Institute, Belgrade, 1984), and the GIS Centre geodatabase (University of Sarajevo – Faculty of Science)

Most of Sarajevo Canton is characterized by a temperate humid climate (Cfb), while higher elevations transition towards colder snow-forest and Dfb climatic conditions, reflecting pronounced altitudinal differentiation typical of the central Dinarides (Drešković, 2011). According to long-term observations at the Sarajevo-Bjelave meteorological station (1888–2024), the average annual air temperature is 9.8°C, while the average total annual precipitation amounts to 918.8 mm. Over this period, air temperature increased by 1.7°C, accompanied by a decrease of approximately 20 mm in total annual precipitation, indicating a clear warming trend (Drešković, Hrelja, 2025a).

Long instrumental climate series from Sarajevo provides a strong basis for analyzing climate fluctuations and long-term trends in temperature and precipitation regimes. These climatic trends are relevant for assessing cumulative stress on exposed stone heritage. At the city-basin scale, temperature inversions represent a defining microclimatic feature of the Sarajevo Valley, strongly influencing humidity conditions and the accumulation of air pollutants (Mašić et al., 2016; Sivac, 2022). These processes are particularly important for surface soiling and chemically driven weathering pathways on carbonate stone. Taken together, these climatic realities are directly relevant for stećci conservation and tourism planning, as they influence seasonality, outdoor thermal comfort and site-specific risk profiles related to visitor access and maintenance, including extreme precipitation events, heat waves and freeze-thaw cycles.

Biogeographically, Sarajevo Canton belongs to the Dinaric mountain system and is characterized by forest ecosystems with pronounced altitudinal zonation and high habitat diversity (Đug & Drešković, 2012). Forests and forest land cover approximately 83,000 ha, or about 65% of the cantonal territory, forming an important natural matrix within which many stećci sites are embedded. The canton belongs to the Black Sea drainage basin and is drained by the Bosna River and its main tributaries - Miljacka, Željeznica and Zujevina, which structure settlement patterns and accessibility corridors.

Protected areas such as Bijambare, Trebević, Skakavac, Bentbaša and Vrelo Bosne represent the basis of nature-based tourism and provide relevant planning and governance frameworks where cultural heritage and conservation objectives intersect (Đug & Drešković, 2012). Recent planning practice increasingly applies GIS-based spatial analysis to support sustainable tourism and protected-area management in Sarajevo Canton, an approach that can be extended to stećci sites to better manage visitation, accessibility and climate-related vulnerability (Sivac et al., 2023).

Sarajevo Canton represents the most demographically concentrated area in Bosnia and Herzegovina, characterized by a dense urban core and a pronounced concentration of population, services and infrastructure within the Sarajevo metropolitan zone. The functional dominance of the capital region strongly shapes tourism flows, accommodation capacity and market accessibility, reinforcing Sarajevo's role as the primary tourism gateway in the country. Tourism indicators for Sarajevo Canton demonstrate a strong post-pandemic growth trajectory.

Tourist arrivals increased from 565,139 in 2022 to 716,293 in 2023, reaching 806,597 arrivals in 2024, while overnight stays rose from 1,185,115 in 2022 to 1,432,133 in 2023 and 1,545,491 in 2024, confirming Sarajevo's position as one of the leading urban tourism destinations in the country (Federalni zavod za statistiku Federacije Bosne i Hercegovine, 2025). This centrality can be strategically leveraged for the valorization of stećci through thematic routes, interpretative frameworks and day-trip visits, provided that conservation constraints and climate-related risks are explicitly integrated into planning and management processes (UNESCO World Heritage Committee, 2018). Recent geospatial analyses of tourism development in Sarajevo emphasize the need for more coherent planning instruments, data-driven spatial monitoring and product diversification, approaches that are directly applicable to cultural heritage tourism development under conditions of increasing climate stress (Sivac et al., 2023).

The canton's accessibility is structured by a multi-level road network and by the Sarajevo International Airport, which links Sarajevo to regional and selected European hubs. Internal mobility is supported by urban public transport and by mountain access corridors to Igman-Bjelašnica and Trebević.

For stećci tourism, this transport configuration creates opportunities for integrating sites into short-stay and excursion products; however, it also implies that climate-related disruptions (heavy precipitation, winter icing, heat stress) and urban environmental conditions, particularly recurrent winter smog episodes associated with temperature inversions, can affect both visitor experience and operational logistics for site management, as evidenced by recent air-pollution events in Sarajevo (Reuters, 2024).

As a result of long-term settlement processes, Bosnia and Herzegovina possesses an exceptionally rich cultural-historical heritage, among which stećci - medieval tombstones - hold particular significance. Of an estimated 70,000–100,000 stećci, around 60,000 are located within Bosnia and Herzegovina across approximately 3,300 sites. Within Sarajevo Canton, 1,995 stećci have been digitized and analyzed

in the framework of this research, providing an empirical basis for spatial and climate-related assessment. Stećci, as climate-exposed, open-air stone monuments, represent not only symbols of local identity but also an essential element of the tourism offer, contributing to the development of cultural and sustainable tourism within Sarajevo Canton. Within the Horizon Europe STECCI project research agenda, stećci are approached as climate-exposed, open-air stone monuments affected by interacting hazards, including changing climate extremes, environmental pollution and anthropogenic pressures (UNESCO World Heritage Committee, 2018; STECCI Project, 2023).

In Sarajevo Canton, the combined effect of mountain-basin topography and pronounced topo climatic variability, carbonate lithology and high tourism accessibility creates a particularly relevant setting for examining how climate change reshapes both conservation priorities and tourism valorization pathways. Consequently, the canton provides a representative case for linking (i) regional climate signals and local microclimatic specificity, (ii) stone-material sensitivity and site exposure and (iii) tourism planning instruments, especially GIS-based spatial analysis, aimed at balancing heritage protection with sustainable destination development (Hrelja et al., 2021; Sivac et al., 2023).

METHODOLOGY

For the purpose of analyzing climate change, cultural heritage (stećci) and sustainable tourism planning in the Sarajevo Canton, several methods were applied. Specifically, general scientific methods (spatial analysis methods, geostatistical methods), GIS-based methods (digitalization of the spatial distribution of stećci, spatial analysis of factors relevant to flood-prone areas, multicriteria analyses and flood risk modeling), as well as field observation methods (validation of the results obtained through desk-based research) were used. The flood risk model and its impact on the cultural and historical heritage (stećci) was implemented through three phases:

Phase 1:

Collection of all necessary spatial data (climatic, geomorphological, hydrological, land cover and the spatial distribution of stećci), followed by geoprocessing, digitization and validation of the data.

Phase 2:

Multi-criteria analysis of the factors influencing flood occurrence.

Flood Risk Map (FRM) = Elevation + Slope + Land Cover + Precipitation + Proximity to Streams/Channels.

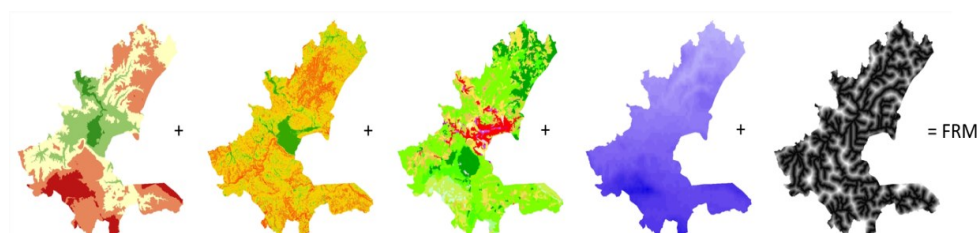


Fig. 2. Multicriteria analysis methodology for flood risk mapping

Source: Authors' own elaboration based on GIS analysis using spatial data from the GIS Centre geodatabase (Department of Geography, University of Sarajevo – Faculty of Science) and CORINE Land Cover 2018 (European Environment Agency, Copernicus Land Monitoring Service).

For each defined factor, weighted interpolation values were determined according to their influence on flooding in specific areas of Sarajevo Canton.

Phase 3:

Analysis, synthesis and systematization of spatial flood risk data and the spatial distribution of stećci.

RESULTS AND DISCUSSION

The conducted multi-criteria analysis indicates that nearly one-third (27%) of Sarajevo Canton is exposed to moderate to very high flood risk, while low and very low risk zones cover about 73% of the territory.

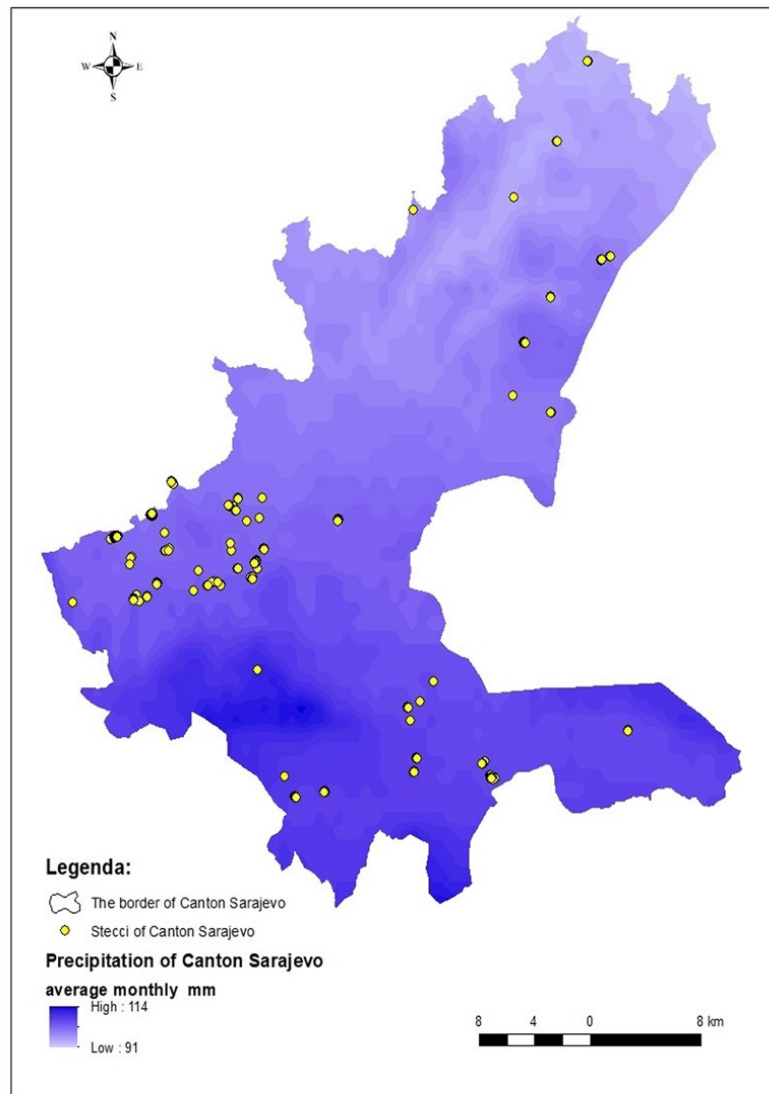


Fig. 3. The average monthly precipitation for the recent thirty-year climatic period and the spatial distribution of stećci in Canton Sarajevo

Source: Authors' own elaboration based on data from the Annual Yearbooks of the Federal Hydrometeorological Institute of Bosnia and Herzegovina (1994–2024) and the geodatabase of the GIS Centre, Department of Geography, University of Sarajevo – Faculty of Science

The main reason for this spatial distribution lies primarily in the geomorphological and climatic characteristics of the research area, particularly the pluviometry regime. The highest flood risks occur in the lowland hypsometric zones and in the valley and basin expansions of major river systems.

Areas located below 700 meters above sea level represent more than one-fifth (22.1%) of the total territory. Approximately 3.5% of the territory lies at an elevation of up to 500 meters. Flat terrains (with a slope of 0–5°) account for 11.1%, of which 7.14% have a slope of less than 2°.

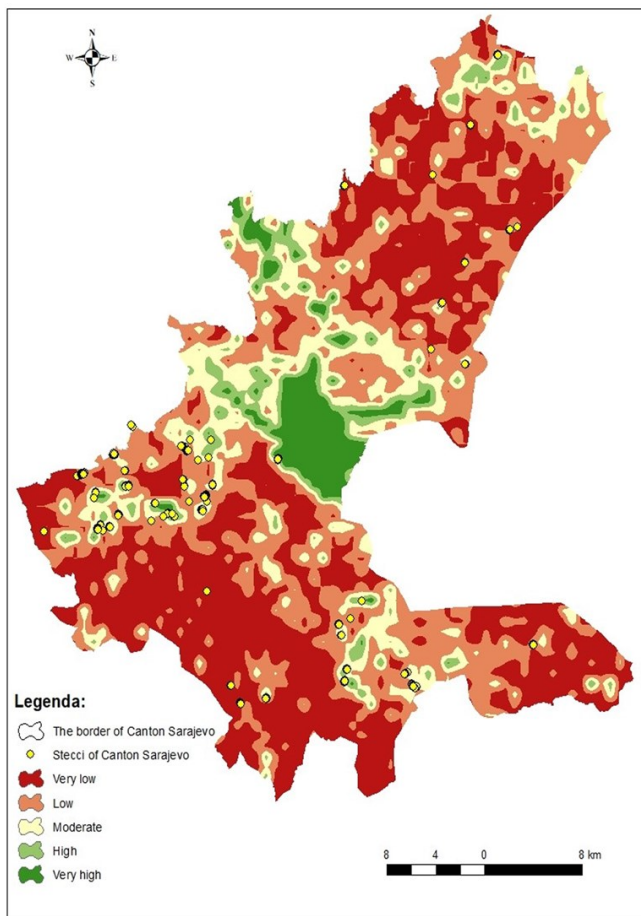


Fig. 4. Flood Risk Map and the spatial distribution of stećci in Canton Sarajevo
Source: Authors' own elaboration based on GIS-based interpolation and spatial analysis using data from the Annual Yearbooks of the Federal Hydrometeorological Institute of Bosnia and Herzegovina (1994–2024) and the geodatabase of the GIS Centre, Department of Geography, University of Sarajevo – Faculty of Science

Parameters of the pluviometry regime, depending on other physical-geographical factors, are crucial for defining flood risk zones. The long-term average maximum monthly precipitation is 114 mm, while the minimum is 91 mm. The average monthly precipitation over the past 30 years has been 78.17 mm. The lowest average amount of precipitation occurs in August, while the highest occurs in December.

A comparative analysis between flood risk zones and the spatial distribution of stećci reveals that more than one-third of all monuments (35.8%) are in areas of moderate to very high flood risk, highlighting their considerable vulnerability. Of the total 1,995 digitized stećci, 13.3% are situated in very low-risk zones and 50.9% in low-risk zones, while 24.2% are in moderate, 5.2% in high and 6.4% in very high flood-risk zones.

These findings emphasize the need to integrate heritage preservation into broader flood-risk management and spatial planning frameworks. Future research should prioritize the comprehensive digitization and georeferencing of all stećci across Sarajevo Canton and expand the analysis to include other climate-induced hazards such as landslides and wildfires, to develop a more holistic and proactive approach to safeguarding cultural heritage under changing environmental conditions.

CONCLUSION

Climate change is evident at the global, regional and local levels. This is demonstrated by numerical indicators of global warming amounting to 1.1 °C at the global level, 2.1 °C at the European level and 1.7 °C at the level of Sarajevo Canton. Indicators of global warming differ across these scales (global, regional and local) due to the physical-geographical and socio-geographical characteristics of the area. The consequences of climate change are manifested through prolonged droughts, forest fires, landslides, floods and other extreme events. For the purpose of adaptation to and mitigation of climate change impacts, it is crucial to model these processes in order to enable predictive actions aimed at protecting natural resources, human lives and material assets, including cultural heritage.

The analysis confirms that a significant portion of Sarajevo Canton is exposed to flood risk, with more than one-third (35.8%) of all digitized stećci located in moderate to very high-risk zones. This finding highlights the vulnerability of cultural heritage to climate-induced hazards and emphasizes the importance of continuous monitoring, mapping and risk evaluation.

As stećci represent not only a unique cultural-historical legacy but also a valuable element of the tourism offers, the obtained results should be incorporated into sustainable tourism and spatial development strategies, particularly those related to special-interest and heritage-based tourism. Integrating cultural heritage protection into broader climate adaptation and spatial planning frameworks is essential for ensuring the long-term preservation and sustainable use of these monuments under changing environmental conditions.

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