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The influence of altitude on the preservation of stećci tombstones in the Tuzla Canton

Edin Hadžimustafić
University of Tuzla, Faculty of natural sciences and mathematics, Department of Geography; Tuzla, Bosnia and Herzegovina
edin.hadzimustafic@untz.ba

Abstract

This paper examines the impact of elevation and morphological forms on the physical preservation of stećci (medieval tombstones) in Tuzla Canton (northeastern Bosnia and Herzegovina). The research was conducted on a refined sample of N = 1,342 stećci tombstones. Geospatial processing was performed using Geographic Information Systems, while statistical analysis was carried out in the R environment. The hypothesis regarding the primary influence of elevation on stone erosion was partially rejected: the Spearman test revealed a weak correlation ($\varrho = 0.078$, $p < 0.01$). The Kruskal-Wallis test ($\chi^2 = 235.56$, $p < 0.001$) demonstrated that morphological form is the dominant factor in degradation. Gable with pedestal exhibit the highest resistance, whereas slab-like and amorphous monuments show the greatest degree of degradation. The results provide a scientific basis for prioritizing conservation and protection efforts for this cultural-historical heritage, as well as for establishing a regional GIS register of necropolis vulnerability to facilitate more effective cultural heritage management.

Keywords

tombstones, elevation, Tuzla, differential weathering, heritage conservation

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Vpliv nadmorske višine na ohranitev stečkov v kantonu Tuzla

Edin Hadžimustafić
Univerza v Tuzli, Fakulteta za naravoslovje in matematiko, Oddelek za geografijo; Tuzla, Bosna in Hercegovina
edin.hadzimustafic@untz.ba

Izvleček

Članek obravnava vpliv nadmorske višine in morfoloških oblik na fizično ohranjenost stečkov (srednjeveških nagrobnikov) v Tuzlanskem kantonu (severovzhodna Bosna in Hercegovina). Raziskava je bila izvedena na prečiščenem vzorcu 1.342 stečkov. Geoprostorska obdelava je potekala s pomočjo GIS, statistična analiza pa v okolju R. Hipoteza o prevladujočem vplivu nadmorske višine na erozijo kamna je bila delno zavrnjena: Spearmanov test je pokazal šibko korelacijo ($\rho = 0{,}078$, $p < 0{,}01$). Kruskal-Wallisov test ($\chi^2 = 235{,}56$, $p < 0{,}001$) je pokazal, da je morfološka oblika prevladujoč dejavnik pri propadanju. Največjo odpornost izkazujejo stečki v obliki hišice s podstavkom, medtem ko največjo stopnjo propadanja kažejo stečki v obliki plošče in tisti z amorfno obliko. Rezultati zagotavljajo znanstveno podlago za določanje prednostnih nalog pri ohranjanju in varovanju te kulturno-zgodovinske dediščine ter za vzpostavitev regionalnega registra GIS o ogroženosti nekropol, kar bo omogočilo učinkovitejše upravljanje kulturne dediščine.

Ključne besede

nagrobni spomeniki, nadmorska višina, Tuzla, diferencialno preperevanje, varovanje kulturne dediščine

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1 Introduction

The subject of this paper is the impact of elevation on the preservation of stećci (plural for stećak; medieval tombstones) in the Tuzla Canton, located in northeastern Bosnia and Herzegovina. The Tuzla Canton comprises 13 of the 143 municipalities in Bosnia and Herzegovina. This paper analyzes 1,342 stećci across 124 necropolises.

The aim of this study is to determine whether the elevation at which necropolises are located primarily influences the degree of preservation of the stećci. Climate changes with increasing elevation: temperatures drop and air density decreases, while precipitation levels rise. It is logical to assume that climatic conditions affect stećci carved from stone—predominantly limestone. However, other factors may also contribute to the degradation of the stone from which a stećak is carved.

Long-term, complex physicochemical and biological processes - known as structural deterioration and atmospheric weathering - drive stone erosion. The rate and nature of erosion depend primarily on the geographical location (specifically its microclimate and orientation) and the elevation of the necropolis (Yan & Wang, 2024). At higher altitudes, water enters the pores of the rock and freezes at lower temperatures; the resulting expansion in volume causes the rock to crack. Temperature fluctuations—high during the day and low at night—cause the minerals within the rock to expand and contract. At lower altitudes, there is a higher concentration of air pollutants (SO2, NOx, CO2). When combined with rainwater, these gases form acids that dissolve carbonate rocks. Acidic precipitation can accelerate the chemical dissolution of limestone, leading to mass loss, changes in porosity, and the degradation of the rock's mechanical properties (Yin et al., 2026). On northern slopes, moisture remains longer, which favors the development of bacteria, lichens, mosses and fungi. On the southern slopes, the microclimatic processes of heating and cooling of the stone are pronounced.

The research objectives include field data collection; systematization and filtering of the database, which comprised a homogeneous and refined sample of N = 1,342 monuments; hypsometric correlation analysis; descriptive non-parametric analysis; and an examination of the influence of stećak shapes on their state of preservation.

The main hypothesis is that the physical preservation of stećci is primarily conditioned by elevation, with the relationship between elevation and preservation showing a high correlation. The auxiliary hypothesis is that the morphological form of the stećci constitutes a secondary factor in the process of selective weathering of the rock from which they were carved.

This study builds upon previous research regarding the preservation status of stećak necropolises in the Tuzla Canton (Hadžimustafić, 2025) - research that classified stećci by category and form and mapped the geographical distribution of all necropolises, yet employed only descriptive statistics rather than inferential statistical tests. Based on available information, no studies have been recorded in the Tuzla Canton—or across the wider territory of Bosnia and Herzegovina—that encompass such an extensive sample of geographically precisely located stećak necropolises categorized by elevation. Existing analyses include studies on the impact of climate on a smaller number of locality, such as the analysis of ten necropolises situated in different climatic zones (Drešković et al., 2026).

1.1 General characteristics of stećak tombstones

According to their shape, stećci are divided into: lying and standing. Lying are further divided into types: slab, crate, crate with pedestal, gable and gable with pedestal. Standing forms include: column, cross and amorphous forms (Figure 1). Development, growth and metamorphosis from simpler and smaller to more complex larger forms is one of the first characteristics of stećak (Lovrenović, 2009).

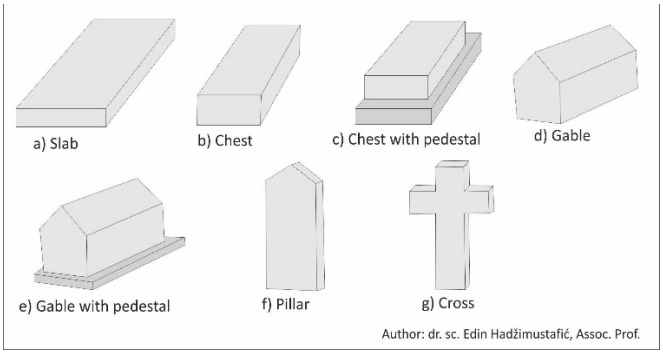


Figure 1: Basic shapes of stećak tombstones.
Source: Hadžimustafić, 2025.

Throughout Bosnia and Herzegovina, there are unique tombstones, special for their diverse and unusual shapes, decorations, and inscriptions. Tombstones have a specific name - "stećak", derived from the word “stand”. They "stand" for almost a thousand years witnessing the turbulent and mystical Bosnian past (Hadžimustafić et al., 2023). Almost as a rule, necropolises with stećak tombstones are located on hills, on river banks or in places that offer a good view of the surrounding land (Benac, 1967). The preservation of medieval cultural heritage remains an important challenge in Bosnia and Herzegovina, as also highlighted by Mirić et al. (2017) in their study of medieval fortresses.

In general and quite simply, it can be said that stećci are stone tombstones that are characteristic of the area of the old Bosnian state (Bešlagić, 1982). Stećci were carved in the period from the 13th to the 16th century. Their age significantly affects their preservation.

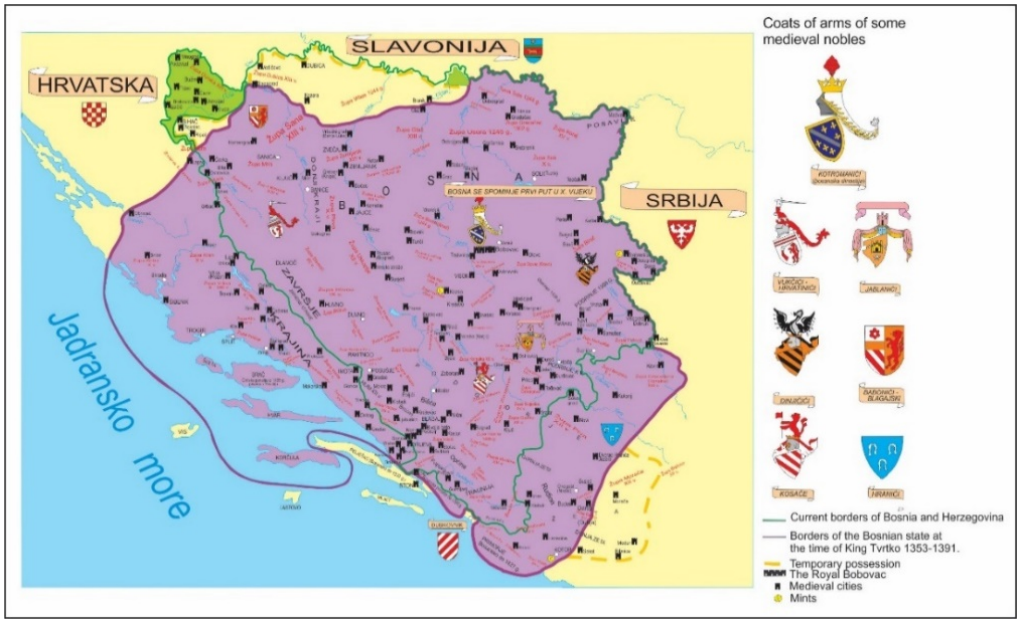


Figure 2: The Bosnian state in the time of King Tvrtko in 14th century.
Source: Hadžimustafić, 2015. Created by the author according to: Marko Vego (1957). Map of the medieval Bosnian state, Geokarta, Belgrade.

The customs of carving stećak tombstones spread to the entire area of medieval Bosnia. During the reign of Ban Stjepan II Kotromanić, the borders of medieval Bosnia and Hum reached the Adriatic coast and the Cetina River, including the city of Omiš, and during the reign of King Tvrtko I, from 1378 - 1390, they included the area up to near Zadar, including the cities of Split, Trogir and Šibenik, and the islands of Brač, Hvar and Korčula. During the time of Tvrtko I (Figure 2), the cities of Kotor, Nikšić and Herceg-Novi were also in the Bosnian borders. Wherever the people of medieval Bosnia lived and died, regardless of whether they were members of the Bosnian, Catholic or Orthodox Church, stećci tombstones can be found also (Bešlagić, 1971).

The largest number of stećci necropolises, 2,687 sites or 84.97%, are located in Bosnia and Herzegovina. The remaining stećci are located in the border areas of the neighboring countries of Croatia, Serbia and Montenegro, which were once part of the medieval Bosnian state (Bešlagić, 1982).

2 Methodology

2.1 Study area

The Tuzla Canton is one of the ten cantons of the Federation of Bosnia and Herzegovina. It consists of 13 municipalities that together have an area of 2,649 km², which is about 5% of the total area of Bosnia and Herzegovina (Figure 3).

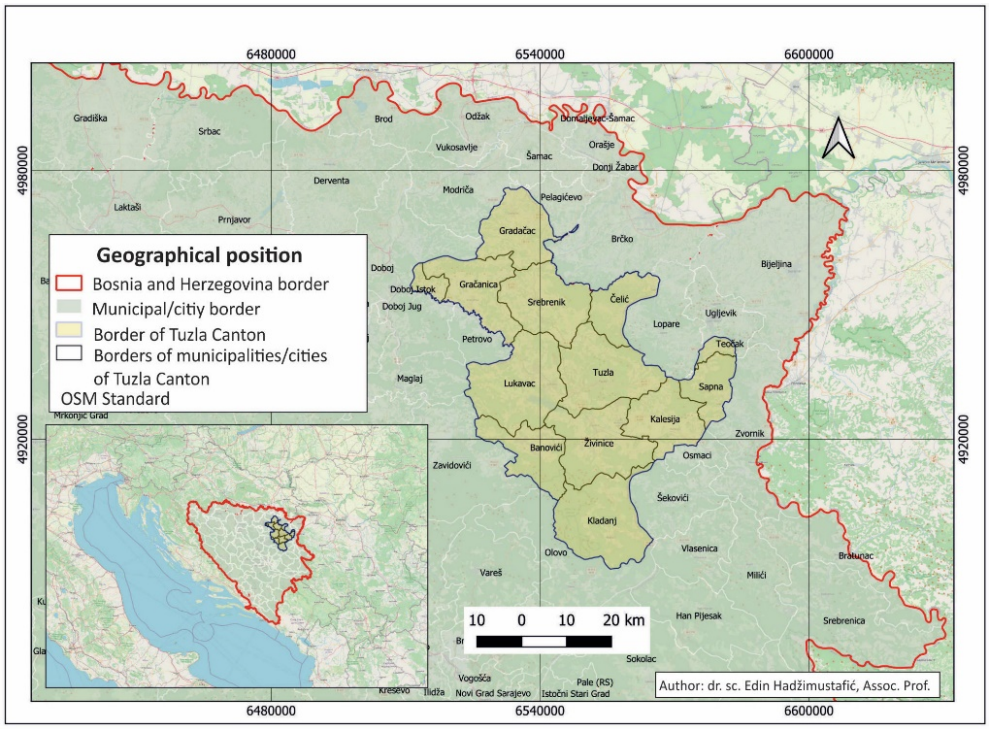


Figure 3: Geographical position of Tuzla Canton.
Source: Hadžimustafić, 2024. Basemap: OpenStreetMap contributors.

The northernmost point of the Tuzla Canton is located at a specific latitude (φ = 44° 55' N), the southernmost point at latitude (φ = 44° 09' N). The easternmost point is at a specific longitude (λ = 19° 02' E), while the westernmost point is at longitude (λ = 18° 08' E). (Hadžimustafić & Smajić, 2016).

The Tuzla Canton has a diverse relief characterized by low and medium-high mountains, foothills and valleys. The highest peak is located on the Konjuh mountain with an altitude of 1,327 m, and the lowest point at an altitude of 95 m is located in the Gradašnica riverbed

in the Gradačac municipality. The Canton is mostly located on the northeastern foothills of the Dinaric mountain system, in the area between the river valleys of the Bosna, Drina, Sava and Krivaja rivers (Hatunić et al., 2013). The Spreča Valley and the Tuzla Basin are the most striking relief depressions. The relief of the Tuzla Canton, except for Konjuh, is part of the macrogeomorphological region of the Lowlands, low mountains and hills, valleys and basins of northern Bosnia (Lepirica, 2009).

The Tuzla Canton also has significant hydropower potential. The most important watercourses are the Spreča, Oskova, Jala, Turija, Tinja and Drinjača rivers (Mešanović & Hadžimustafić, 2010). The average annual air temperature is 10.1 ℃, while the average annual precipitation in Northeastern Bosnia is 928 l/m² (Federal Hydrometeorological Institute).

The preservation of stećak tombstones was carried out in situ at the necropolises of the Tuzla Canton. The basis for analysis in geographic information systems is that data is georeferenced, that its exact geographic location on the Earth's surface is known (Hadžimustafić, 2023). Therefore, the position of necropolises, as well as stećak tombstones, was determined using the global positioning system (GPS). The data collected in this way were used to create a digital relational database "one-to-many", i.e. one necropolis to many stećak tombstones. The database was integrated into geographic information systems.

The state of preservation of the stećci is categorized into five levels (Figure 4). The total number and percentage share of the stećci are listed below: poor – 383 (28.52%); fair – 415 (30.98%); good – 508 (37.83%); very good – 34 (2.53%); and intact – 2 (0.15%).

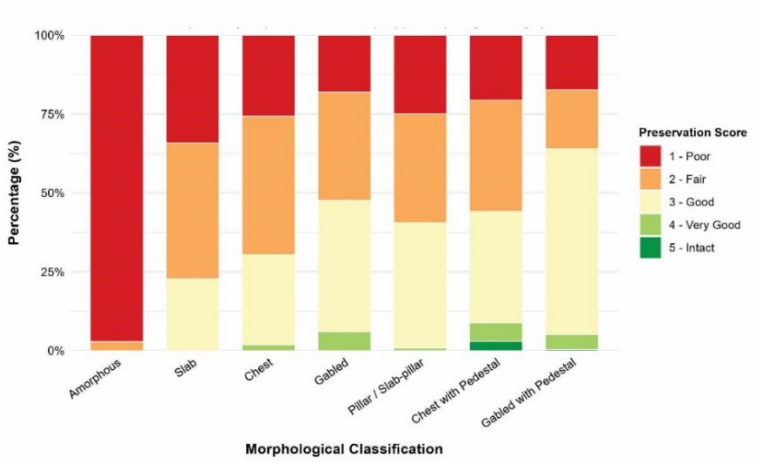


Figure 4: Percentage share of stećak preservation by shape.
Source: Hadžimustafić, 2025. Data: Field research, 2015.

A poorly preserved stećak is a critically damaged or destroyed threatened with complete loss of physical integrity (Figure 5). The form shown is barely recognizable, the stećak is broken into several parts. Decorations and inscriptions were completely destroyed. Extreme erosion and crumbling of the stone is noticeable on the surface, which leads to further decay.



Figure 5: Poorly preserved stećak (Tuzla municipality, Avdibašići settlement. Oštrila locality).
Source: Hadžimustafić, 2015.

A fair-preserved stećak, it has lost most of its original appearance. The original form is damaged, the edges are completely lost or there is a greater breakage. The relief decorations are barely noticeable, while the inscriptions are completely or mostly illegible. Pronounced deep cracks, separation of stone layers and heavy vegetation coverage.

A good-preserved stećak has basic design features that are still clearly recognizable. The edges are considerably rounded, with noticeable broken pieces along them. Decorations and inscriptions are recognizable with shallow and rounded contours. The inscriptions are more difficult to read. Visible erosion of the surface layer of the stone, there are shallower cracks, and more pronounced biological degradation.

A very good-preserved stećak, is with slight traces of weathering. The basic form is preserved, but the edges and corners are slightly rounded. Decorations and inscriptions are easily visible and legible, although the finest details have slightly eroded on the surface. Slight surface erosion is noticeable, as well as moderate lichen or moss coverage.

The well-preserved (intact) stećak is in an almost perfect, original condition, with no visible or measurable damage (Figure 6). Its geometric shape is fully intact, and the edges are undamaged. The carvings and inscriptions are completely legible and deeply incised, retaining the finest details of their craftsmanship. There are no structural cracks, spalling, or stone flaking.



Figure 6: A well-preserved stećak (Municipality of Kalesija, Mramorje necropolis in Bulatovci settlement).
Source: Hadžimustafić, 2015.

In order to provide a clearer picture of the geospatial distribution of necropolises, three geographic maps of the distribution of stećak necropolises in the Tuzla Canton area were created. The data was processed, the maps were created, in geographic information systems, QGIS 3.34 software.

A total of 1,517 stećaks in 177 necropolises, in all 13 municipalities, were analyzed in Tuzla Canton (Hadžimustafić, 2024). For the purpose of researching the preservation of stećaks in this paper, necropolises that have been moved from their original location, as well as stećaks that have been damaged by human activity (moved, broken or built over) are excluded. 1,342 stećaks were analyzed, which are divided according to their form into: slab - 44 (3.28%); chest - 214 (15.95%); chest with pedestal - 34 (2.53%); gabled - 216 (16.1%); gabled with pedestal - 236 (17.59%); pillar - 493 (36.74%) and amorphous - 105 (7.82%).

2.2 Statistical methods

Prior to conducting inferential analyses, descriptive data processing was performed on a sample of N = 1,342 stećci. Descriptive parameters regarding the elevations at which the stećci are located were analyzed: range (Min–Max), median, mean (arithmetic mean), and interquartile range (IQR: 1st Qu. – 3rd Qu.). For the purposes of statistical processing, the qualitative assessment of the preservation of the monument was transformed into a quantitative ordinal variable, defined on a scale from 1 to 5 (poor = 1, relatively good = 2, good = 3, very good = 4, intact = 5), where 1 represents an extremely eroded - poorly preserved monument, and 5 an exceptionally preserved monument. After that, the average rank of preservation of stećak was calculated (Mean Rank).

Hypothesis testing regarding the normality of the distribution of elevation was performed using the Shapiro–Wilk test. Spearman's rank correlation (ϱ) was used to examine the strength and direction of the relationship between elevation and the degree of preservation of stećci. The analysis was conducted at an aggregate level, comparing the mean elevation of the necropolis—specifically, the mean elevation of all stećci at the site—with the median preservation status calculated for individual necropolises.

The Kruskal–Wallis test (Kruskal & Wallis, 1952) was used to test the hypothesis of the existence of statistically significant differences in preservation between seven different forms of stećak. Since the ordinal scale of preservation results in a large number of tied ranks, the corrected H-statistic—incorporating a correction factor for tied ranks—was automatically applied during calculations in R.

After establishing the statistical significance of the overall effect of shape on preservation ($p < 0.001$), Dunn's post-hoc test (Dunn, 1964) was conducted to identify specific pairs of morphological shapes exhibiting significant differences in preservation. To control the risk of Type I errors associated with multiple hypothesis testing, the Bonferroni correction for p-values was applied (Bonferroni, 1936).

All statistical analyses and graphical representations were produced in the R programming environment (version 4.5.2), using the dplyr package for data manipulation, FSA for Dunn's test, and ggplot2 for creating visualizations.

3 Results and discussion

3. 1 Geographical distribution of stećak necropolises

Stećci are distributed in all 13 municipalities of the Tuzla Canton, in 94 settlements, in 124 necropolises. For clearer visualization, the geographical distribution of necropolises is represented with three maps, which partially show the Tuzla Canton (Figure 7, Figure 8 and Figure 9).



Figure 7: Geographical distribution of stećak necropolises in the municipalities: Doboj Istok, Čelić, Gračanica, Gradačac, Lukavac, Srebrenik and Tuzla.
Source: Hadžimustafić, 2025. Data: Field research by the author. Basemap: OpenStreetMap contributors.

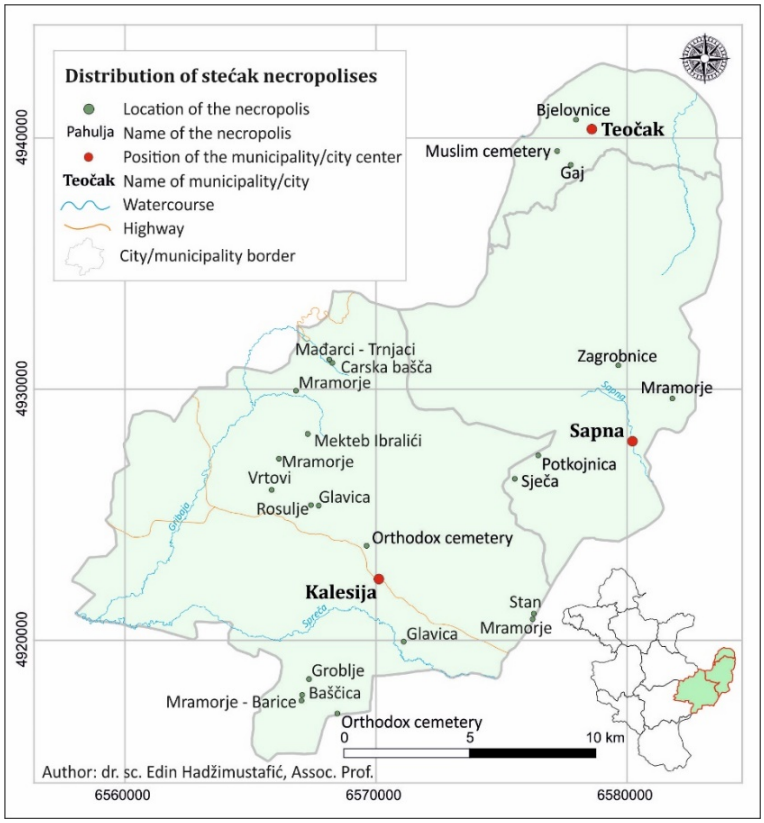


Figure 8: Geographical distribution of stećak necropolises in the municipalities of Kalesija, Sapna and Teočak.

Source: Hadžimustafić, 2025. Data: Field research by the author. Basemap: OpenStreetMap contributors.

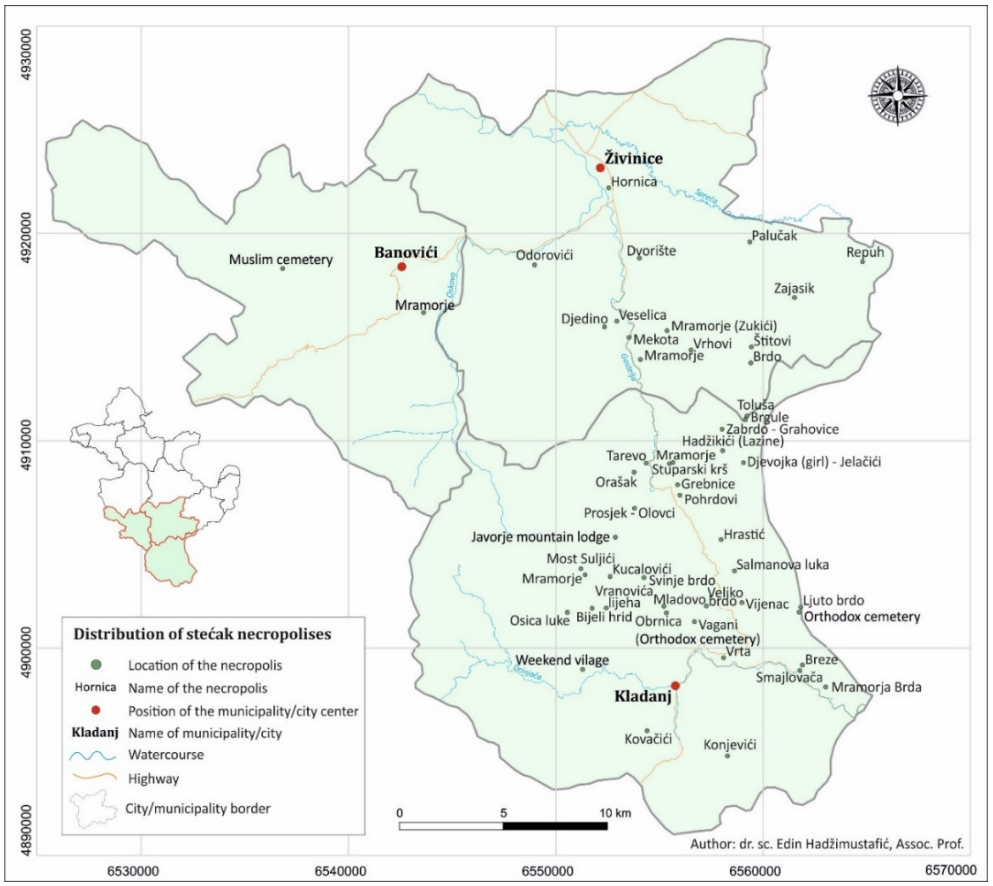


Figure 9: Geographical distribution of stećak necropolises in the municipalities: Banovići, Kladanj, Živinice.

Source: Hadžimustafić, 2025. Data: Field research by the author. Basemap: OpenStreetMap contributors.

3. 2 The impact of altitude on the preservation of stećci

Following the statistical analysis, useful results were obtained showing the geographical distribution of stećak necropolises, the potential correlation between the elevation at which the stećci are located and their state of preservation, as well as which forms of stećci are better preserved compared to others.

The quantitative analysis included a sample of N = 1,342 stećak. The analyzed monuments were classified into seven morphological categories: slab (n = 44; 3.28%), chest (n = 214; 15.95%), chest with pedestal (n = 34; 2.53%), gable (n = 216; 16.10%), gable with pedestal (n = 236; 17.59%), pillar (n = 493; 36.73%) amorphous (n = 105; 7.82%).

The lowest necropolis is located at 103 m above sea level. and the highest at 1,010 m above sea level. Stećci are located at an average altitude of 492.5 m above sea level with a median of 450 m, which shows that half of the total number of stećci are at lower and the other half at higher altitudes. The interquartile range, Q1 = 360 m a.s.l. and Q2 = 598 m a.s.l., shows that half of the stećaks are located in this altitude range. Since the mean value (492.5 m) is noticeably higher than the median (450.0 m), the altitude distribution is skewed to the right, that is, it has positive asymmetry.

Given that the variable "preservation of stećci" belongs to an ordinal measurement scale, and that the Shapiro-Wilk test yielded low statistical significance values ($p < 0.001$), a deviation of the data from a normal distribution was confirmed.

The assessment of the physical condition or preservation of the stećak was measured on an ordinal scale from 1 to 5. The ranking of the preservation of the stećak by morphological forms was calculated.

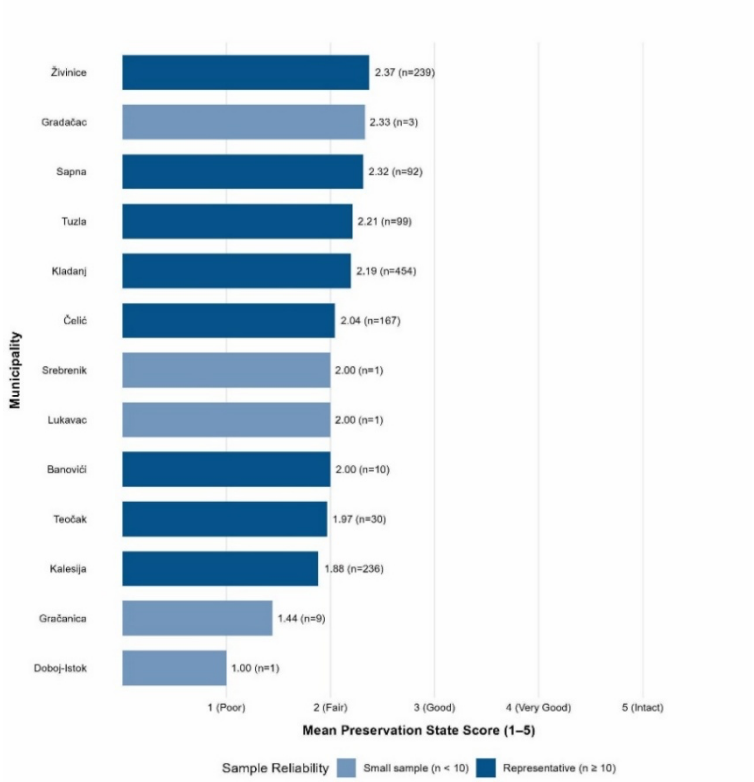


Figure 10: Regional variation in mean physical preservation scores of stećci across municipalities in Tuzla Canton.
Source: Hadžimustafić, 2025. Data: Field research, 2015.

Spatial distribution analysis indicates continuous regional variations in mean preservation scores. Specifically, among municipalities with representative sample sizes ($n \geq 10$), Živinice exhibits the highest mean preservation score ($M = 2.37$, $n = 239$), reflecting more favourable microclimatic or lithological conditions, whereas Kalesija, demonstrates the lowest average score ($M = 1.88$, $n = 236$). Municipalities with smaller sample sizes (such as $n < 10$) were retained in the comprehensive regional overview (Figure 10) to preserve spatial completeness, though their statistical weight is interpreted with caution. Bars represent average preservation scores on a 1–5 scale. Lighter shading highlights administrative units with sample sizes below the statistical threshold ($n < 10$), retained strictly for spatial completeness.

The highest average rank of preservation is achieved by gables with pedestal (Mean Rank = 831), followed by gables (Mean Rank = 755), then chest with pedestal (Mean Rank = 737), pillar (Mean Rank = 681), chest (Mean Rank = 633), slab (Mean Rank = 559), while amorphous monuments (as expected) show the lowest rank (Mean Rank =203).

The relationship between the elevation of the necropolises and the degree of monument preservation was assessed using Spearman's rank correlation coefficient (ϱ). The analysis revealed a statistically significant but extremely weak positive correlation ($\varrho = 0.078$, $p = 0.004$). This slight positive trend may be attributed to reduced anthropogenic pressure in higher mountainous areas (Figure 11). It also suggests that elevation itself does not act as a direct or primary isolated microclimatic factor driving the physicochemical deterioration of the stone. The low correlation coefficient indicates that elevation, as a single factor, accounts for only a small portion of the variation in preservation, and that the physical condition of the stećci is significantly influenced by other factors, such as increased anthropogenic pressure at lower elevations (urbanization, agriculture), the chemical composition of the stone, and specific microclimatic conditions.

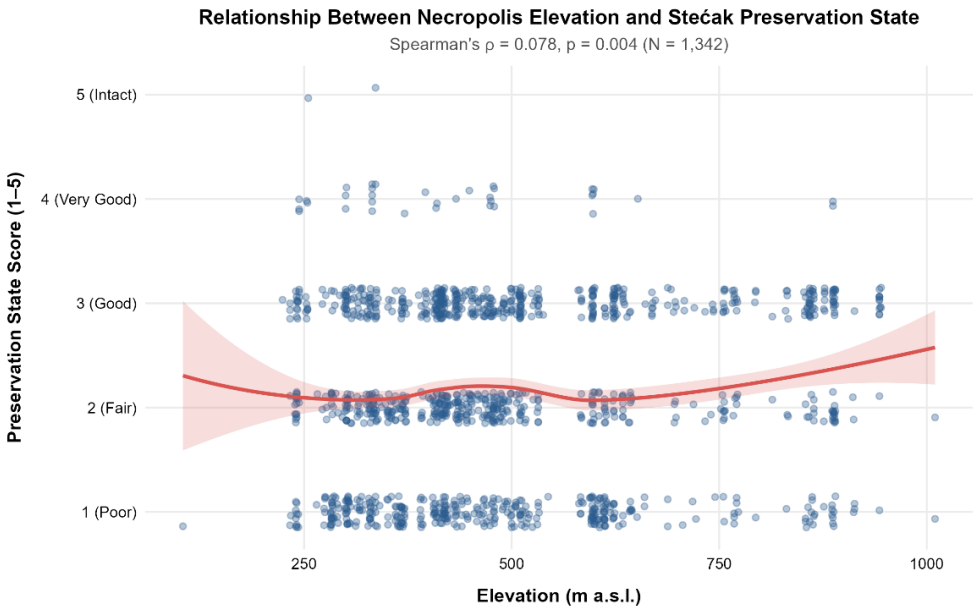


Figure 11: Correlation between the elevations of the necropolises and their state of preservation.
Source: Hadžimustafić, 2025. Data: Field research, 2015.

3.3 The influence of stećak shapes on their physical preservation

To test the null hypothesis regarding the equal distribution of preservation scores across morphological categories, the non-parametric Kruskal-Wallis test was applied. The test results confirmed the presence of statistically highly significant differences in the degree of preservation among the seven analyzed forms: $\chi^2 = 235.56$, df = 6, $p < 0.001$. This clearly indicates that the geometric shape of the stećci is a key factor in their resistance to weathering and physical-geographic degradation. The null hypothesis (H0) of equal preservation across all forms is decisively rejected.

To identify specific pairs of stećak shapes exhibiting statistically significant differences, Dunn's post-hoc test for pairwise multiple comparisons was conducted, applying the Bonferroni correction to the p-values.

The amorphous category exhibits statistically highly significant lower preservation values (as expected) compared to all other forms (padj < 0.001 for all pairs). Pairwise comparisons reveal markedly high negative Z-values, for instance, compared to the gable with pedestal ($Z = -14.61$, padj < 0.001), the pillar ($Z = -12.14$, padj < 0.001), and the slab ($Z = -5.42$, padj < 0.001).

Slabs and amorphous forms are the most susceptible to deterioration: Slabs lie flat on the ground, so water is retained on their upper surface, which accelerates frost destruction and the development of lichens and mosses. Amorphous stećci represent either completely degraded monuments or monuments made of the worst stone, where the original shape has completely disappeared.

The gabled with pedestal shows statistically significantly better preservation compared to monolithic and flat forms: the chest ($Z = -5.71$, $padj < 0.001$), the pillar ($Z = 5.18$, $padj < 0.001$), and the slab ($Z = -4.51$, $padj < 0.001$). The gabled form also demonstrates significantly better preservation than the chest ($Z = -3.45$, $padj < 0.012$) and the slab ($Z = -3.23$, $padj < 0.026$).

Gables (with and without pedestal) show the greatest resistance: The roof form ("on two roofs") enables the fastest drainage of rainwater, which drastically reduces the retention of moisture on the surface of the stone. The pedestal additionally raises the monument above the ground and protects it from capillary absorption of moisture from the soil.

There is no statistically significant difference between gables with a pedestal and gables ($Z = -2.19$, $padj = 0.597$). Also, in the group of flat, horizontal and columnar forms (slab, chest, pillar), the differences did not reach the threshold of statistical significance ($padj > 0.05$ for the pairs of slab-chest, chest-pillar and slab- pillar).

The following figure (Figure 12) illustrates the morphological categories of stećci ordered in ascending sequence by their median preservation state—ranging from the lowest preserved forms (Amorphous) on the left to the best preserved structures (Gabled with Pedestal) on the right. The plot displays medians and interquartile ranges, accompanied by jittered sample density points representing individual monuments.

The obtained non-parametric results provide empirical confirmation of the influence of stećak shapes on the microclimatic, physicochemical, and biological weathering of the rock material.

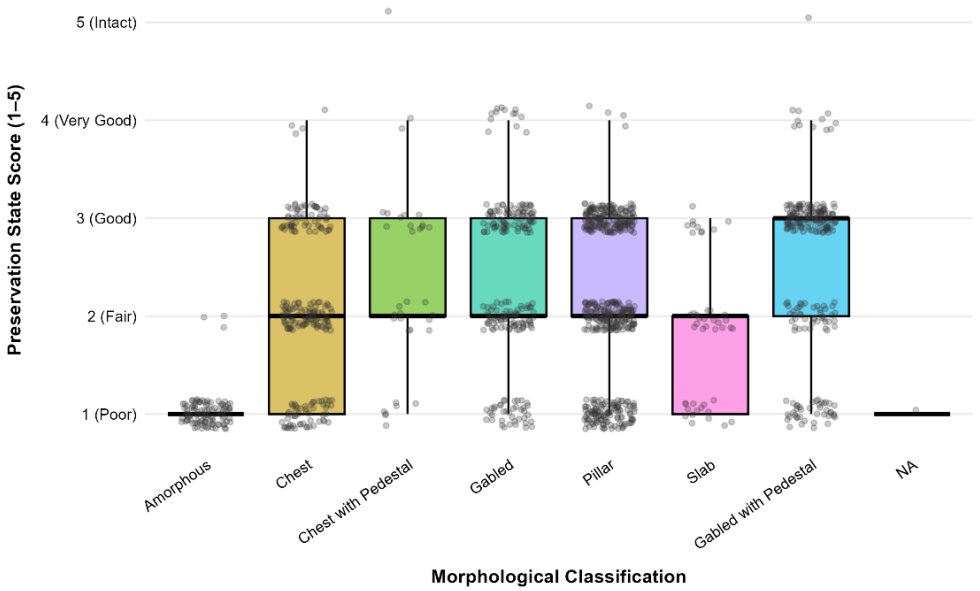


Figure 12: Physical preservation scores across morphological categories of stećci (N = 1,342). Box plots display medians and interquartile ranges, with overlaid jittered points representing individual monuments.

Source: Hadžimustafić, 2024. Data: Field research and processing by the author.

Conclusion

The conducted research provides the first extensive empirical and quantitative evidence regarding the impact of physical-geographic and morphological factors on the differential weathering and state of preservation of medieval tombstones.

Based on a field evaluation of a sample of N = 1,342 stećci in the Tuzla Canton area, geospatial analysis in GIS, and statistical modeling in the R environment, two hypotheses were tested in the study, with the following outcomes:

- The main hypothesis, which posited that the physical preservation of stećci was primarily determined by elevation, has been entirely rejected. Hypsometric correlation results indicate that elevation exhibits a statistically significant yet extremely weak positive relationship with the degree of preservation ($\varrho = 0.078$, $p < 0.01$). The hypsometric location of the necropolises itself is not the primary driver of stone deterioration in the regional setting under study.
- The auxiliary hypothesis, which treated the morphological form of stećak as a moderating factor of erosion, was confirmed and upgraded. Non-parametric analysis of variance (Kruskal-Wallis test, $\chi 2 = 235.56$, $p < 0.001$) proved that the shape of the

stećak is not a subordinate, but a dominant determinant of physical degradation. Different types of stećaks show pronounced differential wear: gables with a pedestal stand out as the most resistant structural category, while amorphous monuments and slabs represent the terminal stage of wear.

In conclusion, the hypsometric position of the stećak in itself does not represent the primary isolated microclimatic driver of the rock mass decomposition. The morphological shape and lithological characteristics of the stećaks themselves proved to be a decisive factor in their resistance to weathering. The obtained results have a direct application in the practice of cultural and historical heritage protection. Field protection priorities should primarily be directed towards horizontal forms (slabs), while gables with pedestal possess natural structural immunity to degradation processes.

Declarations

Funding
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The author declares that they have no financial or non-financial competing interests relevant to the content of this article.

Author contributions:
The author performed all stages of the work.

Data availability
The data are available from the corresponding author upon reasonable request.

Ethical approval
Not applicable: this study did not involve human participants, animal experiments, or sensitive personal data requiring ethical approval.

Use of AI tools
The author did not use generative artificial intelligence (AI) tools in the preparation of this manuscript.

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Povzetek

Prispevek obravnava celovito geoarheološko ovrednotenje srednjeveških nagrobnikov – stečkov - na območju Tuzlanskega kantona v Bosni in Hercegovini, pri čemer avtor poveže standardizirano ocenjevanje ohranjenosti (na lestvici od 1 do 5) z morfološkimi klasifikacijami v okviru ponovljivega sistema, ki temelji na orodjih GIS in programskem jeziku R. Kvantitativna analiza razkriva različne vzorce ohranjenosti med morfološkimi kategorijami. Oblike z prevladujočo maso (kot so dvokapni in skrinji monoliti) so pokazale večjo strukturno odpornost v primerjavi z amorfnimi ali manjšimi ploščatimi tipi, ki kažejo večje posedanje in površinsko degradacijo. S kvantifikacijo teh stanj ohranjenosti v trinajstih občinah raziskava presega opisne popise in se osredotoča na natančno prostorsko-statistično vrednotenje. Te ugotovitve prinašajo pomembne praktične posledice za upravljanje kulturne dediščine. Zagotavljajo na podatkih temelječa spoznanja za določanje prednostnih nalog pri ohranjanju zelo ogroženih spomenikov. Nadaljnje raziskave bodo nadgradile te temelje z razširitvijo analize na okoljske spremenljivke, značilnosti terena in napredne statistične metode, z namenom poglobljenega razumevanja procesov propadanja in ohranjanja, ki vplivajo na nekropole s stečki.