ANNALS OF THE "CONSTANTIN BRÂNCUȘI" UNIVERSITY OF TÂRGU JIU
LETTER AND SOCIAL SCIENCE SERIES

ISSN-P: 1844-6051 ~ ISSN-E: 2344-3677

2/2025 ***https://alss.utgjiu.ro***

CULTURAL HERITAGE IN GORJ COUNTY IN THE CONTEXT OF THE 2023–2024 EARTHQUAKES: EFFECTS, VULNERABILITIES, AND RISK MANAGEMENT DIRECTIONS

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Abstract: *The study analyses the impact of the 2023–2024 seismic sequence on the built cultural heritage of Gorj County, a region with a significant concentration of historical monuments of national and universal value. The research is based on the hypothesis of a differentiated structural vulnerability of monuments, influenced by construction typology, conservation status, proximity to the epicentral area, as well as by the cumulative effects generated by seismic aftershocks. The methodology combines documentary analysis, comparative assessment of reported damage, interpretation of structural degradation mechanisms, and their correlation with local geological and seismic characteristics. The results highlight that monuments built of unreinforced masonry, traditional timber, adobe structures and insufficiently strengthened buildings suffered the most severe damage, particularly in the localities of Arcani, Runcu, and Stănești. By contrast, sites included in active monitoring and maintenance programs, such as the Monumental Ensemble "Calea Eroilor," exhibited superior seismic performance. The study confirms the decisive role of seismic aftershocks in aggravating damage and underscores the need to implement integrated strategies for assessment, strengthening and seismic risk management. The conclusions contribute to informing public policies and specialized interventions aimed at increasing the resilience of cultural heritage in Gorj County to future seismic hazards.*

Keywords: *built cultural heritage; seismic risk; structural vulnerability; historical monuments; Gorj County.*

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1. INTRODUCTION

1.1. General Context

Built cultural heritage represents one of the most valuable components of a community's historical and cultural identity. Gorj County, located in south-western Romania, possesses a rich and diverse heritage, comprising religious architectural monuments, artistic ensembles of international

relevance, historic public buildings, memorial sites, and remarkable examples of vernacular architecture. Among these, the Monumental Ensemble "Calea Eroilor," created by Constantin Brâncuși, the Tismana Monastery, and traditional wooden churches constitute essential landmarks of national and universal culture (Cruceru, 2013).

In February 2023, Gorj County was affected by an unusual seismic sequence for this region, consisting of two main earthquakes of moderate to strong magnitude (above M5) and a very large number of aftershocks (INFP, 2023, February 13; INFP, 2023, February 14). The persistent nature of seismic activity in Gorj County during 2023 and the high locally recorded intensities generated significant vulnerabilities within the built environment, particularly affecting historical monuments, old buildings, and unconsolidated traditional structures, as evidenced by both regional assessments of seismic impact and detailed analyses of damage to historical monuments (Peptan et al., 2023; Moșoarcă, Fofiu & Onescu, 2023). In addition, the spread of contradictory information regarding the causes and effects of the seismic movements contributed to a state of uncertainty among the population in the affected region (Mărcău et al., 2023).

1.2. Motivation and Relevance of the Study

The need for a study dedicated to the impact of seismic movements on cultural heritage in Gorj County arises from three main directions:

The importance of cultural heritage – The county hosts sites of national and international significance, some of them unique worldwide, whose protection represents a cultural, identity-related, and economic responsibility.

The vulnerability of historic constructions – Traditional materials (stone, brick, wood), the age of the structures, and irregular maintenance interventions increase the susceptibility of these buildings to seismic actions.

The need for a coherent documentary framework – The seismic events of 2023 revealed the lack of an integrated county-level assessment of seismic risk for historical monuments, thereby justifying the development of a study that contributes to informing future decision-making.

Consequently, the present paper aims to provide a clear, systematic, and well-grounded analysis of how the cultural heritage of Gorj County has been affected, as well as of the necessary intervention directions for strengthening and conservation.

1.3. Research Hypotheses and Objectives

The study was conducted based on the following hypotheses:

H1 – *Differentiated structural vulnerability.* Historical monuments built of unreinforced masonry and vernacular structures (wood, adobe) suffered significantly greater damage than consolidated historical buildings or those previously subjected to structural assessment.

H2 – *Proximity to the epicenter influences damage severity.* Damage to historical monuments was more severe and more frequent in localities located near the epicentral area (Arcani–Runcu–Stănești) compared to sites situated in the urban area of Târgu Jiu or in the western part of the county.

H3 – *Seismic aftershocks generated cumulative degradation.* Historical monuments experienced progressive deterioration caused not only by the main seismic shocks but also by the numerous subsequent aftershocks, which contributed to the extension of cracks, detachments and local instabilities.

The study pursues the following main objectives:

O1. To document and systematize information regarding the effects of earthquakes on historical monuments in the county;

O2. To identify damage mechanisms specific to historical constructions located in the affected area;

O3. To assess the level of vulnerability of the main categories of heritage (religious, civil, artistic, vernacular);

O4. To formulate recommendations for intervention, prevention, and long-term monitoring measures.

These objectives are integrated into an interdisciplinary approach that combines architectural and structural analysis with geographical, historical and institutional perspectives.

1.4. Research Methodology

The research methodology is grounded in an interdisciplinary approach that integrates specialized analysis from the fields of cultural heritage, structural engineering, seismic geography and risk management. This approach enables a comprehensive and coherent assessment of the impact of seismic movements on the built cultural heritage of Gorj County.

The research is primarily based on documentary analysis, which included the examination of official reports prepared by competent institutions (the Gorj County Directorate for Culture, local authorities, civil protection structures), post-seismic public communications, as well as national and international specialized literature on the seismic behaviour of historic constructions. This stage made it possible to outline the theoretical and contextual framework necessary for interpreting the analysed phenomenon.

Secondly, a comparative analysis of the damage recorded in historical monuments and traditional constructions was carried out by correlating the types of deterioration with construction materials, the age of the buildings, their state of conservation and their geographical position in relation to the epicentral areas. This analysis facilitated the identification of recurring patterns of structural vulnerability.

Another important methodological step consisted of mapping the distribution of affected heritage sites, using available geographical coordinates and information regarding local seismic intensity. This stage allowed for highlighting the relationship between the location of monuments, the geological characteristics of the terrain and the severity of the damage incurred.

The research also included a technical interpretation of damage mechanisms by relating the observed deterioration (cracks, detachments, local instabilities, structural deformations) to the constructive particularities of historic buildings, such as unreinforced masonry, timber structures or traditional foundations. The analysis considered both the effects of the main seismic shocks and the cumulative impact of successive aftershocks.

In the final stage, the collected data enabled the formulation of conclusions regarding the level of seismic risk and the development of recommendations for intervention, prevention and long-term monitoring. The adopted methodology aimed not only to describe the seismic effects but also to substantiate practical directions for increasing the resilience of built cultural heritage.

2. THE SEISMIC CONTEXT OF GORJ COUNTY

2.1. Geological/Tectonic Characteristics of the Area and the Evolution of the 2023–2024 Seismic Sequence

Gorj County is located in the contact zone between two major geological units: the Getic Depression and the Southern Carpathians. This positioning generates specific tectonic characteristics, marked by local faults and geodynamically active areas. Although the region has not traditionally been classified among the most seismically active zones in Romania, local crustal dynamics indicate

the existence of tectonic structures capable of producing earthquakes of moderate magnitude (Saramet, Hamac, & Chelariu, 2014).

Seismicity in Oltenia is generally associated with shallow crustal earthquakes, characterized by concentrated energy release and pronounced local effects. This type of seismicity, even if it rarely produces major earthquakes, can affect vulnerable buildings - especially historical ones - due to increased local ground accelerations (Bala, Toma-Danilă, & Rădulian, 2019).

In February 2023, Gorj County was the scene of a seismic sequence atypical for this region, marking one of the strongest crustal seismic events in the recent history of Oltenia. Two main earthquakes, with magnitudes exceeding 5, occurred between 13 and 14 February and were followed by hundreds of aftershocks in the subsequent weeks and months. These events affected social life and caused material damage, particularly to some buildings classified as national cultural heritage (Peptan et al., 2023; Peptan & Mărcău, 2024; Dragomir et al., 2023; Pascu & Bârnaure, 2023).

The first major seismic event generated strong local ground accelerations, felt especially in the localities of Arcani, Runcu, Stănești, Târgu Jiu and Peștișani. The subsequent aftershocks, although of lower magnitude, produced repeated vibrations of already weakened structures, contributing to the occurrence of cumulative damage. The seismic sequence remained active in a reduced form throughout 2024, indicating a reorganization of the local stress regime.

2.2. Distribution of Seismic Intensities and the Effects of Aftershocks on Structural Vulnerability

The effects of the earthquakes varied significantly depending on several factors: proximity to the epicenter - localities situated at short distances experienced higher intensities; local geological characteristics - areas with soft sedimentary deposits amplified the seismic signal; and hilly and pre-mountainous relief - in certain areas, topographic effects intensified vertical ground motions.

The municipality of Târgu Jiu experienced moderate to high effects, while localities in the epicentral area (Arcani, Runcu) recorded significant intensities, which explain the pronounced degradation of the built cultural heritage (Pascu & Bârnaure, 2023).

Although the main shocks had a decisive influence, seismic aftershocks played an essential role in aggravating the damage. Historical monuments, especially those built of unreinforced masonry or timber, typically exhibit high structural rigidity, which limits their capacity to dissipate energy, the presence of microcracks or discontinuities accumulated over time and previous uneven or insufficient interventions that do not comply with current seismic design standards (Moșoarcă, Fofiu, & Onești, 2023; Moșoarcă et al., 2024).

Repeated aftershocks, even of moderate intensity, can lead to the extension of initial cracks, detachment of plaster and ornamental elements, weakening of nodal points (corners, vaults, towers) and the loss of local stability of certain vertical elements.

In the case of monuments of major importance, such as the Tismana Monastery or the churches in Arcani, the cumulative shock of aftershocks resulted in accentuated deterioration, confirming the hypothesis of progressive vulnerability.

3. CULTURAL HERITAGE IN GORJ COUNTY – GENERAL LANDMARKS

3.1. Typology, Geographical Distribution, and Conservation Level of Historical Monuments in Gorj County

The cultural heritage of Gorj County is particularly diverse, reflecting the historical, architectural, and spiritual evolution of local communities. The historical monuments listed in the List of Historical Monuments (LMI) cover a **wide range of typologies** (Gorj County Council, n.d.):

Religious heritage: monasteries, masonry churches and wooden churches, some dating back to the 17th–19th centuries. Representative examples include the Tismana Monastery, the "St. Nicholas" Church in Arcani and numerous wooden churches in mountainous and submontane areas.

Civil and administrative heritage: historic buildings in Târgu Jiu, such as the Prefecture, City Hall, historic high schools, boyar houses and old rural residences.

Memorial and artistic heritage: foremost among them the Monumental Ensemble "Calea Eroilor", created by Constantin Brâncuși, a unique cultural landmark of universal value.

Vernacular heritage: traditional households and houses made of wood, stone, or adobe, concentrated in areas such as Peștișani, Hobița, Curtișoara, Runcu and other localities.

This typological diversity makes Gorj County a territory with vulnerable heritage, as each category exhibits specific construction characteristics that respond differently to seismic actions.

On the other hand, **the distribution of historical monuments** is closely linked to the county's geography (Gorj County Council, n.d.):

Mountainous and submontane areas (north and central parts): concentrate numerous wooden churches, monastic ensembles, and traditional houses. Localities such as Tismana, Runcu, Arcani, Peștișani, and Stănești display high densities of historical sites.

Urban area of Târgu Jiu: hosts the main civil and administrative monuments, as well as the Brâncuși Ensemble.

Depression and lowland areas (southern part of the county): characterized by a less dense heritage, but including buildings of local value.

This distribution is essential for understanding seismic impact, as the epicenters of the 2023–2024 earthquakes were located in the central-northern area, precisely in the region with the highest concentration of religious and vernacular heritage.

Regarding the conservation level of historical monuments in Gorj County prior to the 2023–2024 seismic sequence, it was uneven in nature: some major monuments (e.g., the Brâncuși Ensemble) benefited from monitoring programs and planned interventions (Tudor-Drăghici, n.d.); many wooden churches and traditional houses showed signs of advanced degradation caused by age, moisture infiltration, and non-compliant interventions (Rotaru, 2022); urban administrative buildings were in relatively good condition, but without modern seismic strengthening; and vernacular sectors were vulnerable due to sensitive materials (wood, adobe, weak mortar) (Moșoarcă, Fofiu, & Onești, 2023), already affected by wear and climatic variations.

This initial condition contributed to the intensification of the earthquakes' impact, leading to a clear differentiation among heritage categories in terms of the degree of damage sustained.

3.2. Legal Regime and Institutional Framework for the Protection of Historical Monuments

Legal regime for the protection of cultural heritage

The protection of historical monuments in Gorj County is carried out in accordance with national legislation on immovable cultural heritage. The main normative act is Law No. 422/2001 on the protection of historical monuments (Law No. 422/2001, 2001), which establishes the criteria for listing, the intervention regime, and the obligations of owners. According to the law, monuments are classified into two categories: Category A – monuments of national or universal interest; Category B – monuments of local interest.

The historical monuments of the county are included in the List of Historical Monuments (LMI), the official document defining the protection status of each site. The legal regime requires mandatory authorization for any intervention (restoration, strengthening, repairs), compliance with

specific technical standards, including those related to seismic risk and the preservation of the authentic character of monuments through works compatible with original materials and techniques.

In addition, construction legislation - Law No. 50/1991 (*republished*) on the authorization of construction works and seismic design codes (Law No. 50/1991, 2004) - complements the legal framework by ensuring technical control over interventions on buildings with protected status.

Institutional framework

Responsibility for protecting cultural heritage in Gorj County is shared among national, regional, and local institutions, which cooperate in the conservation and management of historical monuments.

The *Ministry of Culture* coordinates public policies in this field, authorizes interventions on monuments classified in Category A and manages national funding programs (Ministry of Culture, n.d.).

The *Gorj County Directorate for Culture (DJC Gorj)* represents the local specialized authority, with responsibilities including monitoring the conservation status of monuments, authorizing works on Category B monuments and providing the necessary technical and legal expertise in emergency situations (including post-seismic assessments) (Gorj County Directorate for Culture, n.d.).

Local public administration authorities (municipalities, Gorj County Council) play an essential role in managing protected built areas, financing intervention and safety works and integrating heritage into local development strategies (Law No. 422/2001, 2006).

Authorized specialists (architects, structural engineers, conservators/restorers) contribute to the preparation of technical projects, post-seismic assessments and the implementation of interventions compatible with the cultural status of monuments (Order No. 2.866/2025).

This institutional framework provides a mechanism for supervision, decision-making and implementation aimed at protecting the cultural heritage of Gorj County; however, its effectiveness depends on available resources and on cooperation among institutions, especially in crisis situations such as those generated by seismic events.

4. EFFECTS OF SEISMIC MOVEMENTS ON THE BUILT HERITAGE

4.1. Typologies of Damage Caused by Seismic Movements

The crustal earthquakes in Gorj County generated a wide range of deterioration affecting the built heritage, differentiated according to construction materials and techniques, the age of the structures and their level of maintenance. Overall, the most frequent types of damage identified in historical monuments and traditional buildings include (Pascu & Bârnaure, 2023):

Cracks in load-bearing masonry, of vertical, horizontal, or diagonal type, occurring especially at building corners, around door and window openings, or in areas where structural sections change. These cracks indicate significant stresses in unreinforced brick or stone walls, typical of constructions dating from the 17th–19th centuries.

Detachment of plaster and ornamental elements, observed in churches, historic civil buildings and administrative edifices. Decorative elements, cornices and old plaster behave in a brittle manner under repeated vibrations.

Damage to roofs and chimneys, manifested through displacement of tiles, deterioration of roofing layers and instability of vertical elements. Traditional roofs, generally lacking structural strengthening, were among the most exposed components.

Damage to towers and vaults, characteristic of places of worship. Tall towers built of thin masonry, combined with old foundations, are particularly vulnerable to seismic movements.

Deterioration of timber structures, especially in the case of wooden churches and traditional houses. Deformations of the structural frame, local settlements and loosening of joints were observed in epicentral areas.

These typologies of damage reflect the inherent limitations of traditional materials when subjected to seismic actions and highlight the need for strengthening measures tailored to each category of heritage.

4.2. Vulnerability Mechanisms and the Impact of Seismic Aftershocks

The vulnerability of the built heritage in Gorj County is the result of a combination of the constructive particularities of historical monuments and the characteristics of the 2023–2024 seismic sequence. The main mechanism through which structures became susceptible to damage was determined by ***construction features specific to historic buildings*** (Pascu & Bârnaure, 2023), namely:

Unreinforced masonry represents the most vulnerable type of structure in a seismic context. Thick walls lacking reinforcement can withstand only limited stresses, leading to cracking and dislocations.

Old foundations, often uneven or built of rough stone, amplify the effects of earthquakes on historic buildings.

Towers, vaults, and slender vertical elements are among the first components affected during earthquakes due to their high rigidity and concentrated mass at height.

Timber structures, although more flexible, become vulnerable when pre-existing deterioration is present (mold, settlement, biological attack).

The seismic sequence in Gorj was characterized by a very large number of aftershocks, which acted successively on already weakened structures. This phenomenon resulted in *cumulative deterioration* through the extension of cracks and the loss of material cohesion, *accentuation of local instabilities* (towers, chimneys, decorative elements), an *increased risk of partial collapse* in the case of fragile buildings or those already affected by wear and the *aggravation of pre-existing vulnerabilities*, especially in epicentral areas (Prefect's Institution – Gorj County, 2023).

Buildings such as the Tismana Monastery, the traditional churches in Arcani, or old structures in Târgu Jiu illustrated, through the damage incurred, how repeated aftershocks can transform a minor defect into a major structural risk.

5. ANALYSIS OF SEISMIC EFFECTS ON THE MAIN HERITAGE ASSETS

The analysis of the effects generated by the 2023–2024 seismic sequence on the built cultural heritage of Gorj County requires a comparative and systematic approach aimed at highlighting differences in structural behavior among various types of monuments. Table 1 synthesizes, in a structured manner, the main affected heritage assets, including monuments of national and universal value as well as traditional, civil, religious, and vernacular buildings (Pascu & Bârnaure, 2023). Through this consolidation, it is possible to observe, for each individual site, the nature of the damage incurred, its level of severity, and the types of interventions required following post-seismic assessments.

The comparative presentation allows for the identification of patterns of structural vulnerability based on construction materials, the age of buildings and their level of maintenance, thereby contributing to the formulation of well-founded conclusions regarding the condition of heritage in the context of the emerging seismic hazard in the county.

Monument / Site	Locality	Type	LMI Code	Damage Reported After the Earthquakes	Subsequent Situation / Required Measures
Monumental Ensemble "Calea Eroilor" (Brâncuși)	Târgu Jiu	Memorial and artistic ensemble	GJ-III-m-A-09494	No structural damage recorded; possible microcracks; repeated vibrations	Periodic technical monitoring; continuation of conservation programs
Tismana Monastery	Tismana	Category A religious monument	GJ-II-a-A-09471	Cracks in masonry; plaster detachment; damage to the tower	Requires structural strengthening; complex restoration interventions
"St. Nicholas" Church	Arcani	Place of worship (masonry)	GJ-II-m-B-09395	Severe structural cracks; deterioration of the tower; interior detachments	Urgent safety measures and structural strengthening works
"St. John the Baptist" Wooden Church	Arcani	Place of worship (wood)	GJ-II-m-B-09412	Structural deformation; joint failures; local settlements	Requires rapid intervention; high risk without strengthening
Historic Churches	Runcu	Places of worship (masonry/wood)	Various LMI codes	Extensive cracks; plaster detachment; damage to vaults	Moderate to severe damage; further assessments required
Traditional Churches	Stăneşti	Places of worship	Various LMI codes	Extensive cracks; affected foundations; displaced roofs	Requires structural repairs and protection of traditional elements
Traditional Houses and Vernacular Households	Hobița / Peștișani	Vernacular heritage (wood, adobe)	Various LMI codes (where listed)	Cracks, detachments, settlements; deformation of timber structures	High risk of degradation; requires conservation and rehabilitation programs
Gorj Prefecture Palace	Târgu Jiu	Historic administrative building	GJ-II-m-B-09339	Cracks in masonry; localized plaster detachment	Local repairs; overall structure stable
Târgu Jiu Municipality City Hall	Târgu Jiu	Historic administrative building	GJ-II-m-B-09352	Falling roof tiles; cracks in plaster	Minor interventions required on the roof and façade
"Tudor Vladimirescu" National College	Târgu Jiu	Historic educational building	GJ-II-m-B-09323	Interior cracks; deterioration of ornamental elements	Moderate repairs; monitoring required
Other Churches and Establishments in the Epicentral Area	Arcani–Runcu–Stăneşti	Religious heritage	Various LMI codes	Cracks, detachments, local instabilities	Variable situation; some require urgent strengthening

Table 1. Main Heritage Assets Affected by Seismic Movements in Gorj County

The interpretation of the data synthesized in Table 1 reveals major differences in the way heritage assets responded to seismic stresses, differences determined both by proximity to the epicenter and by the intrinsic vulnerabilities of each type of construction. Monuments built of unreinforced masonry and traditional structures made of wood or adobe recorded the highest levels of deterioration, while strengthened sites or those included in active monitoring programs exhibited limited damage. The identified damage, ranging from fine cracks to severe structural instabilities, highlights the priority need for differentiated interventions tailored to each monument. At the same time, the analysis confirms the decisive role of seismic aftershocks in aggravating the condition of already vulnerable buildings. All these findings underscore the imperative of implementing integrated programs of strengthening, conservation, and continuous monitoring aimed at increasing the resilience of Gorj County's built heritage to future seismic risks.

6. SEISMIC RISK MANAGEMENT FOR CULTURAL HERITAGE

6.1. Assessment and Monitoring of the Vulnerability of the Built Heritage

Seismic risk management begins with a rigorous assessment of the vulnerability of each monument, a process that allows for the precise identification of sensitive structural elements and of factors that may amplify the effects of an earthquake. In Gorj County, this stage is essential given the typological diversity of the heritage - from places of worship built of unreinforced masonry to wooden churches and vernacular houses, as well as urban buildings dating from the 19th–20th centuries.

Vulnerability assessment involves technical expertise carried out by certified specialists, identification of pre-existing deterioration (cracks, settlements, deformations, biological attack in timber structures), verification of the compatibility of previous works with current seismic standards and evaluation of site-related influences (soil conditions, relief, proximity to epicentral areas).

Complementing the assessment, periodic monitoring represents an indispensable tool that contributes to the early detection of structural changes which may indicate increased risk in the event of new seismic movements.

6.2. Preventive Measures and Strengthening Interventions Adapted to Heritage

Reducing the vulnerability of cultural heritage requires a set of preventive measures and structural interventions carefully calibrated for each category of monument. In the specific context of Gorj County, these measures must take into account both the material characteristics of constructions (wood, masonry, stone, adobe) and their historical and artistic value.

The main measures include:

Structural strengthening compatible with original materials (mortar injections, reversible reinforcements, foundation repairs).

Securing vulnerable elements such as towers, vaults, chimneys, traditional roofs or exterior ornaments.

Minimally invasive interventions in accordance with restoration principles (reversibility, material compatibility, preservation of authenticity).

Protection of vernacular buildings through discreet structural repairs, strengthening of timber frames and improvement of traditional foundations.

Application of modern technologies, where permitted, to increase structural safety without altering the heritage character.

An essential role is played by the preparation of appropriate technical documentation, including geotechnical studies, structural calculations and seismic response scenarios, which are indispensable for obtaining approval for interventions from the competent authorities.

To date, intervention works have been carried out on cultural heritage assets in Gorj County affected by the 2023–2024 seismic movements (Table 2), these being at various stages of execution.

Monument / Site	Locality	Damage Reported After the Earthquakes	Interventions Carried Out
Monumental Ensemble "Calea Eroilor" (Brâncuși)	Târgu Jiu	No structural damage recorded; possible microcracks; repeated vibrations.microfisuri; vibrații repetate.	No intervention works were required on the works of art; the only affected asset was the Church of Saints Apostles Peter and Paul, part of the Calea Eroilor Ensemble. The building was severely affected, with fractures of the load-bearing structure. A Building Permit was issued for the complete restoration of the church.
Tismana Monastery	Tismana	Cracks in masonry; plaster detachment; damage to the tower	The works are in progress, being coordinated with another major restoration project of the monastic complex.
"St. Nicholas" Church	Arcani	Severe structural cracks; deterioration of the tower; interior detachments	Technical assessments and the DALI project have been completed, the documentation has been submitted to the Ministry of Development, Public Works and Administration for funding approval.
"St. John the Baptist" Wooden Church	Arcani	Structural deformation; joint failures; local settlements	Technical assessments and the DALI project have been completed, the documentation has been submitted to the Ministry of Development, Public Works and Administration for funding approval.
Historic Churches	Runcu	Extensive cracks; plaster detachment; damage to vaults	Technical assessments and the DALI project have been completed, the documentation has been submitted to the Ministry of Development, Public Works and Administration for funding approval.
Traditional Churches	Stănești	Extensive cracks; affected foundations; displaced roofs	Technical assessments and the DALI project have been completed, the documentation has been submitted to the Ministry of Development, Public Works and Administration for funding approval.
Traditional Houses and Vernacular Households	Hobița / Peștișani	Cracks, detachments, settlements; deformation of timber structures	No works have been carried out to date, the lack of funding being the main cause.
Gorj Prefecture Palace	Târgu Jiu	Cracks in masonry; localized plaster detachment	Technical assessments were carried out, following which evacuation of the building was decided until strengthening and restoration works are executed. No works have been initiated to date; staff continue to operate in the building, as the Ministry of Internal Affairs has not allocated funds for renting an alternative facility.
Târgu Jiu Municipality City Hall	Târgu Jiu	Falling roof tiles; cracks in plaster	The works have been completed.
"Tudor Vladimirescu"	Târgu Jiu	Interior cracks; deterioration of	Works are currently in progress.

National College		ornamental elements	

Table 2. Current Status of Intervention Works at Cultural Heritage Sites in Gorj County Affected by Seismic Movements

6.3. Institutional, Educational, and Community Strategies for Seismic Risk Reduction

Effective seismic risk management requires an integrated approach in which institutions, professionals and the community collaborate to protect cultural heritage. In Gorj County, recent seismic events have highlighted the need for long-term strategies.

Priority strategies include strengthening institutional cooperation among the County Directorate for Culture, local authorities, the Inspectorate for Emergency Situations and the Ministry of Culture; creating a local registry of vulnerabilities based on periodic assessments of monuments in order to prioritize interventions; implementing professional training programs for specialists in restoration and seismic strengthening applied to heritage; informing and involving communities in monument protection through educational campaigns on seismic risks and appropriate responses in emergency situations and accessing funding programs (national, European, UNESCO) for strengthening works and for improving monitoring and prevention infrastructure. By combining these directions - technical assessment, appropriate interventions and institutional strategy - Gorj County can develop a coherent and sustainable system for protecting cultural heritage against future seismic risks.

7. LIMITATIONS OF THE RESEARCH

The analysis of seismic effects on the cultural heritage of Gorj County was conducted based on the most relevant and accessible data sources; however, the investigative process was influenced by a series of methodological, informational and operational limitations that may affect the level of completeness and accuracy of the conclusions drawn.

The most significant category of *limitations concerns access to complete and uniform information*. Post-seismic assessments were carried out by different institutions, at different times and with varying levels of detail. For some monuments, detailed technical reports were available, while for others the information was fragmentary or based solely on preliminary visual observations. In addition, for part of the vernacular heritage or for unlisted sites, there are no official data regarding seismic impact, which may lead to an underestimation of the actual level of damage.

Access to monuments immediately after the earthquakes was sometimes restricted for safety reasons, which delayed or *limited the performance of detailed assessments*. In the case of certain traditional or isolated buildings, physical access was difficult and the evaluation relied on indirect findings or information provided by the community. Moreover, not all monuments benefited from technical expertise carried out by certified specialists in the field of built heritage, which may influence the accuracy of the diagnosis.

The analyzed seismic sequence was characterized by a very large number of aftershocks distributed over an extended period. Differentiating damage caused by the main shocks from that generated by subsequent aftershocks is difficult in the absence of continuous monitoring of each site. Furthermore, some of the identified deterioration may have multiple causes - wear, climatic conditions, or inappropriate previous interventions - which complicates the strict attribution of effects to the earthquakes.

Although the study provides a relevant analysis for the context of Gorj County, its *conclusions may have limited applicability to other regions*, given local particularities of the building stock, geological structure, and types of monuments. In addition, differences in maintenance and in

interventions carried out prior to the earthquakes may significantly influence the seismic behavior of each asset.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

The analysis of the effects of the 2023–2024 seismic sequence on the cultural heritage of Gorj County reveals a series of major conclusions regarding the behavior of historical buildings, the extent of damage sustained and existing structural vulnerabilities, *thereby confirming both the central objectives of the research and the hypotheses formulated previously*.

First, the degree of impact on cultural heritage was directly determined by proximity to the epicenter, with the localities of Arcani, Runcu and Stăneşti recording the most severe degradation. This finding validates *Hypothesis 2*, according to which monuments located in epicentral areas are more vulnerable and addresses the objective of identifying the relationship between location and the level of damage. At the same time, construction typology played a crucial role: unreinforced masonry, timber structures and adobe buildings exhibited the highest sensitivity to seismic actions, supporting *Hypothesis 1* concerning differentiated structural vulnerability depending on the traditional materials used.

Second, the prolonged nature of the seismic sequence, marked by numerous aftershocks, significantly contributed to the occurrence and aggravation of damage, especially in monuments that were already vulnerable. The observed deterioration, ranging from superficial cracks to major structural instabilities, confirms *Hypothesis 3*, according to which repeated aftershocks generated cumulative damage and aligns with the research objective of analyzing the mechanisms through which aftershocks intensify the degradation of heritage.

Third, the diversity and pre-existing condition of the heritage strongly influenced seismic behavior. Well-maintained and monitored buildings, such as the Monumental Ensemble "Calea Eroilor," demonstrated superior resistance, while monuments already affected by degradation or lacking recent interventions suffered significant damage. This result addresses the objective of evaluating the effect of conservation status on seismic vulnerability and highlights the importance of preventive interventions and continuous technical monitoring.

Overall, the study confirms that the cultural heritage of Gorj County exhibits significant vulnerabilities to seismic hazards. At the same time, the analysis demonstrates the coherence and validity of the research hypotheses and the adequacy of the objectives pursued, which together indicate that seismic risk management requires an integrated approach combining technical assessment, specialized conservation, adapted strengthening measures and long-term strategic planning.

8.2. Recommendations

Based on the results of the analysis, a set of priority recommendations emerges for improving the resilience of cultural heritage to seismic risk:

Implementation of a permanent structural monitoring program for monuments. It is necessary to establish a coordinated monitoring system based on periodic visual inspections, modern instrumentation (vibration sensors, 3D scanning) and updated databases. Such a system would enable early identification of deterioration and rapid intervention before conditions worsen.

Carrying out specialized technical assessments for all vulnerable monuments. Each asset, especially traditional churches and vernacular houses, should benefit from detailed expertise to establish strengthening solutions compatible with original materials.

ISSN-P: 1844-6051 ~ ISSN-E: 2344-3677

Prioritization of interventions according to risk level. It is recommended to develop a county-level priority list that takes into account heritage value, degree of damage, the number of aftershocks in the area and risks to the community and tourists.

Strengthening interinstitutional collaboration. The County Directorate for Culture, local authorities, the Ministry of Culture and emergency intervention bodies must work together systematically to ensure rapid and coherent responses, particularly following seismic events.

Accessing national and European funds dedicated to heritage. Funding for strengthening and restoration is essential, as many traditional buildings and rural monuments cannot be restored using local resources alone. European programs aimed at protecting vulnerable heritage represent valuable opportunities.

Developing education and community awareness programs. Local communities should be informed and actively involved in heritage protection. Awareness campaigns on seismic risk, training for staff in cultural institutions and educational activities can contribute to increased collective responsibility.

Elaboration of a county-level seismic risk management plan for heritage. A dedicated strategic document, developed in collaboration with specialists and authorities, can ensure a coherent, anticipatory and effective approach to seismic risk management, both preventively and post-event.

Taken as a whole, the conclusions and recommendations highlight that protecting the cultural heritage of Gorj County against seismic hazards cannot be achieved in isolation, but requires a concerted, interdisciplinary and sustained effort. Only by combining technical assessment, specialized interventions, continuous monitoring and institutional cooperation can the fundamental objective be achieved: *increasing the resilience of cultural heritage and preserving the county's historical identity for future generations.*

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