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FLOOD SUSCEPTIBILITY ANALYSIS OF THE CULTURAL HERITAGE IN THE SUCEVITA CATCHMENT (ROMANIA)

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Abstract

The intensification of natural hazards and the expansion of human impact are likely to threaten the cultural heritage of a region. The multidisciplinary approach identifies the flood susceptible areas, it relates them to the cultural heritage sites and it also provides the flood risks mitigation measures for these monuments. The Sucevita catchment is unique considering certain important landmarks of the national heritage and the UNESCO World heritage (monasteries). The flood risk maps are considered important tools to determine the vulnerability of the heritage monuments in developing the protection and the conservation strategies. The GIS technique and the comparative assessment of the risk factors allowed the identification of the heritage monuments that belong to the highest flood susceptibility area by applying the Analytic Hierarchy Process (AHP). This area corresponds to the localities that are situated near the main course of the Sucevita river. In order to preserve the cultural heritage, it is necessary to implement some strategies and activities of flood risk management through structural and non-structural measures.

Keywords: *Flood measures; GIS analysis; Analytic Hierarchy Process (AHP); Preventive conservation; UNESCO.*

Introduction

A major concern is globally noticed in terms of conservation of the heritage because it reflects the sense of belonging and the cultural identity of individuals [1-3]. In the last decade, a rise in the intensity and frequency of natural risks that produce significant worldwide damage was noted, both on the human settlements and the environment, but also on the cultural heritage [4]. The most destructive events are the floods [5-7].

The cultural heritage is affected by natural hazards both externally and internally. The external cause is given by the disruption or the damage of the sites, and the internal cause is represented by the brittleness of the structure or materials of the cultural heritage and their sensitivity to the environment [8]. For the conservation of the cultural heritage, several methods were applied in order to identify the monuments vulnerable to natural risks and some appropriate protective measures were proposed [9-16].

The floods are one of the main risk factors for the cultural heritage sites, and the idea of "preventive conservation" represents the basis of the studies for creating the risk maps of these

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sites. The risk maps have become useful tools in identifying the vulnerability degree of the cultural heritage, establishing preventive measures and developing the conservation strategies of the heritage [17-22]. The preventive measures provide a flood risk sustainable management and include the following: technical measures for control and management; land-use regulation measures; settlements' planning; economic measures; conservation measures of cultural heritage etc. [23, 24].

To achieve an efficient flood risk management, a series of policies, procedures and practices were implemented for identifying the flood susceptible areas, their analysis and evaluation, and determining the necessary measures to reduce the risk [25]. This type of analysis can be applied to the natural heritage, represented by the rural area with its ethnographic characteristics, and also to the archaeological and cultural heritage. From this point of view, the rural area located at the contact between the Obcina Mare and Radauti Depression has been highlighted due to its traditional architecture, preservation of traditions, crafts, and existence of monasteries and churches that emphasize the importance of these places [26]. This area overlaps the Sucevita catchment which is often affected by floods.

The rainfalls recorded over the past decade in the Sucevita catchment have caused some high flow rates (historical highs) that have highlighted the vulnerability of this area and have affected large areas of land in the perimeter of the localities adjacent to riverbeds. In this context, the 2005, 2008 and 2010 floods, from the north-eastern part of Romania, have had a major impact on the communities, and the flash floods have caused significant material damages, as well as life losses [27-32]. The aim of this work is to identify the flood vulnerability of the heritage monuments and to propose protective measures using the GIS software and multi-criteria analysis tools.

Geographical location

The Sucevita catchment is located in the north-eastern part of the Eastern Carpathians and drains an area of 199 km^2. Sucevita is the tributary of the Suceava River and it has a length of 41 km (Fig. 1). Analyzing the maximum flows recorded at the Sucevita river gauge, one can observe a significant increase from 214 m^3/s in 2007 to 467 m^3/s in 2010. These flows have affected large areas of land within the 7 localities situated near the riverbeds. This expansion of the flooding border increases the heritage monuments vulnerability of that area, but references regarding the Sucevita river floods have appeared since the eighteenth century [25, 27].

Since ancient times, the geographical space has been inhabited due to the natural conditions that have provided a framework favoring the development of the communities. These circumstances have encouraged the existence of certain national and international heritage monuments which were later taken by UNESCO. In a confined space, one can find the following: fragments of pottery from the Iron Age (Hallstatt) and the Late Bronze Age (New Culture) were discovered in the archaeological sites of that area; medieval settlements mainly located downstream, at their confluence area; Monastery of Sucevita - included in the UNESCO World Heritage sites; black pottery from the Marginea village (dated from the Neolithic Age); Rudolf of Habsburg's Obelisk (testament to the occupation of the Habsburg Empire) etc. [33].

Materials and methods

Within the analysis on the flood vulnerability degree of the heritage monuments in the Sucevita catchment, four methodological steps were taken: identifying the physico-geographical factors that determine the distribution of floods; creating the modeling for flood susceptibility by integrating the AHP into the GIS software; identifying and locating the heritage monuments; assessing the heritage monuments vulnerability and establishing protective measures.

The physico-geographical factors taken into account when identifying the flood susceptible areas are represented by slope, profile curvature, soil texture, lithology and land use. In order to obtain the thematic layers which generate the slope and the profile curvature, the Numeric Model of the Terrain 1:5000 was used. The geological and pedological maps 1:200000, as well as the land-use were extracted from Corine Land Cover, 2012. Each thematic layer was reclassified and values from 1 to 5 were assigned according to their contribution to the flood propagation. The physico-geographical parameters (the morphometric and those of land-use) were integrated into the Analytic Hierarchy Process (AHP) in order to compare the analyzed factors, to determine their relative importance and influence in preparing the flood susceptibility map.

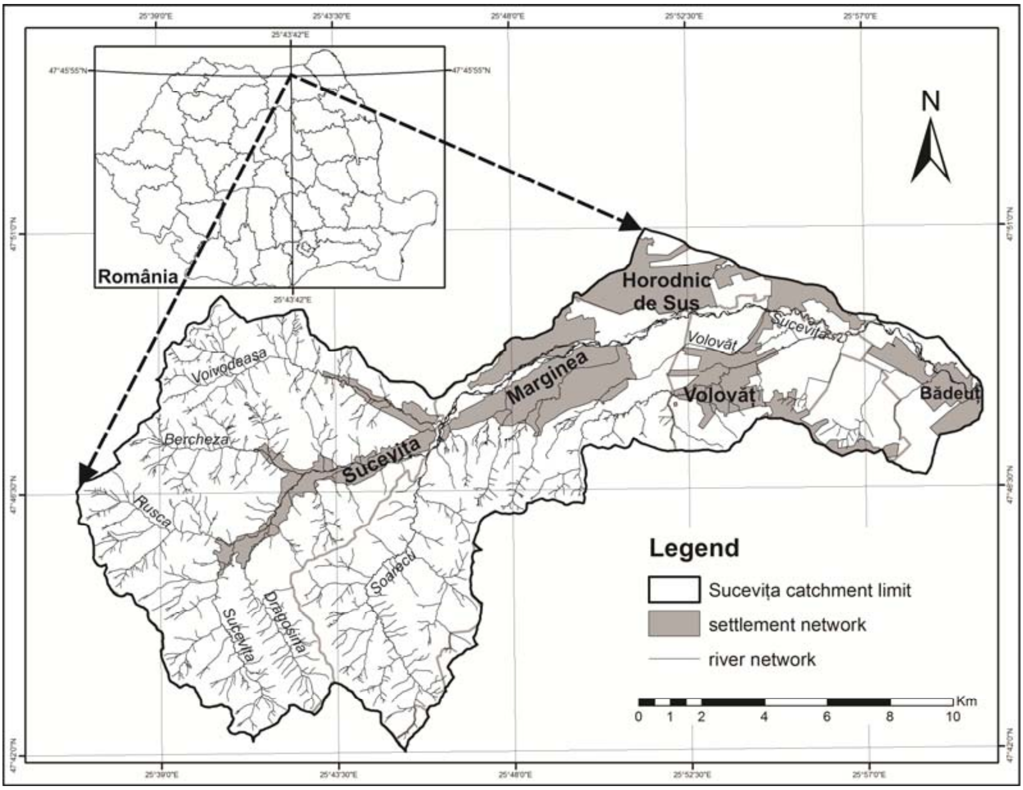

Fig. 1. Geographical location of the study area

To identify and locate the national heritage monuments of the study area, an updated List of Romanian Historical Monuments was consulted (annex to the Order of the Minister of Culture, no. 2361/2010, published in the Official Gazette of Romania), the National Archaeological Repertory of Romania (NAR) and the UNESCO World heritage. Within the Sucevita catchment, 17 heritage monuments were identified and located using the coordinates from the field surveys, from the information provided by the Map Server for the National Heritage (developed by the Institute for Cultural Memory CIMEC), as well as from the General Urban Plans of the localities of the studied area.

The method used is based on the summation of the thematic layers using spatial analysis programmes. Since the analyzed factors do not have the same weight in the propagation of floods, these weights were calculated using the Analytic Hierarchy Process (AHP) [34]. This process is used as a tool of multi-criteria analysis and it is a decision-making technique that provides a systematic approach for evaluating the impact of certain factors and it involves a number of qualitative and quantitative information [35, 36].

The AHP method has been worldwide applied in many domains to determine the importance of certain factors in solving some problems or making important decisions. In the natural hazards studies, the AHP has been integrated into the Geographical Information Systems to identify the areas affected by landslides [37-39], floods [40-43] and to identify the cultural heritage monuments vulnerable to various natural events [9, 44]. The data were processed using the spatial analysis software ArcGis (ESRI, Redlands, CA, USA) and the calculation of weights was performed in Microsoft Office Excel by applying the AHP. The sites, buildings, structures and objects considered important to the cultural heritage [21] are included in the National Register of Historic Monuments in Romania.

Results and discussions

In order to implement this method, it is essential to create a matrix based on pair comparison (pairs of two) of various criteria for analyzing the priorities regarding their importance in achieving the goal (table 1). Comparing pairs of the alternatives are provided within a matrical pattern, based on the scale of preference between two factors, proposed by Saaty in 1980 [34] which includes values from 1 (not important) to 9 (extremely important). After completing the matrix, the values are normalized by summing each column and then dividing the total amount with each value from the columns. The next step is to identify the weights for each analyzed criterion by dividing the sum of each row to 5 (because the matrix is formed of five factors).

Table 1. Application of AHP methodology

No	Factor	Slope	Profile curvature	Soil texture	Land-use	Lithology	Sum	Weights
1	Slope	1	2	3	4	3	13.0	**0.388**
2	profile Curvature	0.5	1	3	2	4	10.5	**0.261**
3	Soil texture	0.33	0.33	1	0.33	2	4.0	**0.102**
4	Land-use	0.25	0.5	3	1	3	78	**0.175**
5	Lithology	0.33	0.25	0.5	0.33	1	2.4	**0.073**

To verify the lack of precision or the discrepancy between the pair comparative judgments, the Consistency Ratio (C.R.) was calculated after taking into account the Consistency Index (C.I.) [Equation (1)] and the Random Consistency Index (R.I.):

$$C.I. = \frac{\lambda_{max} - n}{n-1} = \frac{5,2834 - 5}{5-1} = 0,071 \quad (1)$$

Where: λ_{max} is the total amount between the sum of each column of the matrix and the relative weights obtained (s_i/p_i), and n = 5 (the matrix size) Equation (2):

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{s_i}{p_i} \quad (2)$$

Thus,

$$\lambda_{max} = \frac{1}{5}(26,4173) = 5,2834 \quad (3)$$

The Random Consistency Index was taken into consideration in the Consistency Ratio and it was calculated by Saaty in a sample of 500 randomly generated matrices, depending on the number of criteria examined in the study (table 2).

Table 2. Random Consistency Index (R.I.) used to compute Consistency ratios (C.R.)

N	1	2	3	4	**5**	6	7	8
Random Index (R.I.)	0	0	0,58	0,90	**1,12**	1,24	1,32	1,41

The final consistency ratio was estimated through Equation (4)

$$C.R. = \frac{C.I.}{R.I.} = \frac{0,071}{1,12} = 0,063 \quad (4)$$

The value obtained from the consistency ratio is **C.R. = 0.063** (value < 0.10), which indicates that the inconsistency is acceptable [45]. The final map on the flood susceptibility (Fig. 2) has been prepared by Boolean operations, as a sum of the weights of each considered parameter. Thus, the GIS result has been regrouped in ArcGis using the Natural Breaks method of 5 flood susceptibility classes: very high, high, moderate, low and very low.

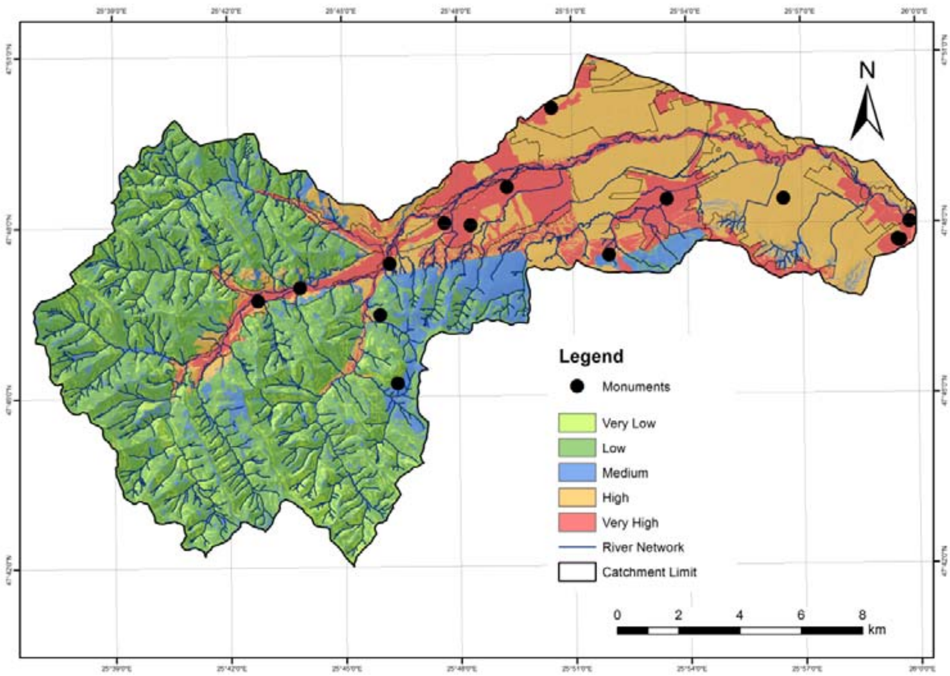

Fig. 2. Map of flood susceptibility and cultural heritage in the Sucevița catchment

Identifying the flood susceptible monuments

The conservation of the cultural, scenic and ethnographic areas requires the application of certain strategies and protective measures against the natural disasters which pose a major threat on the national heritage. From this point of view, several methods are applied for the identification of the vulnerable heritage monuments. Thus, after preparing the map of the flood prone areas in the Sucevita catchment, the thematic layer has overlapped, comprising the territorial location of the heritage monuments. Analyzing the final result, it can be noticed that the high flood susceptible areas overlap those situated in the localities, because they have a longitudinal arrangement in the adjacent area of the Sucevita River, which highly increases the flood risk. This area is 13 km^2 (6.43%) of the Sucevita catchment. Over the last decade, the amplification of the hydrological events has had a negative impact both on the population and on the heritage monuments.

The results of the final map show that 47% of the heritage monuments are included in the very high flood susceptibility class. This alarming percentage is caused by their setting within the localities. The most affected monument is the Monastery of Sucevita, a UNESCO monument, which was damaged by the 2010 floods, according to some reports on the assessment of the damages. The following monuments were also affected: the rural architectural complex made up of groups of houses typical of this area, three archaeological monuments and two medieval settlements located in high flood prone areas. From this analysis, it can be seen that the studied rural area has a major degree of flood vulnerability and it is necessary to implement a preventive conservation strategy.

Measures to reduce flood risk

According to the Directive 2007/60/EC, the flood risk management should focus both on prevention and protection, but also on preparing the vulnerable communities, the economic activities, the conservation and protection of the cultural heritage. The recent flood events are highly questionable regarding the factors that amplify the calamities of the small catchments. To mitigate the impact of the floods, it is necessary to implement an effective flood management based on structural (primary) and non-structural (secondary) measures.

The structural measures are difficult to materialize for the cultural heritage protection, and the latest studies have shown that society must be educated for the non-structural measures. The mapping and monitoring of the heritage monuments would certainly lead to positive results [46]. These structural measures are difficult to materialize as they may compromise the originality and authenticity of the monuments. However, the riverbed regularization works and the riverbank strengthening with the help of gabions can be performed near the vulnerable monuments. After the 2010 floods, the riverbanks of the Sucevita River have been strengthened nearby the Sucevita Monastery.

The issue concerning the floods within the Sucevita catchment and the need for structural measures represent topics that have been addressed since the eighteenth century, when, the media of that period has mentioned the recorded damages and the necessity to regularize the Sucevita River. The archives highlighted that the Sucevita River has represented a constant potential danger for the communities, being an old problem, which has not yet established a balance to mitigate the negative impacts, they even amplifying over time. The construction of some flood defense structures (structural measures) in a particular sector of the river can create certain imbalances and generate the so-called residual risk. The residual risk is a threat that remains after all efforts have been made to mitigate the impact and the occurrence probability of an event. Thus, in the event of flooding, some communities can be protected while others may be affected to a high degree [47]. In order to reduce the negative effects of the high waters in the Sucevita catchment, some specific works have been performed regarding the management of the watercourses: restoration of the bridges damaged by flash floods, riverbed regularization works, riverbanks strengthening with gabions and embankment works.

In addition to the structural measures for the restoration of small catchments located in the transition zones, a series of flood risk mitigation measures can be proposed: implementing some programs to reduce deforestation and to forest the cleared areas; removing the wooden waste that could flow down the slopes during heavy rains and then accumulate next to the bridges, flooding the upstream territories; resizing the bridges and removing the pillars from the riverbed; releasing the floodplains by removing fences; closing the sawmills of the riverbed, etc.

The non-structural measures do not involve the construction of certain structures, but they are based on knowledge, practice or agreement to reduce the impact of floods through policies, legislation, public awareness, training and education [48, 49]. According to the Directive 2007/60/EC, the Member States of the European Union must develop Flood Risk Management Plans. Thus, flood risk management goals are established and are based on reducing their negative effects. Lately, due to the very high costs of the structural measures, the society has been moving towards the implementation of non-structural measures that prove to be much more practical if they rely on effective flood management.

The non-structural measures for the heritage conservation are based on the implementation of some GIS tools that can identify the vulnerability degree of the monuments. Based on the results, heritage preservation guidelines can be created on different types of risk. For the Sucevita catchment, it is necessary to implement some non-structural measures which may include the formation of managerial skills concerning the preservation and capitalization of the cultural heritage, supporting the rural heritage monuments and performing some heritage studies for each monument. Other measures to reduce the flood occurrence probability can be achieved by restoring the watercourses and preventing the soil erosion as well as through measures prohibiting the expansion of the built-up space in the floodable area. In the flood management, the measures to increase resilience are more and more promoted. Within the communities of the Sucevita catchment, certain information campaigns or awareness of the population should be raised on the risk to which they are exposed, some measures to reduce the damages and the importance of the cultural heritage could also be promoted. The awareness and the risk acceptance by the exposed communities is a first step in creating an emergency situation management caused by floods.

Conclusions

The natural and cultural heritage is increasingly threatened by the natural hazards and the risk management has been ignored for a long time. In the last decade, a series of tools have developed for their preventive conservation by using the spatial analysis software. The methodology applied for the identification of the flood vulnerable heritage monuments is based on a series of physico-geographical factors and also the land-use which favors the expansion of the flooded area. Each analyzed factor was integrated into the Analytic Hierarchy Process (AHP) and the results were entered into the GIS technique, obtaining a map on the flood susceptibility. By mapping the existing heritage of the Sucevita catchment and correlating it with the obtained map, the flood vulnerable monuments have been identified.

The results revealed that 47% of the heritage monuments have a high flood vulnerability degree and they need protection and conservation strategies. The results were validated by correlation with data from the reports on the damage assessment after the 2008 and 2010 floods, in the Sucevita catchment. The GIS analysis used for planning the flood risk mitigation strategies regarding the cultural heritage monuments represents a novelty in Romania.

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