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Cultural heritage assessment and vulnerability using Analytic Hierarchy Process and Geographic Information Systems (Valea Oii catchment, North-eastern Romania). An approach to historical maps

Ionut Cristi Nicu[a,b,c,*]

[a] Interdisciplinary Research Department – Field Science, Arheoinvest Platform, Alexandru Ioan Cuza University of Iasi, St. Lascar Catargi 54, 700107 Iasi, Romania

[b] Kazan Federal University, 18 Kremlevskaya Street, 420008, Kazan, Russian Federation

[c] School of Humanities and Creative Arts, Faculty of Education, Humanities and Law, Flinders University, Sturt Road, Bedford Park SA 5042, GPO Box 2100, Adelaide, SA, Australia

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ABSTRACT

The paper presents a method for determining the vulnerability of the landscape that can be applied to cultural heritage sites assessment, based on spatial data gathered from historical maps over a time span of 118 years (1894–2012) and integrated into GIS. Analytic Hierarchy Process (AHP) is employed in order to prioritise the natural and anthropogenic elements extracted from historical maps and orthophotos in order to produce the vulnerability maps and being able to assess and mitigate the effects on cultural heritage sites. In this case, the consistency ratio (CR) has a value of 0.06, which means that the pairwise comparison matrix has an acceptable consistency. The final vulnerability maps for Valea Oii catchment, North-eastern Romania, divided into four vulnerability classes (low, medium, high, and very high), will highlight the most vulnerable areas in terms of natural and anthropogenic elements and will be a powerful tool in the future development plans for the area.

1. Introduction

Vulnerability is a measure of the extent to which a community, structure, service or geographical area is likely to be damaged or disrupted, on account of its nature or location, by the impact of a particular disaster hazard [1]. We will refer in this paper to cultural heritage sites from a small catchment in North-eastern Romania. AHP is widely used in the decision-making process and is being applied in different fields of research belonging to geosciences, such as land suitability analysis [2,3], cultural heritage [4], landslide susceptibility [5,6], flood hazard [7], human settlements planning and development [8,9], soil erosion [10], because of its ability to successfully merge geographical data according to the importance given to the environmental factors (natural and anthropogenic). AHP represents one of the multiple criteria decision-making methods that was originally developed by Saaty in the 1970s [11], and is based on four stages: problem modelling, weights valuation, weights aggregation and sensitivity analysis. AHP has the advantage of allowing a hierarchical structure of the criteria, which grant users with a better core on specific criteria and sub-criteria when allocating the weights. Like any other method, AHP has its limitations [12]. The applications of the AHP are much broader and applied to a wide range of research and economic domains [13,14].

The elements taken into the analysis are structured into natural (gullies, landslides, and drainage network) and anthropogenic (road network, and rural sprawl), which have a good representation on the historical maps and orthophotos. Both globally and locally (north-eastern part of Romania) landslides [15,16] and gully erosion [17,18] are a real problem, affecting not only the human activities [19], cultural heritage as well [20–23]. As shown by [16], landslides and archaeological sites are closely related, prehistoric populations using the landslide depletion areas as defensive systems. Landslides are among the most frequent geomorphological processes in this area, which can be assigned to the category of very high potential, high probability, and average susceptibility to landslides [24]. The landslide susceptibility model of the catchment [22] highlights the fact that more than 65% of the Chalcolithic settlements are located in areas with high and very high susceptibility, raising the chances of degradation in the future.

Worldwide, fast gully head retreat is correlated to the runoff contributing area of the gully and the rainy days [17]; the fact that in

* Correspondence address: Interdisciplinary Research Department – Field Science, Arheoinvest Platform, Alexandru Ioan Cuza University of Iasi, St. Lascar Catargi 54, 700107, Iasi, Romania.

E-mail address: nicucristi@gmail.com.

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the study area torrential rains have a high density (peak values of 145.8 mm/24 h) and concentration during summertime [25], gullies are usually located on the steep slopes, where the prehistoric people were placing their settlements in this way, cultural heritage being very vulnerable to gully head retreat. During March-June the water volume runoff represents 62%, period that was identified as being the critical season for gullying [26].

Historical maps contain significant data, which can help in the analysis of landscape dynamics [27–29]. As shown by [30], landscape dynamics in Central Europe tends to be less diverse, but with a high impact for long term periods; this impact can lead to changes in what concerns the water balance, carrying capacity and usability of the landscape. Nonetheless, these conditions are different from case to case, depending on the economic situation of the country, whether the degree of industrialisation is high, or how the local authorities are implementing the land management laws. Cultural landscapes, on the other hand, have a strong historical background, which should be taken into account. The people's need to satisfy the material and spiritual needs along the time has left in landscape traces of civilisation and culture. The historical value gives the place a special meaning, which is different from other areas that do not have this feature. The fact that within the study area the traces of Cucuteni Culture were discovered and investigated by the German archaeologist H. Schmidt in 1885, gives the landscape an extraordinary and individual meaning; being considered the typical landscape in which Neolithic populations could flourish.

Nowadays, the anthropogenic pressure started to be higher and higher, due to the expansion of human settlements, the need of connecting them and has been identified as being one of the most dangerous factors that are affecting the integrity and value of cultural heritage [31]. The method grants a new approach based on historical spatial data, and will be of high confidence in being cost-effective, decision-making process, and non-invasive, and will reduce the impact of natural and anthropogenic risks on the landscape and cultural heritage sites. The final vulnerability maps can be taken into account by the local authorities and stakeholders [32] when the future development plans of the area are proposed.

2. Materials and methods

Changes in the landscape were determined on the basis of historical maps and modern orthophotos. The main indicators used in this study are the natural ones (drainage network, gullies, and landslides) and anthropogenic (road network, and rural sprawl). The cartographic analysis uses a GIS to integrate the digital data (vector and raster) in a manner established with the help of AHP methodology (Table 1). It is a method that provides measures of judgement consistency, derives priorities among criteria and alternatives, and simplifies preference ratings among decision criteria using pairwise comparisons. It provides a relative dominance value between 1 and 9 to calibrate the qualitative and quantitative performances of priorities [33]; in addition, is considered to reduce bias in decision making and is backing group decision-making through consensus by calculating the geometric mean of separate pairwise comparisons [34]. It was used in this article to obtain the set of weights which will then be integrated into the final equation of vulnerability.

The values of the elements were chosen based on expert judgement and having a good knowledge of the natural hazards and social organisation in this part of the country. The five elements were chosen based on their availability and good representation on historical maps and orthophotos, even though the spatial data used has different scales (as shown above). Comparing the values obtained with other values from the literature [31], and taking into consideration the geographical setting of the study area, the anthropogenic influence dominates over the natural factors; the anthropogenic interventions in the landscape has a higher influence on soil degradation processes rather than the natural characteristics (slope, soil texture, land use, profile curvature). The values obtained can be used in other study areas with the same natural and anthropogenic characteristics, or they can be adapted according to the local conditions and the available spatial data.

After the calculation of the normalised weights (Table 1), the consistency was checked by calculating the consistency ratio (CR); in order to achieve that, the consistency index (CI) was determined with the help of Eq. (1).

$$CI=\lambda - n/n - 1 = 5.30 - 5/5 - 1 = 0.075 \quad (1)$$

where λ is the average vector of the consistency measure and n is the number of criteria used in the study. The final consistency ratio (CR) was calculated through Eq. (2) by dividing CI and RI.

$$CR=CI/RI = 0.075/1.12 = 0.06 \quad (2)$$

where CI represents the value obtained from Eq. (1), and RI is the random consistency index. The value of 0.06 obtained for the CR highlights the fact that the ranking is consistent and reliable.

The vulnerability index represents a measure of the exposure of a population to some hazard (in our case the exposure of cultural heritage sites to hazards – natural and anthropogenic); the index is a composite of multiple quantitative indicators that via a formula, the authors obtain a numerical result. The beginnings of vulnerability indexes as a policy planning tool began with the United Nations Environmental Program; it was used for the first time in economy [35].

The final vulnerability maps was generated with the help of ArcGIS software, using *Raster Calculator* function; the values used in the final equation are the ones generated with the help of AHP methodology road network (RN), human settlements (HS), drainage network (DN), gully erosion (GE), landslides (LD) (Eq. (3)). The final raster was reclassified using the function *Reclassify*; the values of the vulnerability index (Vi) are as follows: low (1 – 1.14), medium (1.14 – 1.5), high (1.5 – 2.3), very high (2.3 – 3.4).

$$Vi=RN \times 33 + HS \times 33 + DN \times 15 + GE \times 10.5 + LD \times 8.5 \quad (3)$$

Geographical and cultural heritage data integrated into a GIS is very helpful for geographers, archaeologists, local authorities, and stakeholders. All the data was georeferenced in Romania's official projection Stereo 70 (Datum Dealul Piscului). The first topographical surveys in Romania were made by Austrians, as a result of the annexation of Bukovina and Transylvania in the second half of 17th century, whereas territories close to the borders of the empire being considered of high interest.

The spatial data has been digitised from a series of historical maps and orthophotos: Topographic Map (scale 1:50 000, the year 1894 –

Table 1
Extracting weights for each factor with the help of AHP methodology.

Factor	Proximity to streams	Roads	Villages	Landslides	Gullies	Normalised weights	Consistancy measure
Proximity to streams	1	0.2	0.33	3	2	**0.150**	**5.242**
Roads	5	1	1	3	2	**0.330**	**5.679**
Villages	3	1	1	4	3	**0.330**	**5.369**
Landslides	0.33	0.33	0.25	1	1	**0.085**	**5.099**
Gullies	0.5	0.5	0.33	1	1	**0.105**	**5.148**
Sum	9.83	3.03	2.91	12	9	**1**	–

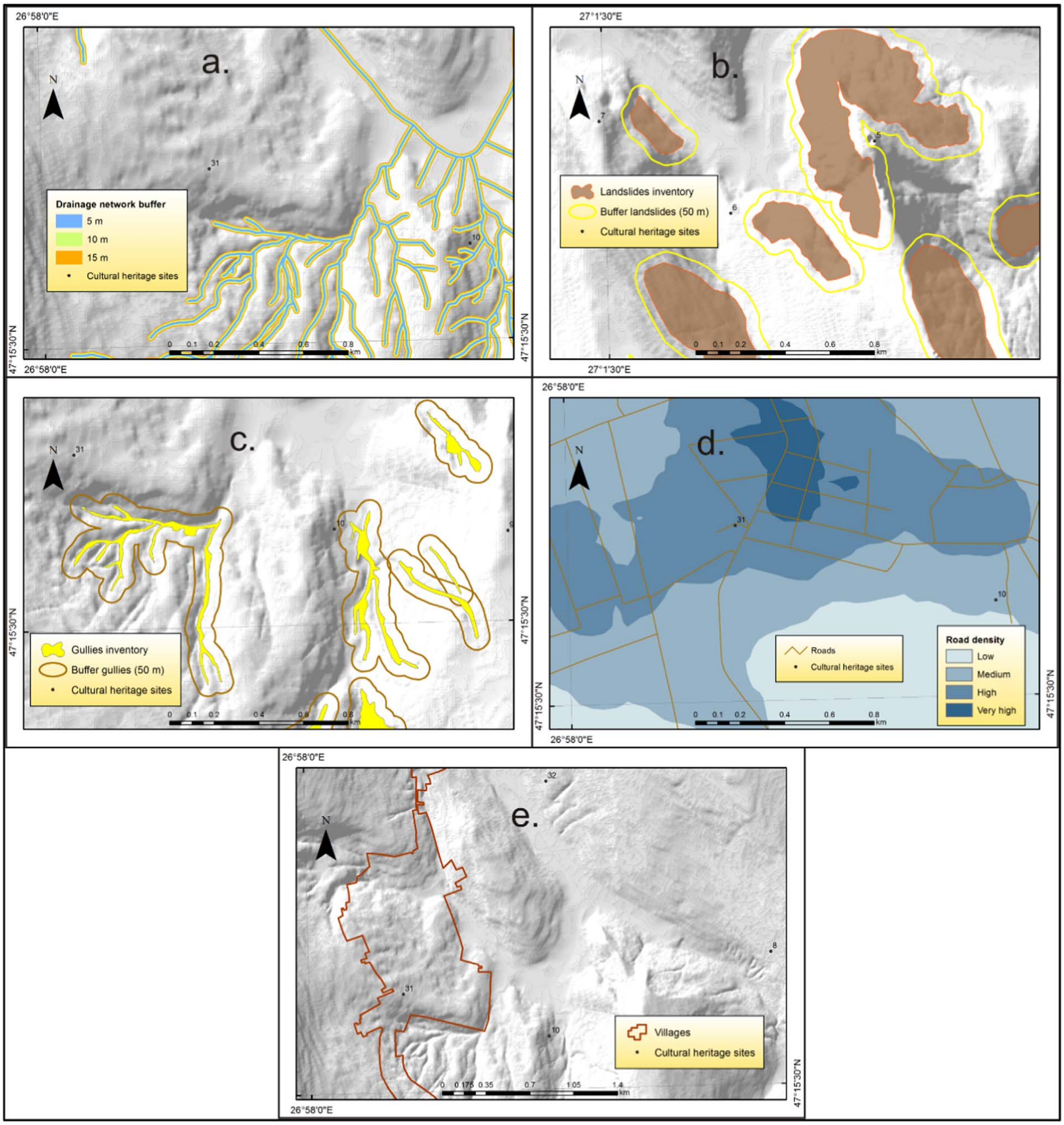

Fig. 1. Detail over the methodological staging of the elements used in the study: (a) Buffer analysis (5, 10, 15 m) performed for the drainage network; (b) 50 m buffer area created around the landslides; (c) 50 m buffer area created around the gullies; (d) Line density analysis for the road network; (e) Human settlements (inside polygon).

the map was realised on the basis of the military topographical surveys, also known as "the first Romanian geodetic concept"), Soviet Maps (scale 1:50 000, the year 1942 – the map is part of a top secret project of Soviet Union to map the entire surface of the earth), Historical Army Maps (scale 1:20 000, the year 1958 – the maps were known under the name "Shooting Plans"), Romanian Topographic Map (scale 1:25 000, year 1984), orthophotos (scale 1:5 000, resolution 0.5 m, edition 2005 – were taken during May-September 2003–2005), orthophotos (scale 1:5 000, resolution 0.5 m, edition 2012 – were taken during May-September 2010–2012). The period analysed covers a time span of 118 years, in which the North-eastern part of Romania has been the target of significant historical, political, territorial planning, and agrarian changes, which had a significant contribution to the transformations that took place in the landscape.

The natural (drainage network, landslides, gullies) and anthropogenic (road network, villages) elements were digitised and analysed. After creation of the vectors for each element, they were subsequently transformed into classified raster datasets:

- The drainage network (permanent, intermittent, potential) was extracted from the topographic plans scale 1:5,000, year 1978 as polylines; taking into consideration the small surface of the catchment and due to repetitive field trips and surveys, the buffer analysis performed was for 5, 10, respectively 15 m from the drainage network, Fig. 1a.
- Landsides – were extracted as polygons from all series of maps and orthophotos used in the study; landslides in the Moldavian Plateau have a density of 1.02 landslides/km^2. In this case, the buffer analysis undertaken around the polygon was 50 m (Fig. 1b), due to the fact that the scarps, the body and the toe of the landslide represent risk areas wich should be taken into account when realising vulnerability maps.

Table 2
Random Consistency Index values (RI).

n	1	2	3	4	**5**	6	7	8	9	10
RI	0	0	0.58	0.9	**1.12**	1.24	1.32	1.41	1.45	1.49

– Gullies – were digitised as polygons from old maps and orthophotos, along with successive field surveys in the case of two gullies from the upper part of the catchment. Gully erosion has a widespread development in the Moldavian Plateau, with an alarming gully-head retreat [26,36,37]. The distance chosen to realise the buffer analysis was 50 m around the gully (Fig. 1c) because both the upper side and the deposition area are producing modification in the landscape, and both have a significant role in the degradation and sedimentation of an archaeological site (point).
– Roads – were digitised as polylines, including the main roads, secondary roads, and the roads used to connect the agricultural lands; afterwards, a density analysis has been undertaken (Fig. 1d) with the help of ArcGIS tools (*Spatial Analyst Tools→Density→Line Density*). This factor has a very important role in our study because the density has increased from 0.9 km/km^2 in 1894–2.6 km/km^2 in 2012. Before any road arrangement or construction an assessment should be made in order to avoid any cuts through known cultural heritage sites; in this case, the site will be modified by anthropogenic interventions and significant data will be lost, which could help in deciphering patterns of prehistoric populations. Furthermore, another aspect that puts cultural heritage sites in danger is the air pollution nearby roads, and the possibility of future rural development.

– Villages – were digitised as polygons then converted into a raster (Fig. 1e); the development of villages in the North-eastern part of Romania is strongly connected with the natural resources of the area (the existence of fertile soils, forests, water resources – ponds), because the main activity in this part of the country is agriculture and animal husbandry. The existence of villages in this area has a long lasting tradition, the oldest mentions of these villages date back to 15th century, the Cucuteni village being mentioned in documents of 5th October 1448, being followed by Băiceni village (Băiceni de Baia – the old name, until de 19th century) mentioned in documents from 25th August 1454 [38]. Compared to the surface of the catchment 97 km^2, the number of rural settlements is high; a number of eleven villages exist within the study area: Stroesti, Baiceni, Cucuteni, Bals, Boureni, Filiasi, Podisu, Gugea, Valea Oii, Baltati and Sarca.

The development and evolution of the five elements analysed in this study is closely related to the four major changes that took place in only one century: the great agrarian reform in 1921, the agrarian reform of 1945, agriculture collectivization between 1949–1962, and the enforcement of the Land Law from 1991 [39]. Taking into consideration the fact that approximately 62% of Romania's total land surface is used for agriculture, the main changes taking place in the landscape are mostly connected with the arable land and pastures (13.8% of the total surface of the country) [40]. The changes that followed the agrarian reforms had a significant contribution to the triggering, development and evolution of the geomorphological processes and rural development of the area. (Table 2).

3. Study area

The study area is located in the North-Eastern part of Romania, Iasi County. The Valea Oii catchment has a surface of 97 km^2 and an altitude between 61.57 and 443.19 m a.s.l., which is part of the Moldavian Plateau (Fig. 2). Within the catchment, there are a number of six communes and eleven villages. The geological deposits dominating the basin belong to Bessarabian (clay marls with sand intrusions), being well known for its high friability and fine granulation, which lead over time to the triggering of the geomorphological processes. Three types of relief are encountered within the study area (sculptural, structural, and accumulation), which is a sub-division of the Moldavian Plain [22].

Because limited funds are allocated to the study and research of cultural heritage, a complete inventory of cultural heritage sites (tangible and intangible) is a necessity. Archaeological data was gathered from the archaeological inventory of Iasi County, available national databases like National Archaeological Registry (RAN), the Institute of Cultural Memory (cIMEC), the National Heritage Institute (INP), and from the field trips. All the sites were checked in the field with a Leica 1200 GPS system; the newly discovered sites were included in the existing database and dated with the help of archaeologists.

According to the Institute of Cultural Memory (cIMEC), in Romania, there is a total of 15925 cultural heritage sites indexed; out of these, Iasi county has a total of 246 cultural heritage sites registered, a number which is by far not according to the reality in the field. Comparing to other counties in the country like Hunedoara with a number of 953 sites, Mures with a number of 571 sites, Prahova with 632 sites, Salaj with 747 sites registered (ran.cimec.ro/sel), Iasi county is one with the lowest number of cultural heritage sites registered. A site has to be registered in order for local authorities and cultural heritage police to protect it from looting activities; in these conditions, a lot of sites are being looted or are under the effect of agricultural work (ploughing), taking into consideration the fact that local population are not educated in this way, or agriculture is their main source of income.

Cultural heritage of the area consists of a number of 47 sites, of which eleven are listed in the List of Historical Monuments (LMI), and nine are listed in the National Archaeological Registry (RAN); these are considered to be of high importance for Neolithic, Geto-Dacian, late Bronze Age, and late Iron Age periods (Table 3). Out of 47 sites, twenty sites are affected by anthropogenic interventions (ploughing, overgrazing), six sites are affected by natural risk phenomena (gully erosion, landslides, weathering), seventeen sites are affected by the combination of natural processes and anthropogenic intervention, and a number of four sites are being affected neither by natural nor by anthropogenic intervention.

The most important site within the study area is Cetatuia (no. 20), discovered by Th. Burda in 1884, followed by archaeological investigation in 1885 (by Butulescu), 1888 (by Beldiceanu), and 1909 (by Schmidt); the multistratified settlement represented the base of the first attempts to determine the periodisation of Cucuteni Culture, along with other seven settlements belonging to the Cucuteni Culture, where systematic excavations were undetaken (sites no. 1, no. 5, no. 16, no. 17, no. 21, no. 22, no. 23). The settlement of Cetatuia gave the name of the largest agrarian culture from Eastern Europe [41].

4. Results

The final vulnerability maps realised as a result of using data from historical maps, integrated into a GIS, and prioritised with the help of AHP methodology are presented below (Fig. 3). The mean values of the vulnerability index show an increase from 1.31 (1894) to 1.39 (1942), to 1.42 (1958), and to 1.61 (2012). The most important factors selected by the AHP are the road network and the villages, which are interconnected and one depends on the other; the road density is directly proportional to the village's surface, from a density of 0.9 km/km^2 in 1894–2.1 km/km^2 in 1984, and to 2.3 km/km^2 in 2005. The villages surface increased in the same manner from 209.04 ha in 1894 to 647.15 ha in 1984, and to 890.99 ha in 2005 [23]. According to this, the areas with a high and very high vulnerability index are located around the villages and where a high density of roads exist.

The number of cultural heritage sites (Fig. 4) located in areas with a

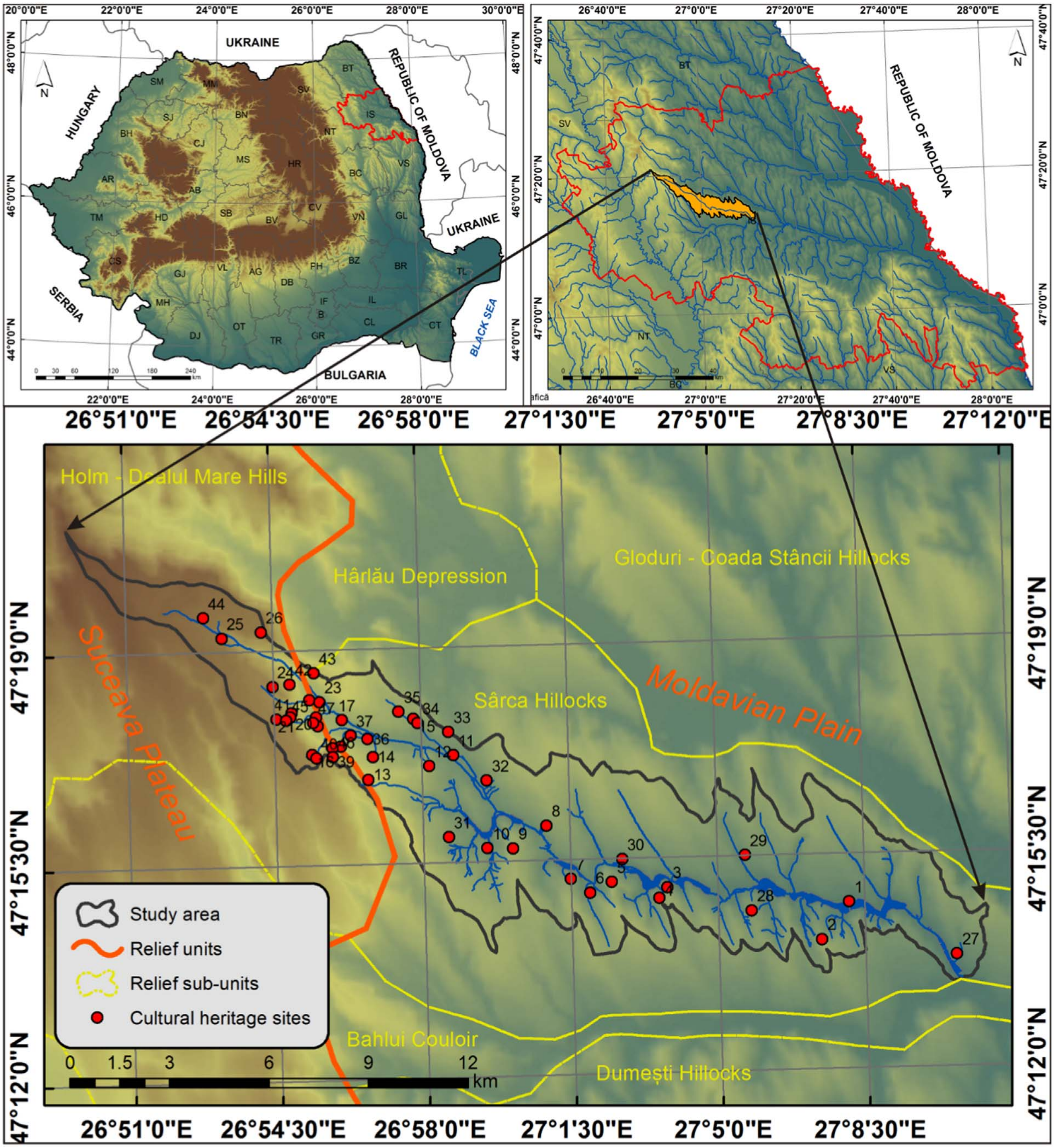

Fig. 2. Geographical location of the study area in Romania and Iasi county (the main geographical units and sub-units are highlighted).

low vulnerability increased from 11 sites in 1894 to 13 sites in 2012; sites located within areas with moderate vulnerability decreased from 18 sites in 1894 to 17 sites in 2012. The decrease is due to the fact that these areas are prone to areas with a high and very high vulnerability; this is reflected by the four agrarian reforms that took place in only one century. The road network connecting the agricultural lands and the pastures has drastically modified the vulnerability of the landscape. The number of sites located in areas with a very high vulnerability index increased from two sites in 1894 to seven sites in 2012; these sites are mainly located inside the inhabited areas (churches – which are located in the centre of the village, spread throughout the entire surface of the catchment; and some sites located at the contact area between the plain and plateau in the upper part of the catchment). There is no increasing or decreasing trend observed in the number of sites located in areas with different vulnerabilities due to the hazardous development of this part of the country.

5. Discussion

Regarding the cultural heritage assessment and protection can be a tricky subject, due to the challenges that are coming along with the financial issues needed in order to save and protect it. Considering that the number of natural hazards is increasing in the course of the global climatic changes [42], and the anthropogenic pressure is getting higher every year, the challenges faced by the cultural heritage are enormous. In order to minimise the negative effects of the natural and anthropogenic factors, sustainable strategies need to be implemented both by national and local authorities.

Protecting the diversity of cultural heritage is a constant and difficult issue, which is different from country to country and from

Table 3
The list of the cultural sites from the study area.

Site no.	Site name	Location (WGS84 coordinates)		Period/culture	Processes affecting the site
		N	E		
1	[a,b]Dealul Mandra/la Iaz/Iazul 3	47d14m43s	27d08m7s	Chalcolithic/Cucuteni A_{3b}, late Bronze Age/Noua culture	Sedimentation, anthropogenic
2	Movila Hartopeanu	47d14m7s	27d07m27s	Chalcolithic/Cucuteni unknown	Landslide, anthropogenic
3	Tarlaua Padurii/Crescătorie 1	47d15m1s	27d03m47s	Chalcolithic/Cucuteni A_3	Landslide
4	Dealul Oilor/Crescătorie 2	47d14m51s	27d03m35s	Chalcolithic/Cucuteni unknown	Landslide
5	[b]Dealul Mare Filiasi/Dealul Boghiu	47d15m8s	27d02m27s	Chalcolithic/Cucuteni A_3	Landslide, gully erosion, anthropogenic
6	SV de Boghiu	47d14m58s	27d01m57s	Chalcolithic/Cucuteni A	Landslide, anthropogenic
7	Dealul Harbuzariei/V de Dealul Boghiu	47d15m14s	27d01m32s	Chalcolithic/Cucuteni unknown	Landslide, anthropogenic
8	Bejeneasa	47d16m4s	27d00m56s	Chalcolithic/Precucuteni, Cucuteni A, 3–4th centuries	Landslide, gully erosion, anthropogenic
9	Dealul Hartopului	47d15m58s	27d00m5s	Chalcolithic/Cucuteni A-B, B	Landslide, anthropogenic
10	Hartochi/Dealul Hartop	47d15m44s	26d59m31s	Chalcolithic/Cucuteni unknown	Gully erosion, anthropogenic
11	Bejeneasa I/la Brigadă	47d17m15s	26d58m45s	Chalcolithic/Precucuteni II-III, Starčevo-Criş, Bronze Age/late Hallstatt	Anthropogenic
12	Mamelon	47d17m5s	26d58m10s	Chalcolithic/Cucuteni unknown	Anthropogenic
13	Ismiceanu	47d14m7s	27d03m47s	Chalcolithic/Cucuteni unknown	Anthropogenic
14	Tarla Luncanului	47d17m15s	26d56m50s	Chalcolithic/Cucuteni A	Anthropogenic
15	Valea Parului III	47d17m52s	26d57m47s	Chalcolithic/Precucuteni II-III	Anthropogenic
16	Dealul Manastirii/la Dobrin/ Dealul Gosanul	47d14m20s	26d55m20s	Chalcolithic/Cucuteni A_3	Gully erosion, small landslide, anthropogenic
17	[a,b]Dambu Morii	47d14m45s	26d56m10s	Chalcolithic/Cucuteni A_2, A-B_1, A-B_2	Landslide, anthropogenic
18	La Bazin/fost Gostat	47d14m55s	26d56m0s	Chalcolithic/Cucuteni B, late Bronze Age/Noua I culture, 4th, 10th centuries	Landslide, anthropogenic
19	Langa Pod	47d14m7s	27d03m47s	Chalcolithic/Precucuteni, late Bronze Age/Noua I culture	Landslide, anthropogenic
20	[a,b]Cetatuia	47d17m55s	26d54m50s	Chalcolithic/Cucuteni A_2, A_3, A-B_2, B_1, B_2, late Iron Age/la Tène culture, Geto-dacian, 4–2nd centuries	Gully erosion, anthropogenic
21	Hurez	47d18m0s	26d54m55s	Chalcolithic/Cucuteni A, 4–3rd century	Anthropogenic
22	[a,b]Dambul lui Pletosu	47d18m10s	26d55m20s	Chalcolithic/Cucuteni A, 1–2nd, 4th, 9–10th, 16–17th centuries	Anthropogenic
23	[a,b]Siliste	47d18m10s	26d55m35s	Chalcolithic/Cucuteni unknown, Roman Period/2–3rd, early Medieval Period/8–10th, Medieval Period/14–17th centuries	Anthropogenic
24	VSV de vatra satului	47d18m17s	26d54m40s	Chalcolithic/Cucuteni unknown	Anthropogenic
25	Barghici	47d19m26s	26d53m15s	Chalcolithic/Cucuteni unknown	Gully erosion, anthropogenic
26	Pietrarie	47d19m19s	26d54m13s	Chalcolithic/Cucuteni A, B	Anthropogenic
27	Sarca church	47d13m49s	27d10m40s	19th century (1983)	–
28	Valea Oilor church	47d14m36s	27d05m47s	20th century (1936)	–
29	La N de sat	47d15m36s	27d05m36s	late Bronze Age/Noua culture	Anthropogenic
30	Dealul Vantului	47d15m30s	27d02m40s	Chalcolithic/Starčevo-Criş	Anthropogenic
31	Boureni church	47d14m7s	27d03m47s	20th century	–
32	Bejeneasa II	47d16m50s	26d59m31s	3–4th centuries	Anthropogenic
33	Bals church	47d17m38s	26d58m39s	20th century	–
34	[a]Valea Parului II	47d17m47s	26d57m54s	Chalcolithic/Starčevo-Criş	Anthropogenic
35	Valea Parului IV	47d17m60s	25d57m28s	3–4th centuries	Anthropogenic
36	Coasta Nucului II	47d17m32s	26d56m43s	Dacian	Landslide, anthropogenic
37	In Hotar	47d17m37s	26d56m20s	18th century	Rill, inter-rill, gully erosion
38	Coasta Nucului	47d17m27s	26d56m3s	late Bronze Age/Noua culture	Anthropogenic
39	Gosan Pietrarie	47d17m25s	26d55m52s	3–2nd centuries, Geto-Dacian	Landslide
40	[a,b]Mlada	47d17m16s	26d55m28s	Geto-dacian, 4–3rd, 3–1st centuries	Gully erosion
41	Laiu II	47d17m53s	26d54m34s	Late Neolithic/Horodiştea-Erbiceni culture, 4th century	Anthropogenic
42	[a]Baiceni wooden church	47d18m28s	26d54m53s	19th century (1808)	Weathering
43	[a,b]Gradina lui Pascal	47d18m38s	26d55m27s	9–10th, 17–18th centuries, early Medieval Period	Landslide, anthropogenic
44	[a]Stroesti church (Sf. Voievozi – Holy Kings)	47d19m34s	26d52m51s	16th century (1500–1550)	Weathering
45	Baiceni Palaeontological Reservation	47d17m52s	26d54m48s	Early Bessarabian fauna	Gully erosion
46	La Pietrarie	47d17m15s	26d55m47s	4th century, Geto-Dacian necropolis (tumuli)	Anthropogenic
47	[a,b]Bogdaneasa	47d29m00s	26d92m00s	Late Iron Age/la Tène culture	Landslide, anthropogenic

Legend: d=degrees, m=minutes, s= seconds.
[a] Listed in LMI (List of Historical Monuments).
[b] Listed in RAN (National Archaeological Registry).

region to region. The difference between developed countries, which have experience in mitigation and conservation of the cultural heritage, and developing countries, which have limited funds and therefore, big issues regarding the protection and conservation; there should be international collaboration and transfer of knowledge between them. In this way, strategies, experiences, and sustainable measures can be taken in order to assess the damage on cultural heritage.

Concerning Romania, a developing country, the general state of the cultural heritage is a poor one. However, over the last years new strategies have been implemented on the base of a series of dysfunc-

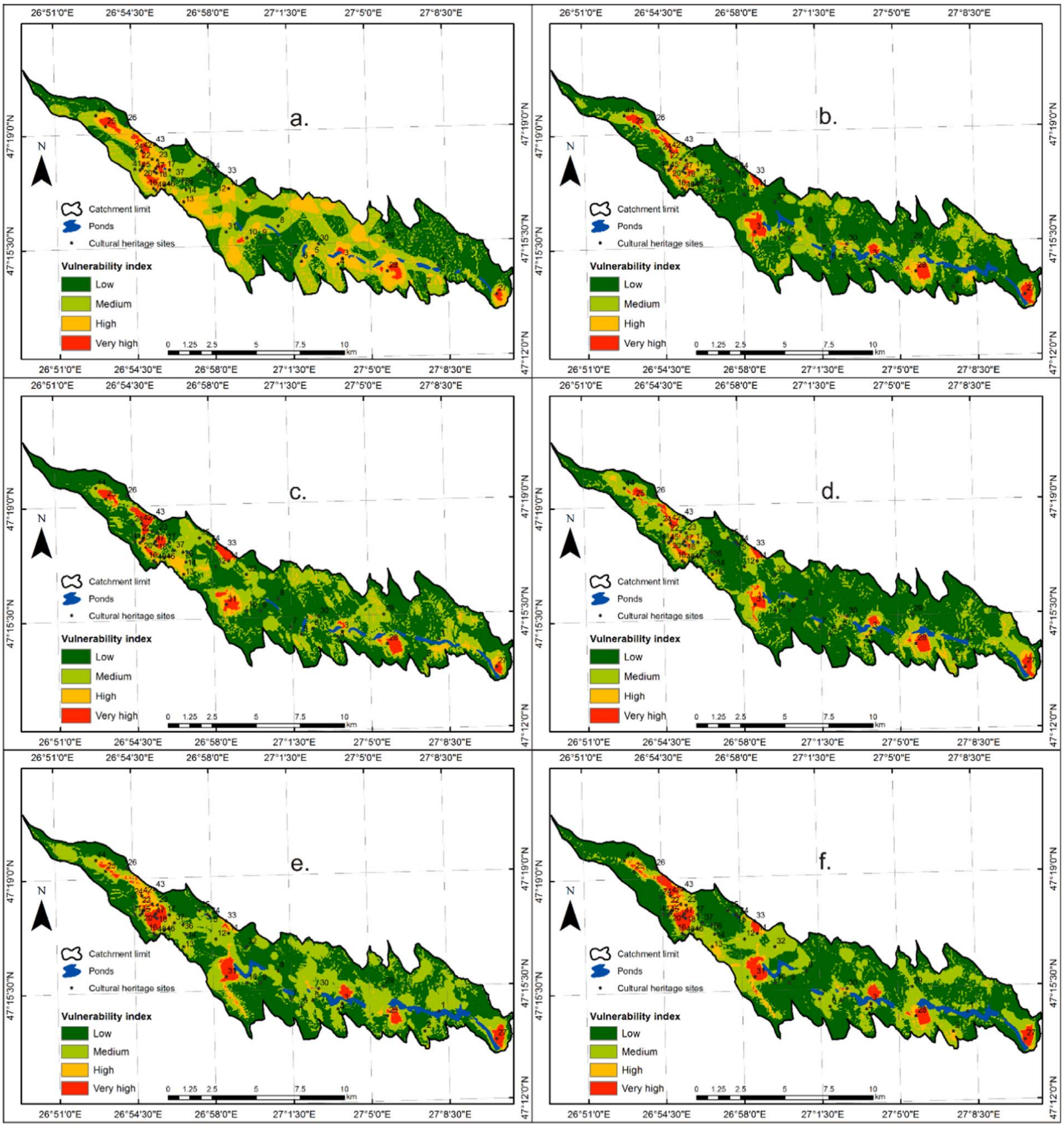

Fig. 3. The final vulnerability maps of the catchment. (a) 1894; (b) 1942; (c) 1958; (d) 1984; (e) 2005; (f) 2012.

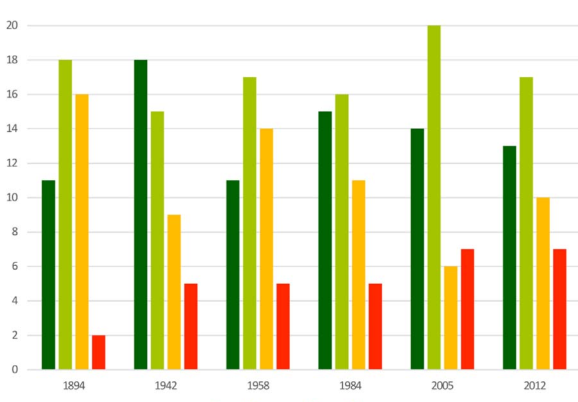

Fig. 4. Cultural heritage sites distribution on vulnerability classes.

tionalities and vulnerabilities: a bad management of the cultural heritage by the local authorities, the lack of education, the lack of a complete inventory with a precise location, the lack of funds, the lack of qualified personnel. The basic principles of the strategy are: the participation of population, improvement in the administration of cultural heritage, development of cultural resources, sustainable use of cultural heritage resources; the principles are according to the European Legislation regarding the protection and conservation of cultural heritage. Fig. 5 shows few of the most important cultural heritage sites in the area, the latter going from the upper part of the catchment until the lower part.

6. Conclusion

This work aims to identify, by using AHP and GIS techniques, the landscape vulnerability and the effects on cultural heritage sites

Fig. 5. Details of cultural heritage sites location, with natural and anthropogenic factors affecting them.

threatened by natural hazards and anthropogenic factors. Valea Oii watershed from North-eastern Romania was selected for this purpose due to the detailed spatial data extracted from historical maps and orthophotos. Following the AHP methodology, the road network (33%) and the extension of the human settlements (33%) were identified as being the most important factors in establishing the vulnerability of this area; the next three factors in descending order are the drainage network (15%), gully erosion (10.5%) and landslides (8.5%). Therefore, the model can be successfully applied to other areas with the same characteristics. The rich cartographic background helped us to realise a pertinent and useful analysis of the landscape vulnerability and the cultural heritage sites affected. A stability is recommended regarding the agrarian reforms, too many changes in the landscape along a short period of time will have negative consequences for the future. Cultural heritage value is increasing if the sites are kept in a good conservation status, the local population has knowledge about the sites existent in the area, and the local authorities are doing the best they can to promote and protect it.

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References

[1] Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York, 1997.
[2] B. Quinn, K. Schiel, G. Caruso, Mapping uncertainty from multi-criteria analysis of land development suitability, the case of Howth, Dublin, J. Maps 11 (3) (2015) 487–495. http://dx.doi.org/10.1080/17445647.2014.978907.
[3] A. Bozdağ, F. Yavuz, A.S. Günay, AHP and GIS based land suitability analysis for Cihanbeyli (Turkey) County, Environ. Earth Sci. 75 (2016) 813. http://dx.doi.org/10.1007/s12665-016-5558-9.
[4] F. Karaca, An AHP-based indoor air pollution risk index method for cultural heritage collections, J. Cult. Herit. 16 (2015) 352–360. http://dx.doi.org/10.1016/j.culher.2014.06.012.
[5] W. Chen, W. Li, H. Chai, E. Hou, X. Li, X. Ding, GIS-based landslide susceptibility mapping using analytical hierarchy process (AHP) and certainty factor (CF) models for the Baozhong region of Baoji City, China, Environ. Earth Sci. 75 (2016) 63. http://dx.doi.org/10.1007/s12665-015-4795-7.
[6] D. Myronidis, C. Papageorgiou, S. Theophanous, Landslide susceptibility mapping based on landslide history and analytic hierarchy process (AHP), Nat. Hazards 81 (2016) 245–263. http://dx.doi.org/10.1007/s11069-015-2075-1.
[7] S. Stefanidis, D. Stathis, Assessment of flood hazard based on natural and anthropogenic factors using analytic hierarchy process (AHP), Nat. Hazards 68 (2) (2013) 569–585. http://dx.doi.org/10.1007/s11069-013-0639-5.
[8] P. Russo, L. Riguccio, L. Carullo, G. Tomaselli, Using the analytic hierarchical process to define choices for re-using rural buildings: application to an abandoned village in Sicily, Nat. Resour. 4 (2013) 323–332. http://dx.doi.org/10.4236/nr.2013.44039.
[9] G.O. Palmisano, K. Govindan, R.V. Loisi, P. Dal Sasso, R. Roma, Greenways for rural sustainable development: an integration between geographic information systems and group analytic hierarchy process, Land Use Policy 50 (2016). http://dx.doi.org/10.1016/j.landusepol.2015.10.016.
[10] J.R. Ni, X.X. Li, A.G.L. Borthwick, Soil erosion assessment based on minimum polygons in the Yellow River basin, China, Geomorphology 93 (3–4) (2008) 233–252. http://dx.doi.org/10.1016/j.geomorph.2007.02.015.
[11] T.L. Saaty, A scaling method for priorities in hierarchical structures, J. Math. Psychol. 15 (1977) 234–281.
[12] A. Ishizaka, A. Labib, Analytic hierarchy process and expert choice: benefits and limitations, OR Insight 22 (2009) 201–220. http://dx.doi.org/10.1057/ori.2009.10.
[13] O.S. Vaidya, S. Kumar, Analytic hierarchy process: an overview of applications, Eur. J. Oper. Res. 169 (2006) 1–29. http://dx.doi.org/10.1016/j.ejor.2004.04.028.
[14] W. Ho, Integrated analythic hierarchy process and its applications – a literature review, Eur. J. Oper. Res. 186 (1) (2008) 211–228. http://dx.doi.org/10.1016/j.ejor.2007.01.004.
[15] B. McGuire, I. Manson, C. Kilburn, Natural Hazards and Environmental Change, Arnold, UK, 2002.
[16] M. Niculita, M.C. Margarint, M. Santangelo, Archaeological evidence for Holocene landslide activity in the Eastern Carpathian lowland, Quat. Int. 415 (2016) 175–189. http://dx.doi.org/10.1016/j.quaint.2015.12.048.
[17] M. Vanmaercke, J. Poesen, B. Van Mele, M. Demuzere, A. Bruynseels, V. Golosov, J.F.R. Bezerra, S. Bolysov, A. Dvinskih, A. Frankl, Y. Fuseina, A.J.T. Guerra, N. Haregeweyn, I. Ionita, F.M. Imwangana, J. Moeyersons, I. Moshe, A.N. Samani, L. Niacsu, J. Nyssen, Y. Otsuki, M. Radoane, I. Rysin, Y.V. Ryzhov, O. Yermolaev, How fast do gully headcuts retreat?, Earth-Sci. Rev. 154 (2016) 336–355. http://dx.doi.org/10.1016/j.earscirev.2016.01.009.
[18] I. Ionita, L. Niacsu, G. Petrovici, A.M. Blebea-Apostu, Gully development in eastern Romania: a case study from Fălciu Hills, Nat. Hazards 79 (1) (2015) 113–138. http://dx.doi.org/10.1007/s11069-015-1732-8.
[19] A. Godfrey, R.L. Ciurean, C.J. van Westen, N.C. Kingma, T. Glade, Assessing vulnerability of buildings to hydro-meteorological hazards using an expert based approach – an application in Nehoiu Valley, Romania, Int. J. Disaster Risk Reduct. 13 (2015) 229–241. http://dx.doi.org/10.1016/j.ijdrr.2015.06.001.
[20] P. Canuti, N. Casagli, F. Catani, R. Fanti, Hydrogeological hazard risk in archaeological sites: some case studies in Italy, J. Cult. Herit. 1 (2) (2000) 117–125. http://dx.doi.org/10.1016/S1296-2074(00)00158-8.
[21] J.L. Pederson, P.A. Petersen, J.L. Dierker, Gullying and erosion control at archaeological sites in Grand Canyon, Arizona, Earth Surf. Proc. Land. 31 (4) (2006) 507–525. http://dx.doi.org/10.1002/esp.1286.
[22] I.C. Nicu, Hydrogeomorphic risk analysis affecting Chalcolithic archaeological sites from Valea Oii (Bahlui) watershed, Northeastern Romania. An interdisciplinary approach, Springer International Publishing, AG Switzerland, 2016. http://dx.doi.org/10.1007/978-3-319-25709-9.
[23] I.C. Nicu, G. Romanescu, Effect of natural risk factors upon the evolution of Chalcolithic human settlements in Northeastern Romania (Valea Oii watershed). From ancient times dynamics to present day degradation, Z. Geomorphol. 60 (1) (2016) 1–9. http://dx.doi.org/10.1127/zfg/2015/0174.
[24] D. Balteanu, V. Chendes, M. Sima, P. Enciu, A country-wide spatial assessment of landslide susceptibility in Romania, Geomorphology 124 (2010) 102–112. http://dx.doi.org/10.1016/j.geomorph.2010.03.005.
[25] D. Mihaila, Studiu Climatic, Editura Universitatii Suceava, Suceava, Moldavian Plain, 2006.
[26] I. Ionita, Gully development in the Moldavian Plateau of Romania, Catena 68 (2–3), pp. 133–140. ⟨http://dx.doi.org/10.1016/j.catena.2006.04.008⟩.
[27] G. Schaffer, N. Levin, Reconstructing nineteenth century landscapes from historical maps – the Survey of Western Palestine as a case study, Landsc. Res. 41 (3) (2016) 360–379. http://dx.doi.org/10.1080/01426397.2015.1078454.
[28] C. San-Antonio-Gómez, C. Velilla, F. Manzano-Agugliaro, Urban and landscape changes through historical maps: the Real Sitio of Aranjuez (1775–2005), a case study, Comput. Environ. Urban 44 (2014) 47–58. http://dx.doi.org/10.1016/j.compenvurbsys.2013.12.001.
[29] P. Furlanetto, A. Bondesan, Geomorphological evolution of the plain between the Livenza and Piave Rivers in the sixteenth and seventeenth centuries inferred by historical maps analysis (Mainland of Venice, Northeastern Italy), J. Maps 11 (2) (2015) 261–266. http://dx.doi.org/10.1080/17445647.2014.947341.
[30] D. Haase, U. Walz, M. Neubert, M. Rosenberg, Changes to Central European landscapes – analysing historical maps to approach current environmental issues, examples from Saxony, Central Germany, Land Use Policy 24 (2007) 248–263. http://dx.doi.org/10.1016/j.landusepol.2005.09.003.
[31] A. Agapiou, V. Lysandrou, D.D. Alexakis, K. Themistocleous, B. Cuca, A. Argyriou, A. Sarris, D.G. Hadjimitis, Cultural heritage management and monitoring using remote sensing data and GIS: the case study of Paphos area, Cyprus, Comput. Environ. Urban 54 (2015) 230–239. http://dx.doi.org/10.1016/j.compenvurbsys.2015.09.003.
[32] C. Aas, A. Ladkin, J. Fletcher, Stakeholder collaboration and heritage management, Ann. Tour. Res. 32 (1) (2005) 28–48. http://dx.doi.org/10.1016/j.annals.2004.04.005.
[33] T.L. Saaty, The fundamentals of decision making and priority theory with the analytic hierarchy process, RWS Publications, Pitsburg, 2000.
[34] S. Zahir, Clusters in group: decision making in the vector space formulation of the analythic hierarchy process, Eur. J. Oper. Res. 112 (1999) 620–634. http://dx.doi.org/10.1016/S0377-2217(98)00021-6.
[35] L.Briguglio, W.GaleaUpdating and Augmenting the Economic Vulnerability Index, ⟨http://citeseerx.ist.psu.edu/viewdoc/download?⟩, http://dx.doi.org/10.1.1.538.6168 & rep=rep1 & type=pdf.
[36] G. Romanescu, I.C. Nicu, Risk maps for gully erosion processes affecting archaeological sites in Moldavia, Romania, Z. Geomorphol. 58 (4) (2014) 509–523. http://dx.doi.org/10.1127/0372-8854/2014/0133.
[37] G. Romanescu, V. Cotiuga, A. Asandulesei, C.C. Stoleriu, Use of the 3-D scanner in mapping and monitoring the dynamic degradation of soils: case study of the Cucuteni-Baiceni Gully on the Moldavian Plateau (Romania), Hydrol. Earth Syst. Sci. 16 (2012) 953–966. http://dx.doi.org/10.5194/hess-16-953-2012.
[38] V. Chirica, M.TanasachiRepertoriul Arheologic al Judetului Iasi, Iasi, 1984.
[39] P.I. Otiman, Romania's present agrarian structure: a great (and unsolved) social and economic problem of our country, Agricultural Economics and Rural Development, New Series 1, 2012, pp. 3–24.
[40] J. Díaz-Diego, The countryside in the Romania of the 21th century: relegated peasants between market productions, B. Asoc. de Geógr. Esp. 69, 2015, pp. 535–539.
[41] M.Petrescu-Dimbovita, Cucuteni, Editura Meridiane, Bucuresti, 1966.
[42] J. Zalasiewicz, M. Williams, W. Steffen, P. Crutzen, The new world of the anthropocene, Environ. Sci. Technol. 44 (7) (2010) 2228–2231. http://dx.doi.org/10.1021/es903118j.