Environ Earth Sci (2017)76:330
DOI 10.1007/s12665-017-6656-z

ORIGINAL ARTICLE

Tracking natural and anthropic risks from historical maps as a tool for cultural heritage assessment: a case study

Ionut Cristi Nicu[1,2]

Received: 20 April 2016 / Accepted: 22 April 2017

Abstract In this study, historical maps and orthophotos were used as a baseline to establish the vulnerability of cultural heritage (CH) sites to natural and anthropic elements as a tool for cultural heritage management in Valea Oii river basin (north-eastern Romania). Starting from the nineteenth century, a series of natural hazards begun to have a frequent occurrence and with a higher degree of destruction as a consequence of anthropic pressure—village extension, connecting the human settlements by a network of roads, and building ponds to save water resources. The main indicators used were derived from cartographic digitisation: landslides, gullies, villages, roads and ponds. GIS integration and mapping allowed the creation of maps with both natural and anthropic factors. Following the GIS analysis of CH sites located within a 50-m distance from the roads, landslides, and gullies, 5 m for ponds, and inside villages, results that the highest number of CH sites (26) was affected by the development of road networks in 2012, while in 1894 only a number of three sites were affected. The creation of vulnerability maps (divided into three classes: low, moderate and high) was undertaken by overlaying the cultural heritage data with the information collected from the historical maps; these maps will then provide a comprehensive database to help local stakeholders, policy makers and local authorities to adopt proper protection and mitigation measures.

Keywords Historical maps · Cultural heritage · GIS · Mitigation · North-eastern Romania

Assessing Human Vulnerability due to Environmental Change: Concepts, Issues, Methods and Case studies, UNEP/DEWA/TR, Nairobi

✉ Ionut Cristi Nicu
nicucristi@gmail.com

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

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

Introduction

Monitoring landscape changes and evolution from historical maps is widely used in different disciplines, such as geomorphology (Furlanetto and Bondesan 2015), hydrology (Zanoni et al. 2008), archaeology (Schuppert and Dix 2009; Rondelli et al. 2013), environmental and landscape changes (Haase et al. 2007; Patru-Stupariu et al. 2011; Sâvulescu and Mihai 2011); historical maps contain significant data regarding the historical characteristics of the landscape- and human-induced activities. This information can help us in the analysis of past changes to understand and predict future dynamics of the landscape. Despite the fact that the historical maps have a widespread applicability and usage, there are no studies regarding the approach towards CH assessment. A diachronic analysis was made to highlight how the changes in the landscape have affected the integrity of CH. With the help of modern techniques (GIS) (López-Vicente and Navas 2009), the assessment (Szlafsztein and Sterr 2007) and management of CH has become easier with more efforts being made in order to save the world's CH and keep a legacy for future generations (Martínez-Graña et al. 2011; Hadjimitsis et al. 2013; Agapiou et al. 2015, 2016). For this, historical maps and orthophotos were used as a baseline to establish the vulnerability of CH sites to natural and anthropic elements.

Published online: 28 April 2017

The 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 (Glossary of Environment Statistics 1997). UNEP's GEO Vulnerability Working Group defines vulnerability as "the exposure to hazard by external activity and coping capacity of the people to reduce the risk at a particular point in time" (UNEP 2000). Assessing the vulnerability is not an easy task and is not yet established by a certain formula or method (Cutter et al. 2003); it is conditioned by the factors that are being analysed. In our case, the vulnerability index is a tool for identifying and prioritising the natural and anthropic elements in the assessment of CH sites. The vulnerability comprises the exposed vulnerable elements and the vulnerability factors. The vulnerable element is in this case CH sites; their vulnerability varies according to the vulnerability factors: natural and anthropic, in this case, gullies and landslides, road network, village extension and ponds, respectively.

Identifying areas with high vulnerability (Cutter 1996) that are affecting the cultural heritage integrity will lead to a better understanding, mitigation, and management for the government, local authorities and stakeholders (Aas et al. 2005); this approach can be extended to other cultural heritage sites from other areas, helping in the planning of economic activities in order to minimise the damages costs, and the most important aspect, CH protection and assessment. The importance (Ghilardi et al. 2008) of integrating a geographical database (connected to the mapping and conversion of the in situ data in digital format, undertaking spatial analysis, 3D visualisation) (Martínez-Graña et al. 2014, 2016), with an archaeological one (placement of sites) within a GIS environment is well known. Connecting different components of the natural and anthropic environment, from geography and archaeology, from a public sector to a private sector, can help in having a better assessment (Del Río and Gracia 2009) of the CH.

A significant role in the development (rural development, infrastructure) of the country had the Land Laws from 1864, 1877, 1881, 1918-1921, 1945 (also known as "The Communist Reform"), and Law no. 18/1991. During the nineteenth century, the property structure of the Romanian agriculture changed due to the capitalist development of the society. Two political trends were opposed in that period: the French model supported by the liberals led by M. Kogălniceanu and the German model backed by the conservative B. Catargiu. The Law of agricultural reform issued in 1864 promoted the French model. After the World War I, the fragmentation of the land property entered a new phase, on a larger scale, with the Agricultural Reform of 1921. By the end of 1945, the great land properties had completely disappeared. The latest agricultural reform brought a new fragmentation of the land property in 1990 with disastrous outputs, the development of Romanian Agriculture being almost impossible (Vorovenci 2003).

The north-eastern part of Romania (Moldavian Plateau) is well known for its degraded lands, where soil erosion processes (Băcăuanu 1967, 1980; Moţoc 1983) and floods (Romanescu et al. (2011); Romanescu and Stoleriu 2014) were and still are an actual problem. Landslides (Bălteanu et al. 2010; Ioniță et al. 2014; Nicu 2016) and gully erosion (Ioniță 2006; Romanescu et al. 2012; Romanescu and Nicu 2014; Ioniță et al. 2015) will be assessed, as being one of the most popular natural hazards in this area.

The study area is highly representative for studies regarding the analysis of natural hazards and anthropic interventions in the attempt of saving as many data of the geographical and archaeological character, the mitigation and assessment of cultural heritage. Among the CH sites from the study, the site from Cucuteni-*Cetățuia* (no. 20) represents the discovery place of Cucuteni culture, one of the most representative prehistoric cultures of Eastern Europe. In Romania, like many other countries with a transitioning economy, the assessment and protection of cultural heritage is a real challenge; this comes as a consequence of an incomplete archaeological inventory. The primary databases available are the National Archaeological Registry (RAN), the Institute of Cultural Memory (CIMEC) and the National Heritage Institute (INP) (Oberländer-Târnoveanu 2014). The cultural heritage of the study area summarises a number of 47 CH sites; this comprises Neolithic archaeological sites of European significance (e.g. the archaeological site from Cucuteni—*Cetățuie*, the eponymous site of the Cucuteni culture), sites dating from Geto-Dacian period (4–2nd centuries, 3–2nd centuries and a necropolis), late Bronze Age (Noua culture), late Iron Age (la Tène culture), one palaeontological reservation (with early Bessarabian fauna), wooden vernacular architectural structures from sixteenth century, and churches from eighteenth to nineteenth centuries. Out of these (Table 1), eleven are in the List of Historical Monuments (LMI) and nine are in the National Archaeological Registry (RAN); they are considered of having an important historical and archaeological importance. The Cucuteni culture is known as the last great Eneolithic civilisation of Old Europe, part of Cucuteni-Trypillia Cultural Complex (Lazarovici et al. 2009).

Study area

Valea Oii river basin is located in the north-eastern part of Romania, Iași County, at the contact area between Moldavian Plain and Suceava Plateau, between 47°21′0.86″ N and 47°13′23.32″ N latitude and 26°49′37.07″ E

Table 1 List of CH sites from the study area

Site no.	Site name	Location (WGS84 coordinates)		Period/culture	Processes affecting the site
		N	E		
1	Dealul Mândra/la Iaz/Iazul 3* #	47°14′43″	27°08′7″	Chalcolithic/Cucuteni A_{3b}, late Bronze Age/Noua culture	Flooding, sedimentation, anthropic
2	Movila Hârtopeanu	47°14′7″	27°07′27″	Chalcolithic/Cucuteni unknown	Landslide, anthropic
3	Tarlaua Pădurii/Crescătorie 1	47°15′1″	27°03′47″	Chalcolithic/Cucuteni A_3	Landslide
4	Dealul Oilor/Crescătorie 2	47°14′51″	27°03′35″	Chalcolithic/Cucuteni unknown	Landslide
5	Dealul Mare Filiași/Dealul Boghiu#	47°15′8″	27°02′27″	Chalcolithic/Cucuteni A_3	Landslide, gully erosion, anthropic
6	SV de Boghiu	47°14′58″	27°01′57″	Chalcolithic/Cucuteni A	Landslide, anthropic
7	Dealul Harbuzăriei/V de Dealul Boghiu	47°15′14″	27°01′32″	Chalcolithic/Cucuteni unknown	Landslide, anthropic
8	Bejeneasa	47°16′4″	27°00′56″	Chalcolithic/Precucuteni, Cucuteni A, 3–4th centuries	Landslide, gully erosion, anthropic
9	Dealul Hârtopului	47°15′58″	27°00′5″	Chalcolithic/Cucuteni A-B, B	Landslide, anthropic
10	Hârtochi/Dealul Hârtop	47°15′44″	26°59′31″	Chalcolithic/Cucuteni unknown	Gully erosion, anthropic
11	Bejeneasa I/la Brigadă	47°17′15″	26°58′45″	Chalcolithic/Precucuteni II-III, Starčevo-Criș, Bronze Age/late Hallstatt	Anthropic
12	Mamelon	47°17′5″	26°58′10″	Chalcolithic/Cucuteni unknown	Anthropic
13	Ismiceanu	47°14′7″	27°03′47″	Chalcolithic/Cucuteni unknown	Anthropic
14	Târla Luncanului	47°17′15″	26°56′50″	Chalcolithic/Cucuteni A	Anthropic
15	Valea Părului III	47°17′52″	26°57′47″	Chalcolithic/Precucuteni II-III	Anthropic
16	Dealul Mănăstirii/la Dobrin/Dealul Gosanul	47°14′20″	26°55′20″	Chalcolithic/Cucuteni A_3	Gully erosion, small landslide, anthropic
17	Dâmbu Morii* #	47°14′45″	26°56′10″	Chalcolithic/Cucuteni A_2, A-B_1, A-B_2	Landslide, anthropic
18	La Bazin/fost Gostat	47°14′55″	26°56′0″	Chalcolithic/Cucuteni B, late Bronze Age/Noua I culture, 4th, 10th centuries	Landslide, anthropic
19	Lângă Pod	47°14′7″	27°03′47″	Chalcolithic/Precucuteni, late Bronze Age/Noua I culture	Landslide, anthropic
20	Cetățuia* #	47°17′55″	26°54′50″	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, anthropic
21	Hurez	47°18′0″	26°54′55″	Chalcolithic/Cucuteni A, 4–3rd century	Anthropic
22	Dâmbul lui Pletosu* #	47°18′10″	26°55′20″	Chalcolithic/Cucuteni A, 1–2nd, 4th, 9–10th, 16–17th centuries	Anthropic
23	Siliște* #	47°18′10″	26°55′35″	Chalcolithic/Cucuteni unknown, Roman Period/2–3rd, Early Mediaeval Period/8–10th, Mediaeval Period/14–17th centuries	Anthropic
24	VSV de vatra satului	47°18′17″	26°54′40″	Chalcolithic/Cucuteni unknown	Anthropic
25	Bârghici	47°19′26″	26°53′15″	Chalcolithic/Cucuteni unknown	Gully erosion, anthropic
26	Pietrărie	47°19′19″	26°54′13″	Chalcolithic/Cucuteni A, B	Anthropic
27	Sârca church	47°13′49″	27°10′40″	19th century	–
28	Valea Oilor church	47°14′36″	27°05′47″	20th century	–

Table 1 continued

Site no.	Site name	Location (WGS84 coordinates)		Period/culture	Processes affecting the site
29	La N de sat	47°15′36″	27°05′36″	Late Bronze Age/Noua culture	Anthropic
30	Dealul Vântului	47°15′30″	27°02′40″	Chalcolithic/Starčevo-Criş	Anthropic
31	Boureni church	47°14′7″	27°03′47″	20th century	–
32	Bejeneasa II	47°16′50″	26°59′31″	3–4th centuries	Anthropic
33	Balş church	47°17′38″	26°58′39″	20th century	–
34	Valea Părului II*	47°17′47″	26°57′54″	Chalcolithic/Starčevo-Criş	Anthropic
35	Valea Părului IV	47°17′60″	25°57′28″	3–4th centuries	Anthropic
36	Coasta Nucului II	47°17′32″	26°56′43″	Dacian	Landslide, anthropic
37	În Hotar	47°17′37″	26°56′20″	18th century	Rill, inter-rill, gully erosion
38	Coasta Nucului	47°17′27″	26°56′3″	Late Bronze Age/Noua culture	Anthropic
39	Gosan Pietrărie	47°17′25″	26°55′52″	3–2nd centuries, Geto-Dacian	Landslide
40	Mlada* #	47°17′16″	26°55′28″	Geto-dacian, 4–3rd, 3–1st centuries	Gully erosion
41	Laiu II	47°17′53″	26°54′34″	Late Neolithic/Horodiştea-Erbiceni culture, 4th century	Anthropic
42	Băiceni wooden church (Sf. Treime—Holy Trinity)*	47°18′28″	26°54′53″	19th century (1808)	–
43	Grădina lui Pascal* #	47°18′38″	26°55′27″	9–10th, 17–18th centuries, Early Mediaeval Period	Landslide, anthropic
44	Stroeşti church (Sf. Voievozi—Holy Kings)*	47°19′34″	26°52′51″	16th century (1500–1550)	–
45	Băiceni Palaeontological Reservation	47°17′52″	26°54′48″	Early Bessarabian fauna	Gully erosion
46	La Pietrărie	47°17′15″	26°55′47″	4th century, Geto-Dacian necropolis (tumuli)	–
47	Bogdăneasa* #	47°29′00″	26°92′00″	Late Iron Age/la Tène culture	Landslide, anthropic

* Listed in LMI (List of Historical Monuments)

Listed in RAN (National Archaeological Registry)

and 27°10′35.68″ E longitude (Fig. 1). The surface of the basin is 97 km^2. Maximum and minimum elevations are 443.19 m and 61.57 m a.s.l., respectively. Lithologically, the Bassarabian deposits of Sarmatian age dominate the basin (Fig. 2) (Ştefan 1989), and in the lower half Pleistocene terrace deposits have been encountered. Moldavian Plain has a sculptural origin, and the general pitch of the strata is from NW to SE. Hydrology has a very significant role in shaping the landscape, modelling began with the successive withdrawal of Sarmatic Sea, being in a continuous evolution even today. Precipitations range between 500 and 700 mm/year. The area represents an old habitation place dating back to Neolithic time until present (Romanescu and Nicu 2014; Nicu 2016; Nicu and Romanescu 2016).

Methodology

Landscape dynamics and changes in the study area focus on detailed mapping of different features, including natural and anthropic factors which allowed a digital representation from conducting field research and gathering information from historical maps. All the data were integrated into a GIS (ArcGIS), which is useful for both geographers and archaeologists. The existing cartographic background was georeferenced in Romania's official projection Stereo 70 (Datum DEALUL PISCULUI 1970), which is a cartographic system based on the same mathematic principles established and applied by the old projection system from 1930. However, this projection system is being known to distort radial lengths but retains

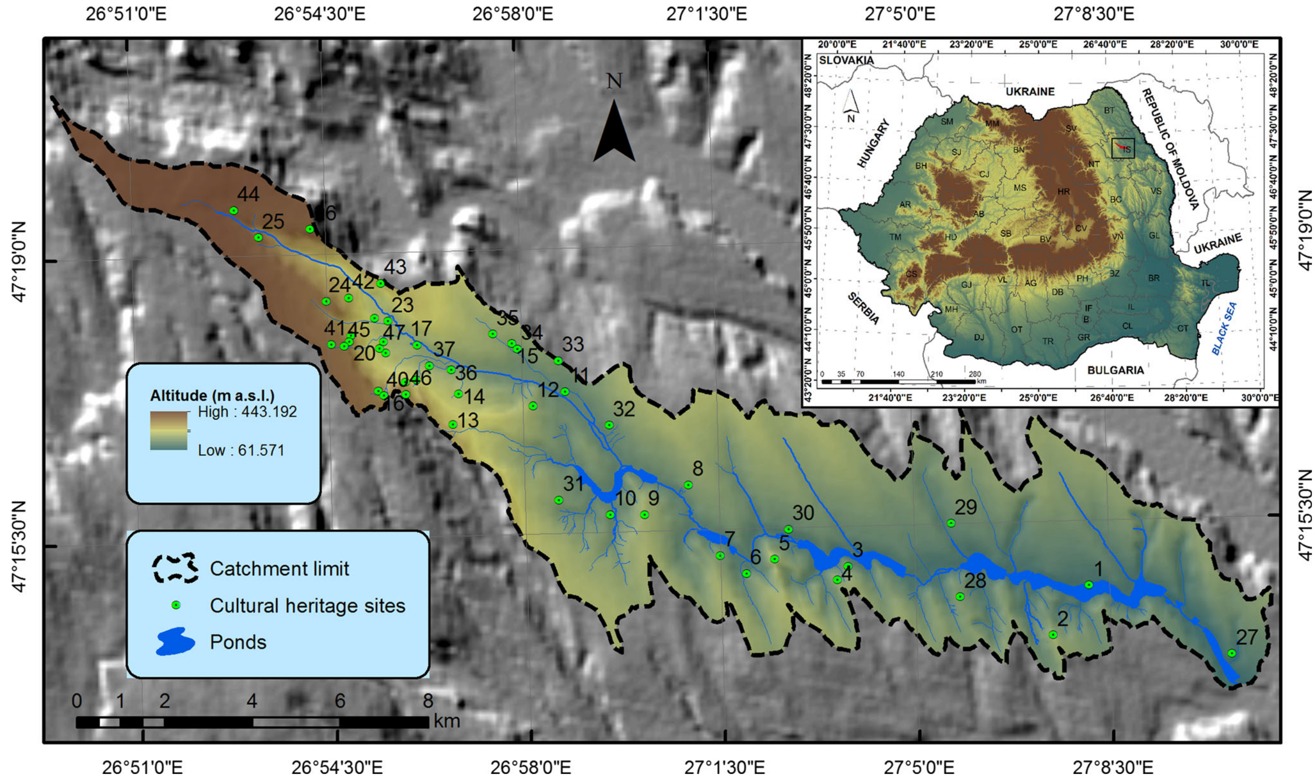
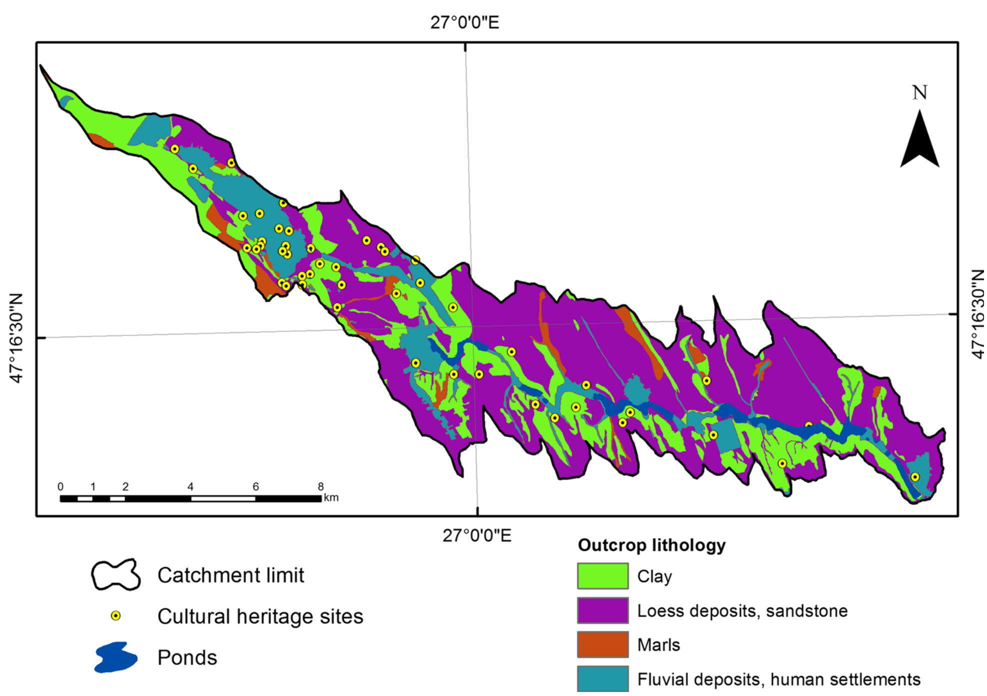


Fig. 1 Location of study area in Eastern European context and in Romania

Fig. 2 Outcrop lithology of the study area and the location of CH sites



the values of the angles (Mihăilă et al. 1995). Six historical references were used, covering a timespan of 118 years, from 1894 till 2012 (Table 2) (Fig. 3). The information utilised in the study (landslides, gullies, roads, villages, ponds) has a good representation on the historical maps and modern orthophotos; the elements from each map were digitised and analysed.

The buffer analysis was created as follows: for road network (a 50-m buffer around the roads), villages (if any of the sites are inside the village limits), ponds (a 5-m

Table 2 Map series used in the study

Map series	Scale	Year	Details
Topographic map	1:50,000	1894	The map was published by the Army Geographic Institute and made on the basis of the military topographic surveys, also known as "the first Romanian geodetic concept" (Fig. 3a)
Soviet maps	1:50,000	1942	The maps were part of an ambitious, top secret project of the Soviet Union to map the entire surface of the earth; until the collapse of the Soviet Union, the entire earth's surface was mapped in detail, at different scales (Fig. 3b)
Historical army maps	1:20,000	1958	The maps were initially realised in Lambert projection system; they were known under the name "Shooting Plans", at 1:20,000 scale, with a total of 2118 sheets covering the entire territory of Romania. The maps were not the result of new surveys; they were from previous sources (Romanian, Austrian, Russian); beginning with 1924 a significant part of the data from these maps have been updated on the basis of orthophotos (Fig. 3c)
Romanian topographic map	1:25,000	1984	Projection system Stereo 70 (Fig. 3d)
Orthophotos	1:5000	2005	The orthophotos were taken during May–September 2003–2005, with analogical and digital photograph cameras on the direction east–west, resolution 50 cm, spectral band RGB, precision ±1.5 m, projection system Stereo 70 (Fig. 3e)
Orthophotos	1:5000	2012	The orthophotos were taken during May–September 2010–2012 (Fig. 3f)

buffer around the ponds, because there is a very low probability of flooding within the catchment and a low density of drainage network of 1.3 km/km^2, Pantazică 1974), landslides (a 50-m buffer around the landslide, as scarps and toes of landslides, represent risk areas), and gullies (a 50-m buffer around the gullies, as they have an alarming rate of head retreat and though a significant amount of sediment in the deposition area) (Fig. 4). The buffer distances represent hot-spot areas, which should not be modified without making an archaeological evaluation of the site.

In order to highlight the anthropic pressure on CH sites, a density analysis was employed for the road network, a 5-m buffer for the ponds and the extension of villages. This tool was chosen to point out the areas with the highest anthropic pressure from 1894 until 2012. The final vulnerability maps were generated using GIS technical into three vulnerability classes (1—low, 2—medium, 3—high). For each raster, a value has been assigned in the final equation (Eq. 1) of vulnerability index (Vi), according to the results from Fig. 5 (inside the highest density of roads is the highest number of CH sites; therefore, this element will have the highest value in the equation; the same was done in descending order with all the factors), expert judgement and a very good knowledge of the area, as follows road network (RN) (40%), village extension (VE) (20%), ponds (PO) (5%), landslides (LD) (25%), gullies (GL) (10%). The final Vi has been calculated with the help of GIS as a sum of all the weights of each elements taking into consideration:

$$\mathrm{Vi} = \mathrm{RN} \times 40 + \mathrm{VE} \times 20 + PO \times 5 + LD \times 25 + GL \times 10 \quad (1)$$

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 risks—natural and anthropic); 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 Programme; it was used for the first time in the economy (Briguglio and Galea). This index has been rather used over the last two years in different research areas belonging to geosciences, such as hydrology (Zachos et al. 2016), climatology (Zanetti et al. 2016) and social geography (Mazumdar and Paul 2016).

Results

The approach used allowed to create maps with the natural processes and anthropic interventions, to analyse both of the elements (natural and anthropic), and to identify the most vulnerable areas that affect the CH sites. The Vi values for each class are: low (0–1), medium (1–1.3), high (1.3–2.1).

Anthropic elements analysis

Road network

Determining the importance of each site by undertaking assessments is of high importance; assessing and recommending protective and preventive measures for the conservation of the remains should be made before the road construction be undertaken to avoid any cuts through

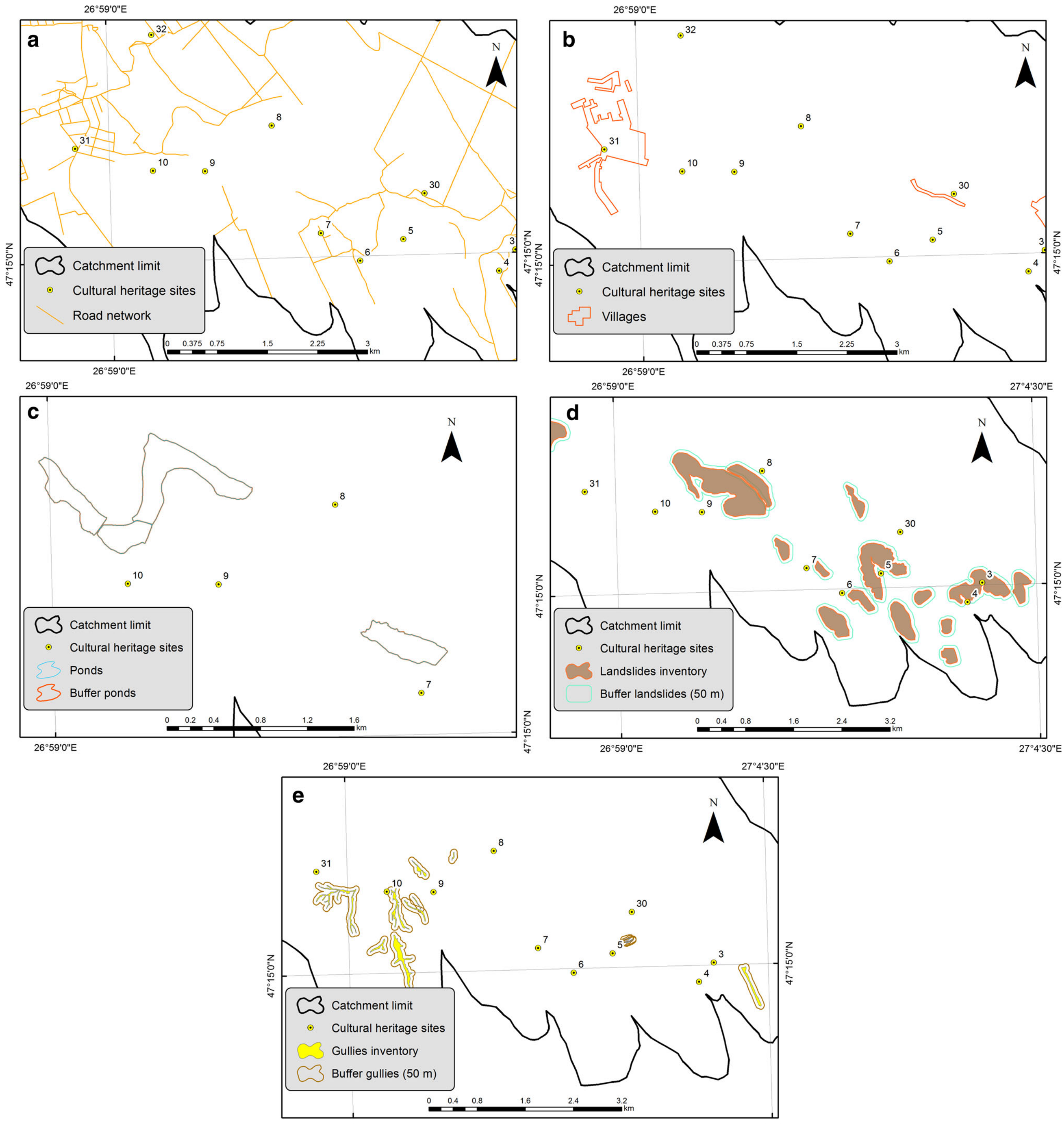


Fig. 3 Map series used in the study. **a**. Topographic map, scale 1:50,000, edition 1894; **b**. Soviet map, scale 1:50,000, edition 1942; **c**. Historical army maps, scale 1:20,000, edition 1958; **d**. Romanian Topographic map, scale 1:25000, edition 1984; **e**. Orthophotos, scale 1:5000, edition 2005; **f**. Orthophotos, scale 1:5000, edition 2012

known CH sites. If a site is uncovered during road works, a re-routing of the road should be considered with minimum costs. Another solution would be to leave a CH site buried beneath the road, with the raising the level of the road. As shown in Fig. 5, of the anthropic elements, the network of roads (50-m buffer) has been identified as one affecting the most CH sites, from a number of three sites in 1894 to 26 sites in 2012; the evolution of road network density is directly proportional (0.67 km/km^2 in 1894, 0.76 km/km^2 in 1984, and 2.64 km/km^2 in 2012) with the villages extension (213.15 ha in 1894, 361.29 ha in 1984, and 795.09 ha in 2012).

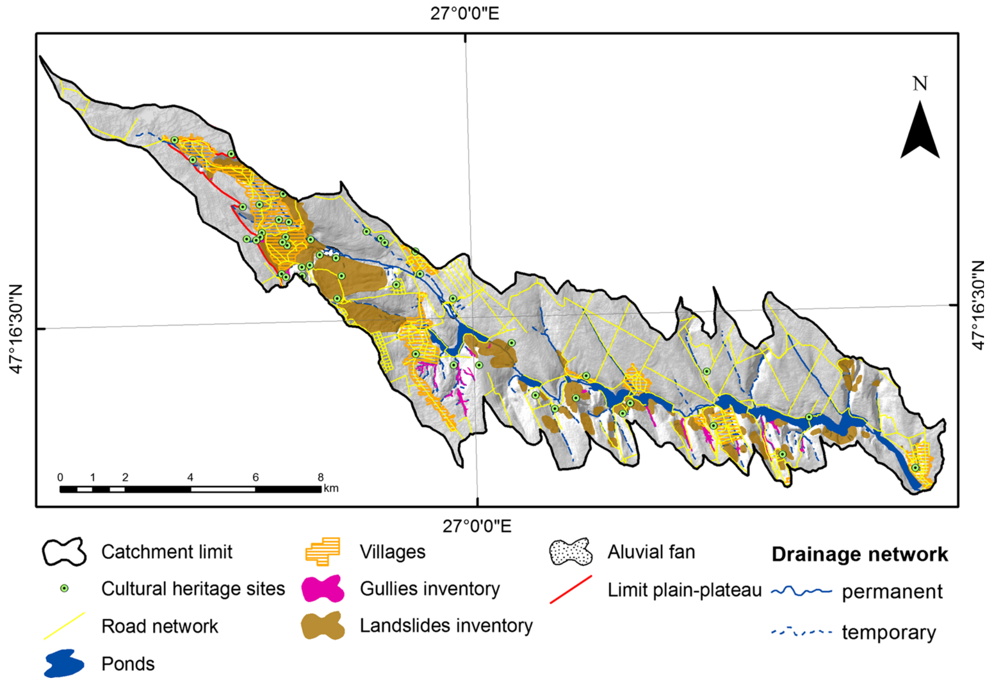


Fig. 4 General map indicating the main information used in the study

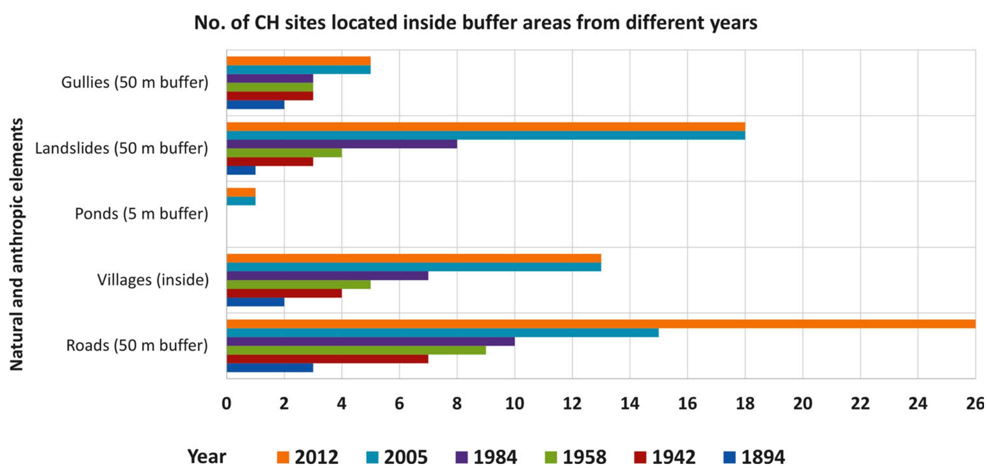


Fig. 5 Number of CH sites located inside buffer areas from different years

Village extension

As shown above, the surface covered by villages increased in 118 years by almost four times. Human settlements, mainly villages, have a long-lasting tradition and existence: Cucuteni village was mentioned in documents dating back to the 5 October 1448, Băiceni (Băiceni de Baia—old name) from 25 August 1454, and Bălțați village (Gugea—old name) in documents from 1473 (Chirica and Tanasachi 1984). With the development of human settlements, the anthropic pressure (deforestations, Land Laws from 1828, 1842, 1864, 1877, 1881, and 1921) started to modify the landscape characteristics; of a high impact was the Land Fund Law No. 18/1991, when the agricultural land was fragmented into small properties, oriented on the hill-valley direction (Romanescu and Nicu 2014). Another effect of human settlements development was the increasing density of the infrastructure (road construction) needed to connect the settlements, and a modern necessity in an increasing mobilised society. The present situation of the rural area in Romania is the result of political, juridical, economic and social events and actions during the twentieth century, as well as the effects of the present agricultural policy after 1989; there is also a good correlation between agricultural areas and severe poverty (Otiman 2012).

Ponds

The construction of the ponds (5 m buffer) hardly affected the integrity of CH sites, with one single site, both in 2005 and in 2012, in the unlikely possibility of a flood. The presence of ponds in the north-eastern part of Romania was recorded in several old cartographic documents, the oldest dating back from 1600, entitled "*Fishing and fish farming in Romanian regions during the upper feudalism—1600*", the map of Moldova (Bawr) surveyed between 1768 and 1774 (scale 1:308,000). Lake basins morpho-hydrographical evolution in Moldova, starting with the fifteenth century, is attributed to the economic development of the country during seventeenth–nineteenth centuries, and a continuous increase in population numbers (Băican 1970). Initially, ponds were used for animal consumption (sheep), rarely for irrigation (Minea 2005). Overall, the tendency was to reduce the number of ponds and increase their surface, to mitigate the negative effects of floods; presently, there are a number of ten ponds, with a very low possibility of a flood taking place in the area (Nicu and Romanescu 2016).

Natural elements analysis

Landslides

Among the natural elements affecting CH, landslides (50-m buffer) are the most dangerous, with an increasing trend, one site being affected in 1894, while in 2012 a number of 18 sites being within the 50-m buffer area. The total area of landslides had an alarming increase, from 215 ha (2.2% of the total area of the basin) in 1894 to 944.5 ha (9.7% of the total area) in 2012. Landslides are the most common natural hazard in the north-eastern part of Romania (Moldavian Plateau), with a total of 24,263 landslides, with a total area of 4534.7 km^2, corresponding to a landslide density of 1.02 landslides per km^2. The landslides are classified in very old landslides (Upper Pleistocene—6550 BP), old landslides (not earlier than 6550 BP), and more recent landslides (last centuries) (Niculiță et al. 2016).

Likewise, a starting point of this work are the mentions of the erosional processes found in archaeological works. "*Cele mai frecvente forme de eroziune torențială, în diferite stadii de evoluție, se întâlnesc către periferia Câmpiei Moldovei, în zona localitătilor Tomești, Voinești,… și pe versantii cu caracter de coastă ai Jijiei, Bahluiului, Bahluiețului, Miletinului, Sitnei, Bașăului, Văii Oilor,* etc." (Băcăuanu 1967)—"*The most frequent forms of torrential erosion, in various states of evolution, can be found towards the periphery of the Moldavian Plain, around the settlements of Tomești, Voinești, … and on the versants front of cuesta character of the Jijia, Bahluieț, Miletin, Sitna, Bașău, Oii valley*, etc." Referring to the site of *Dealul Mănăstirii/la Dobrin/Dealul Gosanul* (no. 16) Chirica and Tanasachi, 1984, p. 107 mention that "the ESE part is being destroyed by landslides", while in the case of the settlement from *Coasta Nucului II* (no. 36) it is stated that it is located in "an area affected by landslides". According to the classification of Hungr et al. (2014), the typology of landslides is translational, rotational slides, and slide-earthflow.

Mitigation works have been undertaken in the north-western part of the Oilor Hill (site no. 4), where stone gabions were erected for stopping the advancement of the landslide colluvium on the road linking the Podișu village with the city of Târgu Frumos, and into the Podișu pond. Other than the permanent destruction of irrecuperable evidence and the damage incurred by archaeological vestiges, the advancement of the colluvium also puts into motion other archaeological remains (ceramic shards, stone tools, flint), exposing and transporting them to the base of the slopes and depreciating much of their scientific value. Monitoring regarding the degradation by natural risk phenomena and geophysical prospection, to establish the precise extent of the settlement were made for site Dealul Mare Filiași/Dealul Boghiu (no. 5) (Asăndulesei et al. 2015).

Gullies

Gullies are the other natural element that has a fast evolution and a negative impact on the landscape and CH. Around Europe, the number of natural hazards, especially gullying from small catchments, was triggered in the course of the global climatic changes (Zalasiewics et al. 2010), and a fast dynamic regarding the land use with high peaks for the first half of the fourteenth, and from mid-eighteenth to the early nineteenth centuries (Dotterweich 2008). Soil erosion, in particular rill erosion and gullying, is a huge problem for agricultural and non-agricultural lands in the Moldavian Plain in Northeast Romania. Several studies highlighted the immense gully erosion potential (Ioniță 2000, 2006; Ioniță et al. 2015), the geomorphic, climatic and anthropic driving factors of gullying (Rădoane et al. 1995) being analysed. Within the study area, starting with 1894, a number of two gullies were inside the 50-m buffer area, while in 2012, a number of five gullies were in these high potential erosion areas; gully erosion does not have a large development within the basin, the total area of gullying in 1984 was 37.2 ha, and in 2012 of 42.4 ha. Gullying does not have an adverse impact on a high number of sites, but as it was shown by Romanescu and Nicu (2014), Nicu (2016), Nicu and Romanescu (2016), when the process is triggered, the gully erosion rate is very high, and the sites are in a real risk of degradation (sites no. 16 and 20). Bibliographic sources indicate the emergence and developing of linear erosion on the background of geological characteristics: "*Un tip aparte de eroziune liniară se întâlnește pe versanții care au deschise la zi orizonturi de marne sarmațiene cu un grad mai ridicat*

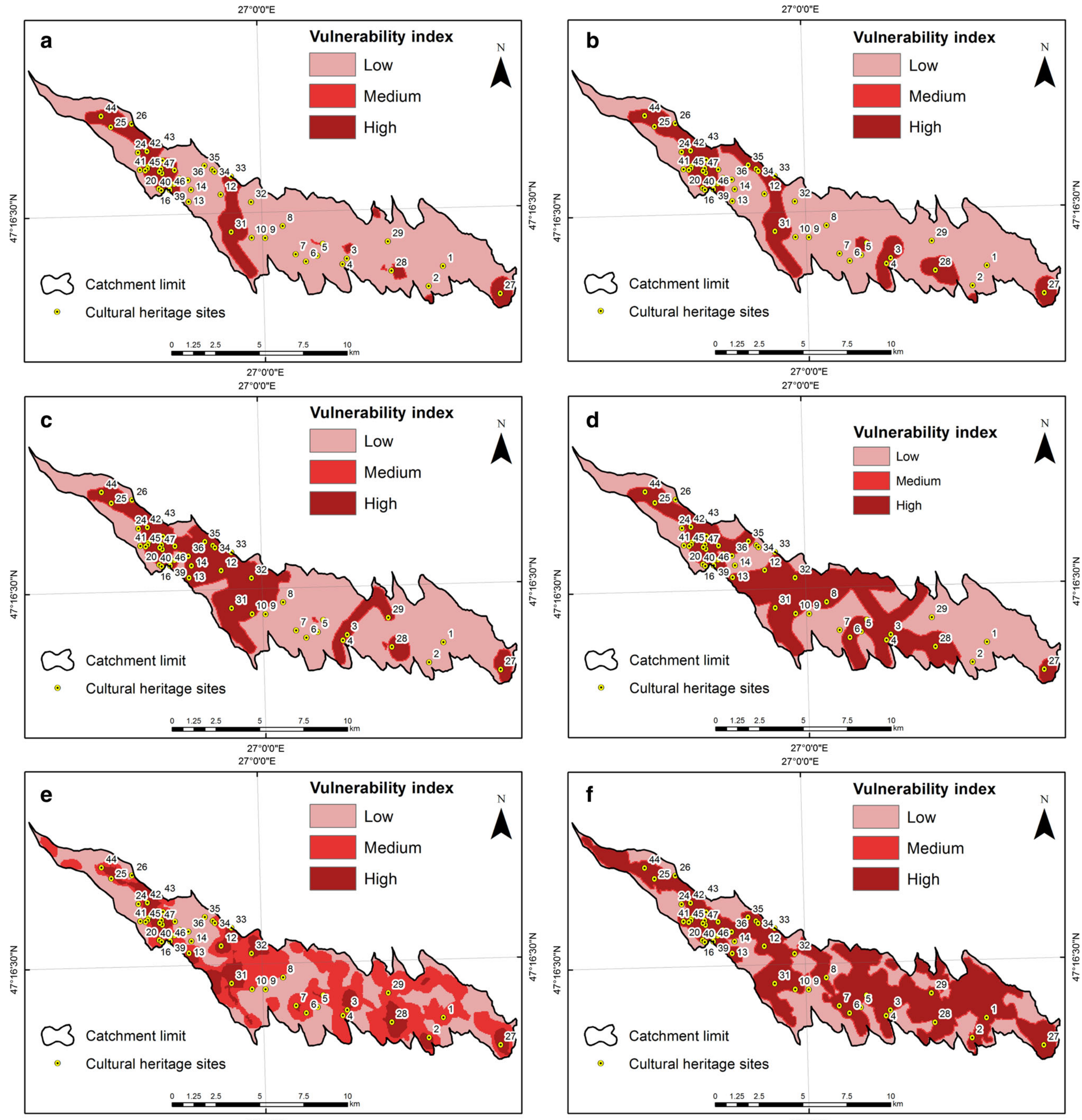


Fig. 6 Final vulnerability maps. **a**. Vulnerability map for year 1894; **b**. Vulnerability map for year 1942; **c**. Vulnerability map for year 1958; **d**. Vulnerability map for year 1984; **e**. Vulnerability map for year 2005; **f**. Vulnerability map for year 2012

de salinizare. La Dumești-Iași… pe versantul sudic al Văii Oilor…" (Băcăuanu 1967)—"*A particular type of linear erosion is found on the slopes that have opened horizons of Sarmatian marls with higher degrees of salinization. At Dumești-Iași,…, on the southern part of the Oii valley…*". As it can be seen from the mentions by geomorphologists as early as the 1950s, the intensity of the gullying was increasing, and its causes were sought through case studies.

Vulnerability index (Vi)

In the following, each period will be analysed according to the final Vi maps.

Before 1894—there were a number of 20 CH sites located in areas with a high Vi (Fig. 6a), two in areas with a medium value of Vi and 25 with a low Vi. Areas with high Vi are located in the middle and upper catchment, in the

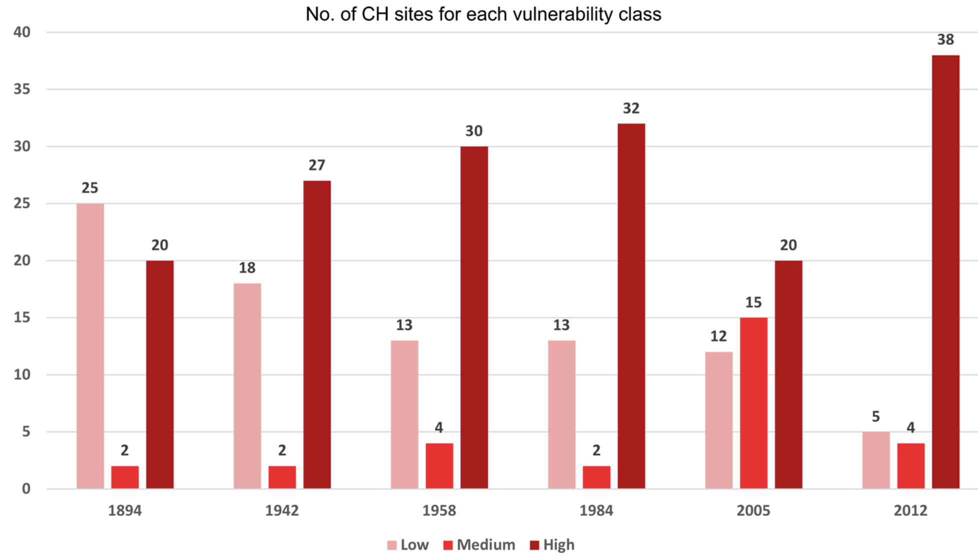


Fig. 7 Classification of CH sites according to vulnerability index for each year

areas of Stroiești, Băiceni, and Boureni villages, where the majority of CH sites is located, although the forested area within the catchment in 1894 was 425.75 ha, unlike 197.67 ha in 2005 (Nicu 2016). The Land Law from 1881 was based on the real estate foreclosure, there was no real preparation or directions in the relocation of people and their lands, and therefore a disorganised land management began.

1894–1942—the Interbelic period with 27 CH sites being located in areas with a high Vi, two in areas with a medium value of VI, 18 CH sites located in areas with a low Vi (Fig. 6b). Unlike the previous period, the Land Law of 1912 and 1938 had a better applicability, with the agricultural land being more compact, and the lack of road network played a major role. As a consequence of the Land Law of 1912 and 1921, the total surface of the arable land of the country has grown from 6.6 mil. ha to 14.6 mil. ha, therefore the increasing number of CH sites located in areas with a high Vi. The agrarian reform from 1918 to 1921 was the most important from the Romania and Europe's history, due to the vast surfaces needed to be expropriated (Romanian Senat 2004).

1942–1958—following the period after the Second World War, the situation of the country was disastrous; this was also reflected in the chaotic development after the war period; a number of 30 CH sites were located in areas with high Vi, while 13 sites in areas with a low Vi (Fig. 6c). The area with the highest vulnerability is found in the upper-middle part of the catchment, which has a better connectivity between the Boureni, Balș, Cucuteni, Băiceni and Stroiești villages. In this period, the arable land was mostly concentrated around the villages.

1958–1984—this period coincides with the Communist era (1965–1989), as agriculture was one of the main branches of economy. During this time, Romania was the largest producer of grain in Eastern Europe. The sustainability of the economy was helped by the large agricultural areas of the southern part of the country; the number of CH sites located in areas with a high Vi is increasing to 32, while 13 sites located in areas with a low Vi (Fig. 6d) are due to the continuous development of rural settlements in the lower-middle part of the catchment.

1984–2005—is characterised by an increasing tendency on village's surface, along with an increase in road density to better connect the villages; a consequence of this caused the fragmentation of agricultural lands of the Land Law no. 18/1991 (Nicu and Romanescu 2016). The increasing density of the road network (from 0.67 km/km^2 in 1894–2.11 km/km^2) led to the development of natural hazards (gully erosion and landslides), 20 sites being located in areas with a high Vi and 15 in areas with a medium Vi (Fig. 6e). Now all the areas with a high Vi are spread on the entire surface of the catchment, being surrounded by areas with medium Vi. The need to connect villages and agricultural lands started to have a higher impact on CH sites, which can be observed over the next period of seven years.

2005–2012—during this period the areas with a high Vi have reached an alarming level (about 80% of the total surface of the catchment) with a number of 38 CH sites located within these areas (Fig. 6f), which are uniformly spread inside the watershed. With the continuous increase in village surface (795.09 ha), road network density (2.64 km/km^2), the anthropic pressure on the landscape and CH sites are growing.

Overall, there is a predisposition that is observed in Fig. 7; a gradually increasing number of CH sites located in areas with a high Vi, according to a multitude of factors: the expansion of villages surface, the political situation of the country, land laws from different years, which had a direct or indirect impact on the triggering and development of natural hazards. Some periods are characterised by a high impact on CH sites, years 1894, 1958 and 2012 being the most representative.

Discussion

There is a strong relationship between anthropic hazards and the role that humans play in; being strongly interconnected, there should have been more efforts done to mitigate the anthropic pressure on the landscape, not only enhancing potential disasters but also how, through education, can help minimise future environmental changes. In the past, the study area represented the place of transition of different populations (Romanian populations from Muntenia, Transylvania, Bukovina, Saxon, Chango, Gypsy, Lipovans and pastoral) coming from the mountain and sub-mountain areas to the plain area, rich in natural resources (fertile soils suitable for agriculture) and an intense habitation since the prehistoric times; the area is known in the literature as ≪Poarta Târgului Frumos≫/≪Târgul Frumos Crossing Point≫). This extended transitional period has left its mark in local toponymy. Gypsy villages: Ruginoasa, Heleşteni, Miclăuşeni. Traces of Saxon origin Hărmăneşti – prefix Hărman = German equivalent of Hermann (Tufescu 1941). Of particular importance remains the pastoral origin, from which toponym *oaia* (sheep) remained, which gave the name of the village Valea Oilor (Sheep Valley) within the catchment, as well as the name of the main river, sheep breeding is the primary occupation in present times. The current layout of the villages is an important legacy from the feudal period (Iurea 2011). The expansion of inhabited areas has been identified, as for Cyprus, as one of the highest susceptible factors with a direct impact on CH sites (Agapiou et al. 2015). Assessing the vulnerability for CH sites (burial mounds) in Bulgaria (Eftimoski et al. 2017) has shown the fact that urbanisation/de-urbanisation has a significant role in their degradation. In what concerns the existing or future management programmes to reduce the effect of natural and anthropic elements on CH sites, there is a management plan to diminish and stop the effects of gully erosion for the sites no. 16 and 40 (Baiceni torrent) and the site no. 20 (Cetatuia torrent). Concrete thresholds were built on the main thalweg of the torrents, and Black Locust saplings were planted on the gully upstream plateau.

Before the construction of a road, an initial assessment is needed, which should include a public consultation or knowledge of prior archaeological or CH sites and also finds within the region; further on, if the information acquired is not enough, a thorough assessment needs to be undertaken: inventories of sites (publications from universities, research centres, and departments of the culture ministry) classified according to the legislation, excavation reports (if any), bibliographic sources, old sketches, old maps (which can reveal old routes and field boundaries), toponyms taken from texts and old maps, orthophotos from different years, and aerial photographs taken from the drone (Margottini et al. 2015).

Conclusion

A diachronic analysis was performed over a timespan of 118 years regarding the precarious situation of CH in an area which is highly important for the Romanian and European archaeology. The rich cartographic background, the digital data saved, and the analysis made with the help of GIS have shown to be a model that can be applied in other areas of the globe. The analysis of the natural and anthropic factors has highlighted the fact that the anthropic factors (road network and village extension) have a higher impact on the vulnerability index and implicitly on CH sites. Any mention of natural or anthropic hazard from old maps, archaeological, geographical and bibliographic sources is of high significance in a study of this kind; as they might indicate the leading causes of emergence or how they are evolving, which can then help researchers and decision-makers in taking the most appropriate mitigation measures. Mitigation measures can include excavation, restoration, rerouting the traffic, site mapping, and erosion control measures; these will be established or implemented according to the local natural conditions and be cost-effective: fences of fascine, stone and wood check dams for high flow rate, water channels, wooden or stone check dams, buried fences, shrub planting, pipes, retention pools.

Acknowledgements This work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University. And from Partnership in Priority Domains project PN-II-PT-PCCA-2013-4-2234 [Grant number 314/2014] of the Romanian National Research Council. Many thanks for the constructive comments of two anonymous reviewers.

References

Aas C, Ladkin A, Fletcher J (2005) Stakeholder collaboration and heritage management. Ann Tour Res 32(1):28–48. doi:10.1016/j.annals.2004.04.005

Agapiou A, Lysandrou V, Alexakis DD, Themistocleous K, Cuca B, Argyriou A, Sarris A, Hadjimitis DG (2015) Cultural heritage management and monitoring using remote sensing data and GIS: the case study of Paphos area, Cyprus. Comput Environ Urban 54:230–239. doi:10.1016/j.compenvurbsys.2015.09.003

Agapiou A, Lysandrou V, Themistocleous K, Hadjimitis DG (2016) Risk assessment of cultural heritage sites clusters using satellite

imagery and GIS: the case study of Paphos District, Cyprus. Nat Hazards 83(1):5–20. doi:10.1007/s11069-016-2211-6
Asăndulesei A, Nicu IC, Balaur Ş, Caliniuc Ş, Asăndulesei M, Cotiugă V (2015) Integrated prospection methods for documenting threatened prehistoric archaeological sites from north-eastern Romania. Archaeol Pol 53:425–430
Băcăuanu V (1967) Microrelieful de eroziune torenţială din Câmpia Moldovei. Series Geologia-Geographia, Fasciculus 2, Cluj
Băcăuanu V (1980) Privire generală asupra proceselor actuale de modelarea reliefului Podişului Moldovei. Analele Ştiintifice ale Universităţii Alexandru Ioan Cuza din Iaşi XXVI(II):135–143
Băican V (1970) Iazurile din partea de est a României oglindite în documentele istorice şi cartografice din sec. XV–XIX. Analele Ştiinţifice ale Universităţii "Alexandru Ioan Cuza" din Iaşi XVI: 65–73
Bălteanu D, Chendeş V, Sima M, Enciu P (2010) A country-wide spatial assessment of landslide susceptibility in Romania. Geomorphology 124:102–112. doi:10.1016/j.geomorph.2010.03.005
Chirica V, Tanasachi M (1984) Repertoriul arheologic al judeţului Iaşi. vol. I, Iaşi
Cutter SL (1996) Vulnerability to environmental hazards. Prog Hum Geo 20(4):529–539. doi:10.1177/030913259602000407
Cutter SL, Boruff BJ, Shirley WL (2003) Social vulnerability to environmental hazards. Soc Sci 84:242–261
Del Río L, Gracia FJ (2009) Erosion risk assessment of active coastal cliffs in temperate environments. Geomorphology 112(1–2):82–95. doi:10.1016/j.geomorph.2009.05.009
Dotterweich M (2008) The history of soil erosion and fluvial deposits in small catchments of central Europe: deciphering the long-term interaction between humans and the environment—a review. Geomorphology 101(1–2):192–208. doi:10.1016/j.geomorph.2008.05.023
Eftimoski M, Ross SA, Sobotkova A (2017) The impact of land use and depopulation on burial mounds in the Kazanlak Valley, Bulgaria: an ordered legit predictive model. J Cult Herit 23:1–10. doi:10.1016/j.culher.2016.10.002
Furlanetto P, Bondesan A (2015) 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):261–266. doi:10.1080/17445647.2014.947341
Ghilardi M, Fouache E, Queyrel F, Syridres G, Vouvalidis K, Kunesch S, Styllas M, Stiros S (2008) Human occupation and geomorphological evolution of the Thessaloniki Plain (Greece) since Mid Holocene. J Archaeol Sci 35(1):111–125. doi:10.1016/j.jas.2007.02.017
Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York, 1997
Haase D, Walz U, Neubert M, Rosenberg M (2007) Changes to Central European landscapes–analysing historical maps to approach current environmental issues, examples from Saxony, Central Germany. Land Use Policy 24:248–263. doi:10.1016/j.landusepol.2005.09.003
Hadjimitsis D, Agapiou A, Alexakis D, Sarris A (2013) Exploring natural and anthropogenic risk for cultural heritage in Cyprus using remote sensing and GIS. Int J Digit Earth 6(2):115–142. doi:10.1080/17538947.2011.602119
Hungr O, Leroueil S, Picarelli L (2014) The Varnes classification of landslide types, an update. Landslides 11(2):167–194. doi:10.1007/s10346-013-0436-y
Ioniţă I (2000) Formarea şi evoluţia ravenelor din Podişul Bârladului. Corson Publishing House, Iaşi
Ioniţă I (2006) Gully development in the Moldavian Plateau of Romania. CATENA 68:133–140. doi:10.1016/j.catena.2006.04.008
Ioniţă I, Chelaru P, Niacşu L, Butelcă D, Andrei A (2014) Landslide distribution and their recent development within the Central Moldavian Plateau of Romania. Carpath J Earth Environ 9 (3):241–252
Ioniţă I, Niacşu L, Petrovici G, Blebea-Apostu AM (2015) Gully development in eastern Romania: a case study from Fălciu Hills. Nat Hazards 79(1):113–138. doi:10.1007/s11069-015-1732-8
Sâvulescu I, Mihai B (2011) Mapping forest landscape change in Iezer Mountains, Romanian Carpathians. A GIS approach based on cartographic heritage, forestry data and remote sensing imagery. J Maps 7(1):429–446. doi:10.4113/jom.2011.1170
Iurea D (2011) Consideraţii asupra sistemului de aşezări din judeţul Iaşi. Urbanism Arhitectură Construcţii 2(2):3–10
Lazarovici CM, Lazarovici G, Turcanu S (2009) Cucuteni. A Great Civilization of the Prehistoric World. Editura Palatul Culturii, Iaşi
López-Vicente M, Navas A (2009) Routing runoff and soil particles in a distributed model with GIS: implications for soil protection in mountain agricultural landscapes. Land Degrad Dev 21 (2):100–109. doi:10.1002/ldr.901
Margottini C, Fidolini F, Iadanza C, Trigila A, Ubelmann Y (2015) The conservation of the Shahr-e-Zohak archaeological site (central Afghanistan): geomorphological processes and ecosystem-based mitigation. Geomorphology 239:73–90. doi:10.1016/j.geomorph.2014.12.047
Martínez-Graña AM, Goy JL, Zazo C (2011) Natural heritage mapping of the Las Batuecas-Sierra De Francia and Quilamas nature parks (SW Salamanca, Spain). J Maps 7(1):600–613. doi:10.4113/jom.2011.1172
Martínez-Graña AM, Goy JL, Zazo C (2014) Ground movement risk in Las Batuecas-Sierra de Francia and Quilamas nature parks (central system, Salamanca, Spain). J Maps 10(2):223–231. doi:10.1080/17445647.2014.892844
Martínez-Graña AM, Goy JL, Zazo Cardenia C (2016) Geomorphological applications for susceptibility mapping of landslides in natural parks. Environ Eng Manag J 15(2):1–12
Mazumdar J, Paul SK (2016) Socioeconomic and infrastructural vulnerability indices for cyclones in the eastern coastal states of India. Nat Hazards 82(3):1621–1643. doi:10.1007/s11069-016-2261-9
Mihăilă M, Corcodel G, Chirilov I (1995) Cadastru general şi publicitate imobiliară—bazele şi lucrările component. Editura Ceres, Bucureşti
Minea I (2005) Evoluţia unităţilor lacustre din bazinul hidrografic Bahlui. Lucrările Seminarului Geografic Dimitrie Cantemir 25:127–137
Moţoc M (1983) Ritmul mediu de degradare erozională a solului în R.S.R. Buletinul Informativ al Academiei de Ştiinte Agricole şi Silvice 2
Nicu IC (2016) Hydrogeomorphic risk analysis affecting Chalcolithic archaeological sites from Valea Oii (Bahlui) watershed, Northeastern Romania. An interdisciplinary approach. Springer, Berlin. doi:10.1007/978-3-319-25709-9
Nicu IC, Romanescu G (2016) Effect of natural risk factors upon the evolution of Chacolithic human settlements in Northeastern Romania (Valea Oii watershed). From ancient time dynamics to present day degradation. Z Geomorphol 60(1):1–9. doi:10.1127/zfg/2015/0174
Niculiţă M, Mărgărint MC, Santangelo M (2016) Archaeological evidence for Holocene landslide activity in the Eastern Carpathian lowland. Quat Int 415:175–189. doi:10.1016/j.quaint.2015.12.048
Oberländer-Târnoveanu I (2014) Patrimoniul arheologic naţional: politici, documentare, acces. In: Musteaţă S (ed.) Arheologia şi politicile de protejare a patrimoniului cultural în România—culegere de studii. Chişinău-Iaşi, pp. 13–42

Otiman PI (2012) Romania's present agrarian structure: a great (and unsolved) social and economic problem of our country. Agric Econ Rural Dev New Ser 1:3–24

Pantazică M (1974) Hidrografia Câmpiei Moldovei. Editura Junimea, Iași

Pătru-Stupariu I, Stupariu M-S, Cuculici R, Huzui A (2011) Understanding landscape change using historical maps. Case study Sinaia, Romania. J Maps 7(1):206–220. doi:10.4113/jom.2011.1151

Rădoane M, Ichim I, Rădoane N (1995) Gully distribution and development in Moldavia, Romania. Catena 24(2):127–146. doi:10.1016/0341-8162(95)00023-L

Romanescu G, Nicu IC (2014) Risk maps for gully erosion processes affecting archaeological sites in Moldavia, Romania. Z Geomorphol NF 58(4):509–523. doi:10.1127/0372-8854/2014/0133

Romanescu G, Stoleriu CC (2014) An inter-basin backwater overflow (the Buhai Brook and the Ezer reservoir on the Jijia River, Romania). Hydrol Process 28(7):3118–3131. doi:10.1002/hyp.9851

Romanescu G, Stoleriu CC, Romanescu AM (2011) Water reservoirs and the risk of accidental flood occurrence. Case study: Stanca–Costesti reservoir and the historical floods of the Prut river in the period July—August 2008, Romania. Hydrol Process 25 (13):2056–2070. doi:10.1002/hyp.7957

Romanescu G, Cotiugă V, Asăndulesei A, Stoleriu CC (2012) 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 16:953–966. doi:10.5194/hess-16-953-2012

Romanian Senat (2004) Documentar privind regimul juridic al terenurilor. http://www.senat.ro/UploadFisiere/0c23530b-e067-46b8-a1d9-33bc45b07d23/REGIMUL%20TERENURILOR.pdf

Rondelli B, Stride S, García-Granero JJ (2013) Soviet military maps and archaeological survey in the Samarkand region. J Cult Herit 14:270–276. doi:10.1016/j.culher.2012.06.006

Schuppert C, Dix A (2009) Reconstructing former features of the cultural landscape near early Celtic princely seats in Southern Germany. A GIS-based application of large-scale historical maps and archival sources as a contribution to archaeological research. Soc Sci Comput Rev 27(3):420–436. doi:10.1177/0894439308329766

Ștefan PD (1989) Geologia regiunii Dealul Mare-Hârlău și perspectivele în resurse minerale utile. Univ. "Al.I.Cuza" Iași

Szlafsztein C, Sterr H (2007) A GIS-based vulnerability assessment of coastal natural hazards, state of Pará, Brazil. J Coast Conserv 11 (1):53–66. doi:10.1007/s11852-007-0003-6

Tufescu V (1941) O regiune de vie circulație: „Poarta Târgului-Frumos". Buletinul Societății Române Regale de Geografie LIX, Imprimeria Națională, București

Vorovenci I (2003) Un secol și jumătate de reforme agrare în România. Jurnalul Economic 11–12:247–253

Zachos LG, Swann CT, Altinakar MS, McGrath MZ, Thomas D (2016) Flood vulnerability indices and emergency management planning in the Yazoo Basin, Mississippi. Int J Disaster Risk Reduct 18:89–99. doi:10.1016/j.ijdrr.2016.03.012

Zalasiewics J, Williams M, Steffen W, Crutzen P (2010) The new world of the anthropocene. Environ Sci Technol 44(7):2228–2231. doi:10.1021/es903118j

Zanetti VB, de Sousa WC, De Freitas DM (2016) A climate change vulnerability index and case study in a Brazilian coastal city. Sustainability 8(8):811. doi:10.3390/su8080811

Zanoni L, Gurnell A, Drake N, Surian N (2008) Island dynamics in a braided river from analysis of historical maps and air photographs. River Res Appl 24(8):1141–1159. doi:10.1002/rra.1086