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River channel dynamics in the contact area between the Romanian Plain and the Curvature Subcarpathians

Florina GRECU¹, Gabriela IOANA-TOROIMAC¹, Paola MOLIN², Francesco DRAMIS²

Abstract. The morphology of river channels results from the genetic and dynamic characteristics imposed by internal and external morphogenetic forcings. We studied reaches of river courses cutting across the contact area between the Romanian Plain (Carpathians foredeep) and the Curvature Subcarpathians, where active faults are located. In this area a wide monocline of tilted foredeep deposits generated a glacis-like macro-landform at the mountain front that connects the Subcarpathians with the Romanian Plain. The headwaters of studied rivers are located in the Subcarpathians (Cricovul Dulce River) and in the Carpathians (Prahova, Buzău and Milcov rivers). More in detail, we investigated river channels in plan view by morphometric and multi-temporal air-photo analysis to define the general trends of channel evolution. The results of this study indicate a spatial and temporal variability in the intensity of fluvial dynamic processes. The braided courses crossing the Subcarpathians and the piedmont plain have restrained their channels in width, between 1980 and 2005: by 69% on Buzău R. (on 88 km) and 44% on Prahova R. (on 70 km). This evolution is due to the absence of floods just before 2005 and to human factors (i.e. reservoir-dams on Buzău and mining activity on both rivers). Beside these common aspects, the analysis of each river needs to be detailed in order to better understand the responsible factors.

Keywords: river channels, longitudinal profile, channels pattern, braiding pattern, narrowing active channel.

1. Introduction

The morphology of river valleys results from the genetic and dynamic characteristics imposed by the geological factors (tectonics, structure, lithology), as well as by the control variables related to the external morphogenetic environment (Fig. 1), at both regional and local scale.

In cross section, we focused on landforms resulting from alternating erosion and accumulation processes of the river. We took into consideration mainly the modifications of the flow channel, corresponding to flow transportation in normal/mean conditions according to hydromorphological criteria of J.L. Ballais (2011).

The highly complex fluvial morphodynamics, due to the interaction of water as a shaping agent, and the channel morphology, including alluvial deposits, needs to be analysed in plan view, in longitudinal profile and in cross-section (Grecu & Palmentola, 2003), which partially corresponds with 2D and/or 3D analyses (Arnaud-Fassetta & Fort,

2004; Arnaud-Fassetta et al., 2005; Ioana-Toroimac, 2009; Ioana-Toroimac et al., 2010). So, the morphometric features of the channel resulted from different forcings determine the type of channel and its evolution. More in detail, in plan view, we classify channels as straight, meandered, braided, and wandering following Leopold & Wolman (1957), based on the sinuosity and the multiplicity degree of the channel (Brice 1964; Schumm, 1977; Richards 1985; Mac 1986; Ichim et al., 1989; Bravard & Petit, 2002; Grecu & Palmentola, 2003; Ielenicz, 2004; Charlton, 2008; Rădoane et al., 2008, 2013; Malavoi & Bravard, 2010; Rinaldi et al. 2011 and others).

Our study relies on two hypotheses: 1) river channels (inscribed into the flow channel) are the most dynamic component of hydrosystems and 2) they adjust easily to external forcings, both natural and human. Therefore it is necessary, from time to time, to establish the new features of river channels, as a result of changing in external inputs.

2. Study area

We studied the contact area between the Romanian Plain (Foredeep/Foreland unit) and the Curvature Subcarpathians (Orogen unit).

The Romanian Carpathians are an arcuate mountain chain, formed in response to the continental collision between the European Plate and several microplates during the Alpine orogeny (Schmid et al., 1998; Maţenco & Bertotti, 2000 and references therein; Csontos & Vörös, 2004). The main depocentre in the Carpathians foredeep is the Focşani Depression, where subsidence continues up to present time (Tărăpoancă et al., 2003). During the Pliocene–Quaternary, the western flank of the Focşani depocentre was tilted as a consequence of the uplift of the neighbouring Carpathian chain

(Maţenco et al., 2003; Tărăpoancă et al., 2003; Necea et al., 2005; Leever et al., 2006; Maţenco et al., 2007). This tilting generated a wide monocline at the mountain front, connecting the Curvature Subcarpathians with the Romanian Plain (Fielitz & Seghedi, 2005; Necea et al., 2005). So the study area is interesting because it is in between opposite important regional vertical movements: the uplifting chain and subsiding foredeep (about ± 5 millimetres per year; Zugrăvescu et al., 1998) at less than 100 km in distance (Fig. 2). It is also characterized by the outcrop of rock types susceptible to erosion: sand, clay, conglomerate and marls that record the change from a marine to a fluvial-lacustrine environment (Molin et al., 2012 and reference therein).

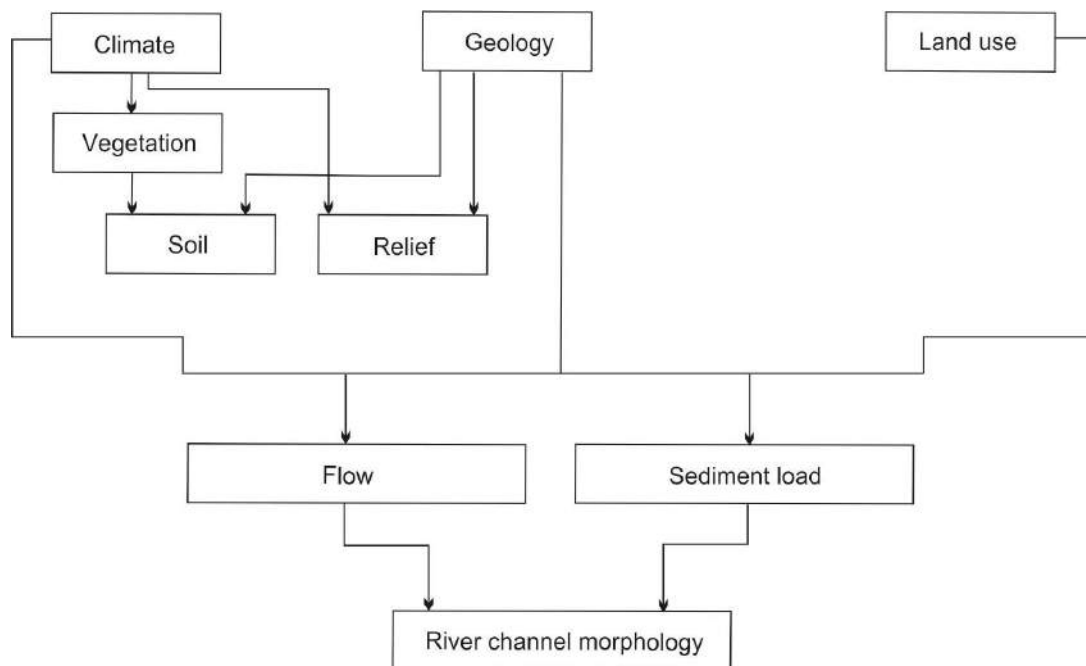


Fig. 1. Control variables related of the external morphogenetic environment (adapted from Knighton, 1984)

From a morphological point of view, the study area includes Curvature Carpathians, Curvature Subcarpathians and Romanian Plain. The contact area between the Subcarpathians and the Romanian Plain is represented by a piedmont belt (glacis-like macro-landform associated with the monocline), traditionally considered a part of the Romanian Plain because of its very gentle slopes (Grecu, 2010). The subsidence of the Romanian Plain coupled with the Carpathian and Subcarpathian uplift induced a regional base level, lowering that

allowed the generation of fluvial terraces and entrenched alluvial fans interacting with the Quaternary climate changes. The element of complexity is also due to local tectonic features, like the anticlines relative to the so-called “Wallachian” phase (Săndulescu, 1988). For example, the anticlines Bucşani and Mărgineni, incised by the Cricovul Dulce and Prahova valleys at the Tinosu point, partially influenced upon the recent evolution and configuration of river network.

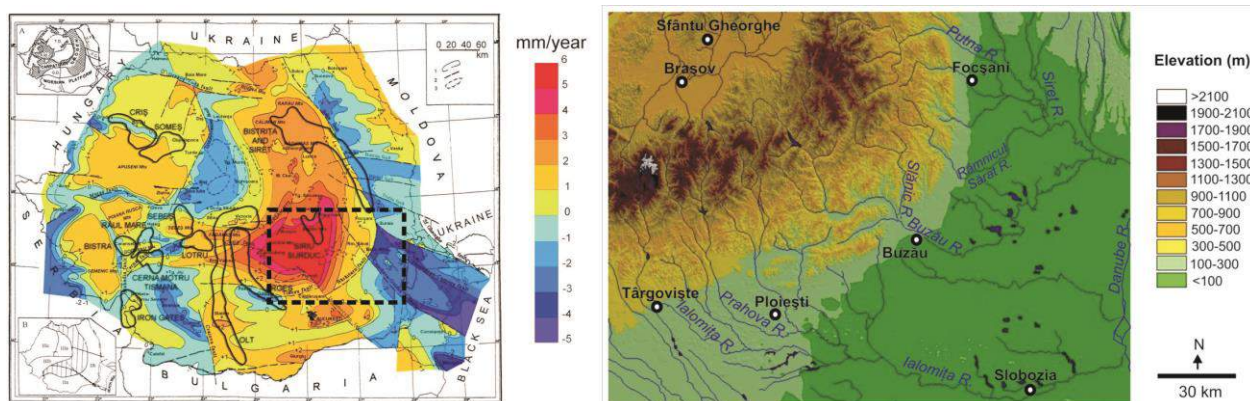


Fig. 2. Study area – Curvature Carpathians: active tectonics (left, within the frame, according to Zugrăvescu et al., 1998) and elevation (right, adapted from SRTM)

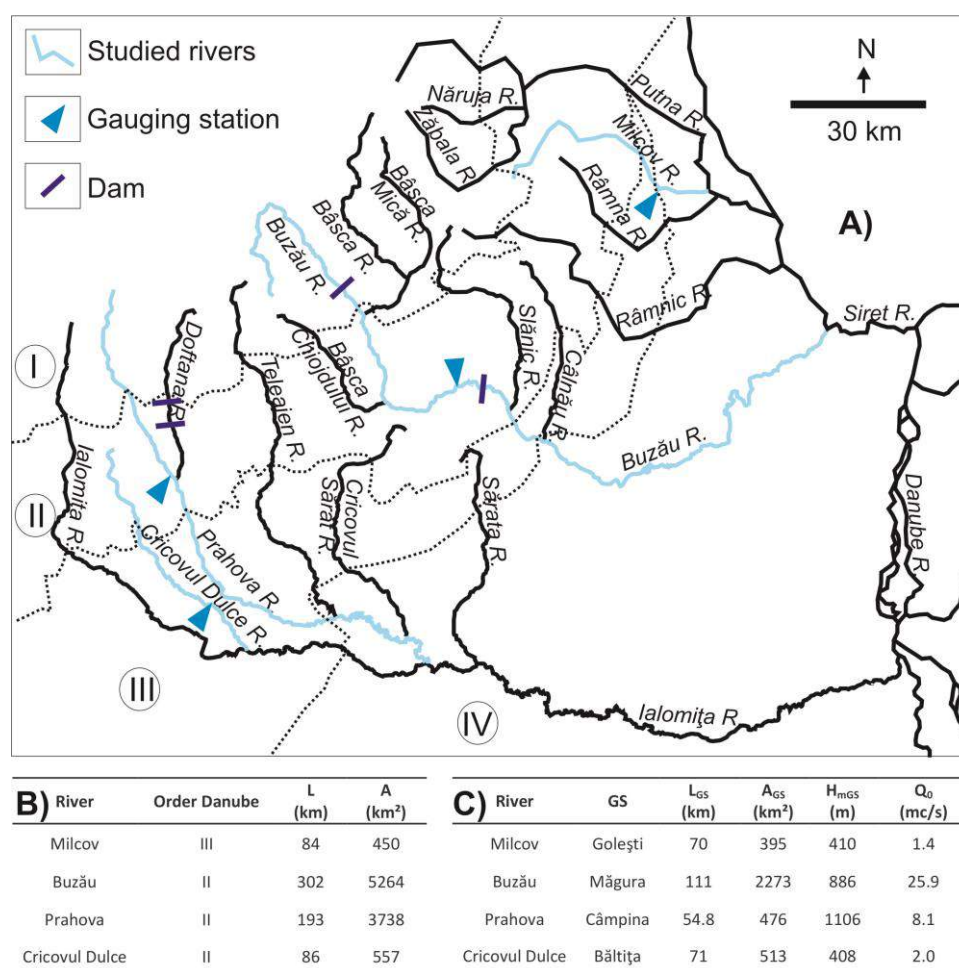


Fig. 3. Studied rivers. A) Geographical position. I: Carpathians; II: Subcarpathians; III: Piedmont plain; IV: Lowland plain. B) Morphometric data of river basins. L: river length; A: catchment area (AQUAPROIECT, 1992). C) Morphometric data of rivers at gauging stations. GS: gauging station; L_{GS}: length; A_{GS}: area; H_{mGS}: mean altitude (source: INMH, 1974); Q₀: mean annual discharge (data from National Institute of Hydrology and Water Management)

These regional features have an influence on rivers crossing the Curvature area. Several rivers of this area have concave and steep longitudinal profiles and they are in a transient state of disequilibrium as a consequence of a more recent emersion of the Curvature Carpathians (Molin et al., 2012). Moreover, other previous studies showed that these rivers have the highest suspended sediments

loads in Romania (up to 25 tonnes per hectare per year) (Mociorniță & Birtu, 1987 cited by Zaharia et al., 2011).

Our study focuses on four rivers flowing down the Carpathians (like Prahova, Buzău and Milcov rivers) or draining just the Subcarpathians (like Cricovul Dulce River). The rivers cross the Carpathian and Subcarpathian (Mesozoic, Paleogene

and Neogene) rocks with different hardness and with great potential to generate landslides. All of them are secondary or thirdly tributaries of the Danube (Fig. 3). The most important (in terms of watershed dimensions and discharge) is Buzău River. Conversely, Milcov River has the smallest drainage basin and discharge.

Besides the natural constraints, the studied rivers are suffering from human recent interventions; some of them will be presented as discussion parts of the paper.

3. Methods and materials

The hydromorphological approach focuses on relief forms of the flow channel generated by sediment-charged water. In the framework of this hydromorphological approach, we determined rivers channel pattern based on two criteria: sinuosity and multiplicity of the branches (Fig. 4). We consider that multiple channel patterns correspond to more than one branch. If the alluvial bars separating the branches lack of vegetation, the channel is considered active. This is the typical example of braiding and wandering patterns.

In order to quantify channel evolution, we compared topographic maps of 1980 (scale 1/25,000) and orthophotos of 2005 (scale 1/5,000). The definition of the active channel on both

topographic maps and orthophotos could be equivocal. On orthophotoplans, we delimited the active channel using colours criteria, but there are several errors related to sediments' humidity, to the hydrological regime phase and, in some cases, to the riparian forest which makes it difficult to digitise its precise limits. On topographic maps, the active channel is represented by a peculiar symbol, but not all channels are represented because of their scale. Therefore, in order to quantify the braiding activity of small rivers, we adopt another parameter: the width of the active channel (according the methods proposed by Peiry, 1988) (Fig. 4). The width is measured along profiles crossing the channel on both topographic maps and orthophotos.

4. Results and discussions

On the basis of these data and methods, we present our results for the four rivers highlighting possible common features.

Buzău River forms a sinuous and unique pattern in the Carpathians, a braiding one in the Subcarpathians and piedmont plain, and a meandering one in the lowlands (Fig. 5A). This is a general picture, because the limits between these patterns are not precise and there are also intermediary types. The braiding pattern corresponds to a slope of 2.7 m/km and it covers 88 km in length.

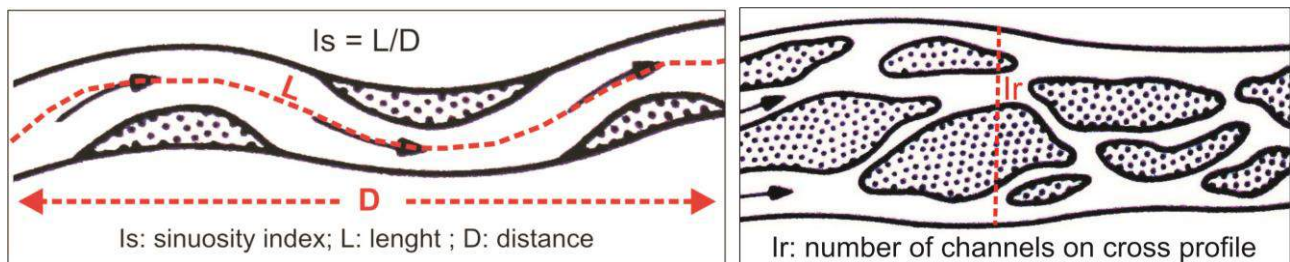


Fig. 4. Methods: sinuosity and braiding indices

Here, we measured its active channel's width on cross profiles located every 500 m on both topographic maps and orthophotos. The results show important variations of the active channel's width (Fig. 5B). For example, it widens at the entrance in the piedmont plain – approximately at the confluence with Slănic River (Fig. 5B). It widens in the vicinity of confluences, which indicate the role of tributaries in bringing yield in the main channel. The width of the active channel started to decrease since 1980, as showed by all the statistic parameters (Fig. 5C). The results relative to the

2005 orthophotos indicate a much smaller variability in channel width. The average width diminished by 69% in 25 years, between 1980 and 2005. In order to visualise this strong decrease, we focused on a 3 km-long reach in Fig. 5D. The inactive channel is presently covered by pasture, which means that the braiding channel could be easily reactivated in the future during extreme floods.

The channel dynamic of Buzău R. appears to be partially influenced by climatic factors acting on short-term and by human-induced factors, mostly dams and mining in the thalweg.

The large width of Buzău river bed in 1980 was probably caused by the floods of the decade 1970-1979 (Grecu et al., 2013). Exceptional floods were recorded in 1975 (when Buzău River reached 2200 m³/s), in 1970, and 1972 (Negru, 2010). The narrowed state of the river channel of 2005 may also be a consequence of the absence of high magnitude floods in the previous years (Grecu et al., 2013); therefore, the channel went back to a state previous to floods.

In the river channel of Buzău R., two dams have been built, one in the upstream course at the boundary between Carpathians and Subcarpathians (Siriu dam) and another one just downstream of the boundary between Subcarpathians and the plain (Cândești dam). Siriu dam is located between the massifs of Siriu and Podu Calului. Its construction began in 1982, and its influence in the river channel dynamics being felt since 1985 (Minea, 2011). The Cândești dam, built up in 1988 and much smaller than Siriu dam, plays also a role in flood control. The position of dams is particularly important as they control river discharge and yield; for example, the maximum water volume that can pass across the Siriu dam is about 3000 m³/s (Negru, 2010). Since the construction of the dams, the maximum discharge was about 925 m³/s (in 2005), thus much smaller than the previous one, diminishing the risk.

Downstream Cândești dam, the mining activity intensified since the '80s (figures 6A and B). More in detail, at the contact between Subcarpathians and Romanian Plain, in the Buzău county, there are more than 50 gravel pits. The exploited volumes differ a lot from one gravel pit to another. For example, the big gravel pit in Săpoca (near the confluence of Slănic into Buzău R.), where 7 commercial societies are involved, only one of them extracts yearly between 40000 – 50000 m³ (according to data from Environment Protection Agency of Buzău County). Gravel mining could cause an increase in both upstream and downstream incision with a consequent transient reduction in channel width.

Another cause of the narrowing may be related to the construction of a canal in the active channel, for water supply of Buzău city, located a few kilometres downstream.

In the case of Prahova River, the scenario is similar to Buzău R. one. The braiding pattern, 70 km long, corresponds to the Subcarpathians and piedmont plain (Fig. 7A) (Ioana-Toroimac, 2009). The active channel's width has been measured every 250 m along cross profiles. Numerous width variations are present. At the entrance in the piedmont plain, downstream the confluence with Doftana River (Fig. 7B), the valley bottom is bordered by terraces few tens of meters high. Its maximum width is located several kilometres downstream, where the terraces disappear. The mean width of Prahova R. diminished by 44% between 1980 and 2005 (Fig. 7C). In order to visualize this evolution, we focused on a smaller section; the abandoned active channel is used as a pasture and may be overflowed (Fig. 7D). This trend of evolution is confirmed by other studies (Ioana-Toroimac et al., 2010; Armaş et al., 2013).

Milcov River has only its springs in the Carpathians, but it drains mostly the Subcarpathians, that are the most important source of water discharge and sediments (Săcrieru, 2009). It forms braiding channels in the Subcarpathians and in the piedmont plain (Fig. 8A) on a reach of 44 km-long and on a slope of 7.7 m/km. Many variations in active channel's width are present all along the river course. For example, it widens in the piedmont plain, whereas natural constraints in the Subcarpathians do not allow active channel widening (Fig. 8B). For a more detailed analysis of the Milcov R. evolution, we focused on this reach of 6 km-long; its mean width diminished by 43% between 1980 and 2005 (Fig. 8D).

Similarly to all the rivers, Cricovul Dulce River forms braiding and wandering channels in the Subcarpathians and in the piedmont plain (Săndulescu, 2011) (Fig. 9A). But this reach has features different with respect to the other studied rivers. It is characterized by alternating braiding reaches and unique reaches (Fig. 9B). Cricovul Dulce River suffers from the same process of narrowing, but it is apparently less important. The average width diminished by 18% (figures 9C and D).

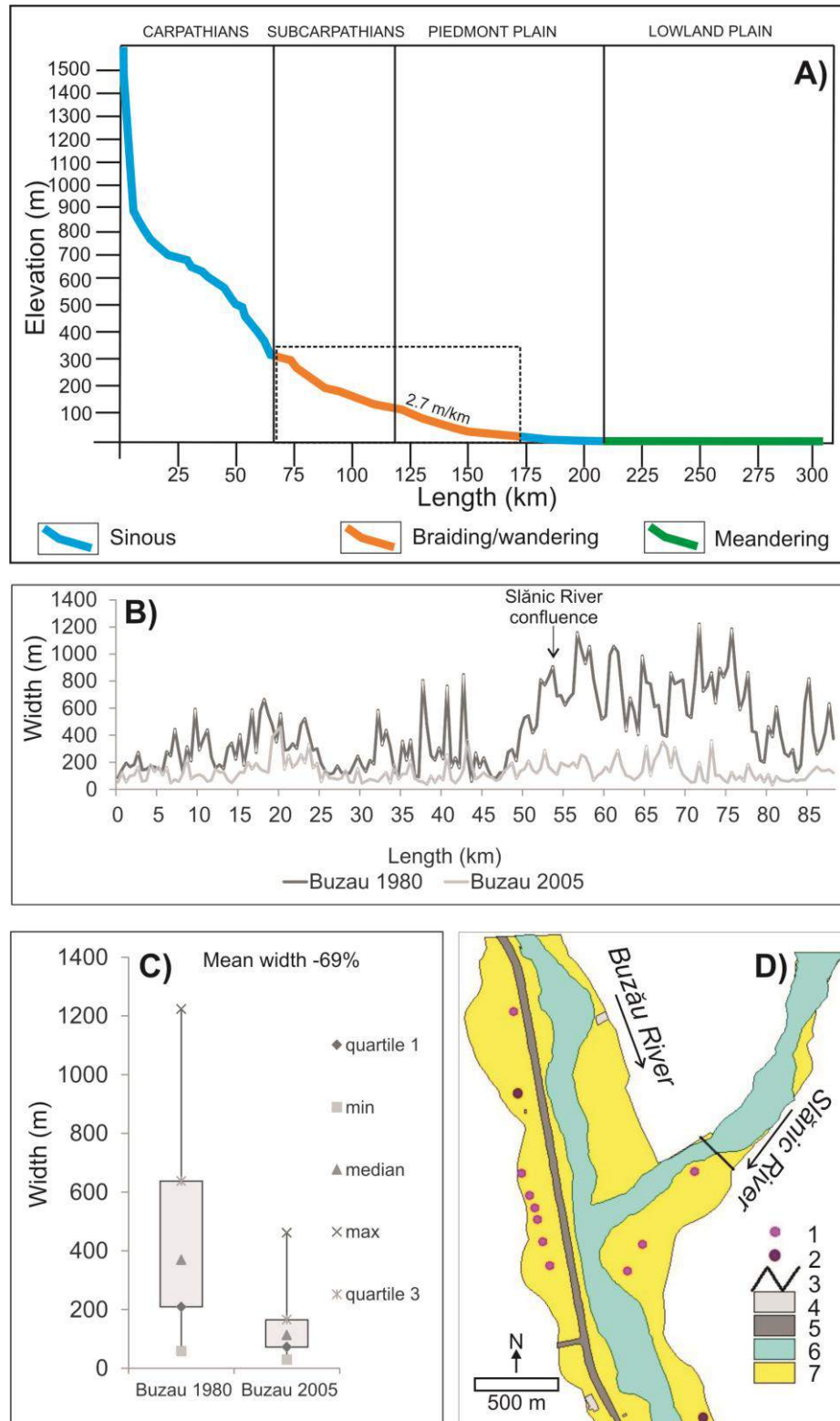


Fig. 5. Buzău River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel, measured every 500 m, in 1980 and 2005. C) Active channel narrowing between 1980 and 2005. D) Active channel dynamics at Buzău – Slănic confluence. 1: ancient/abandoned borrow pit; 2: borrow pit; 3: bridge; 4: built-up area; 5: artificial channel; 6: active channel 2005; 7: active channel 1980

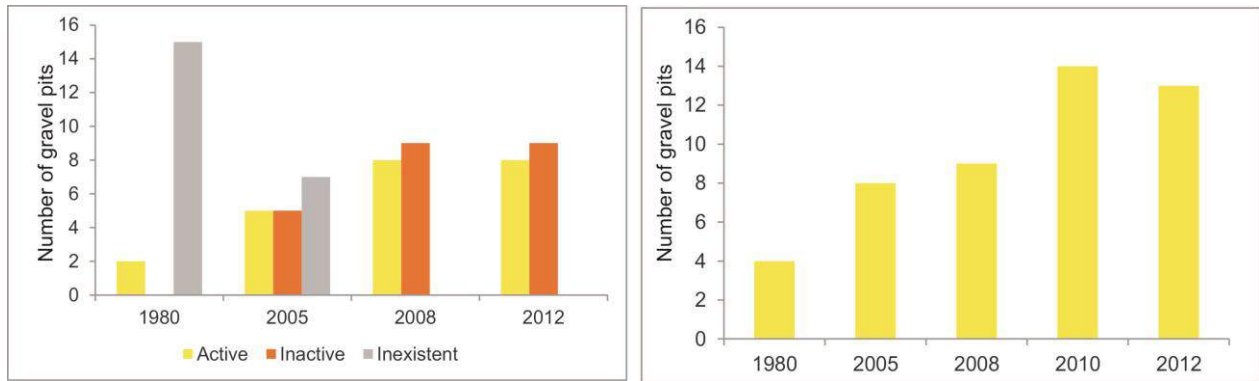


Fig. 6. Mining activity on Middle Buzău River. A) Between km 52 and 68 (according to figure 5B): status compared to the one of 2012. B) Between km 68 and 88 (according to figure 5B): active mining (analysis based on topographic maps of 1980 and several orthophotos of ANCPI, 2014)

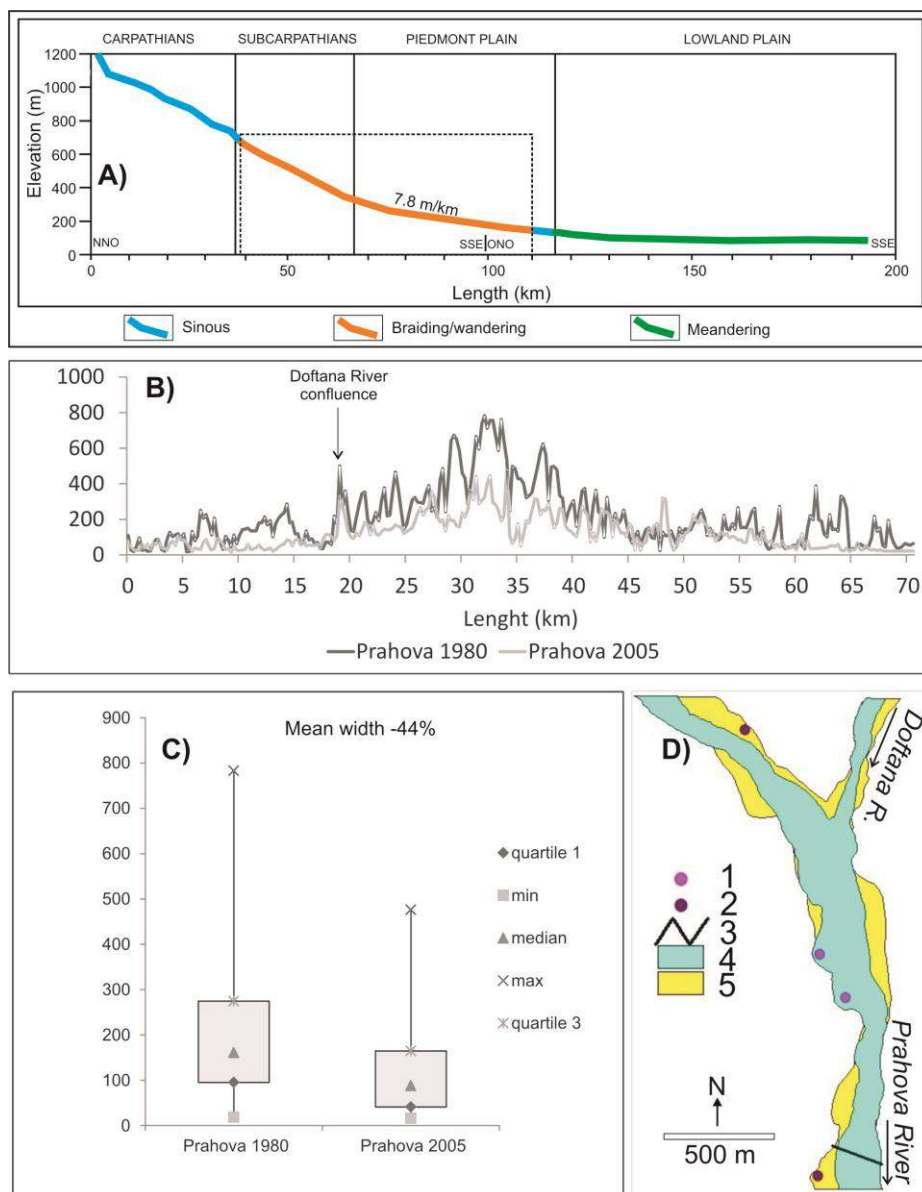


Fig. 7. Prahova River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel, measured every 250 m, in 1980 and 2005. C) Active channel narrowing between 1980 and 2005. D) Active channel dynamics at Prahova – Dofana confluence. 1: ancient/abandoned borrow pit; 2: borrow pit; 3: bridge; 4: active channel 2005; 5: active channel 1980

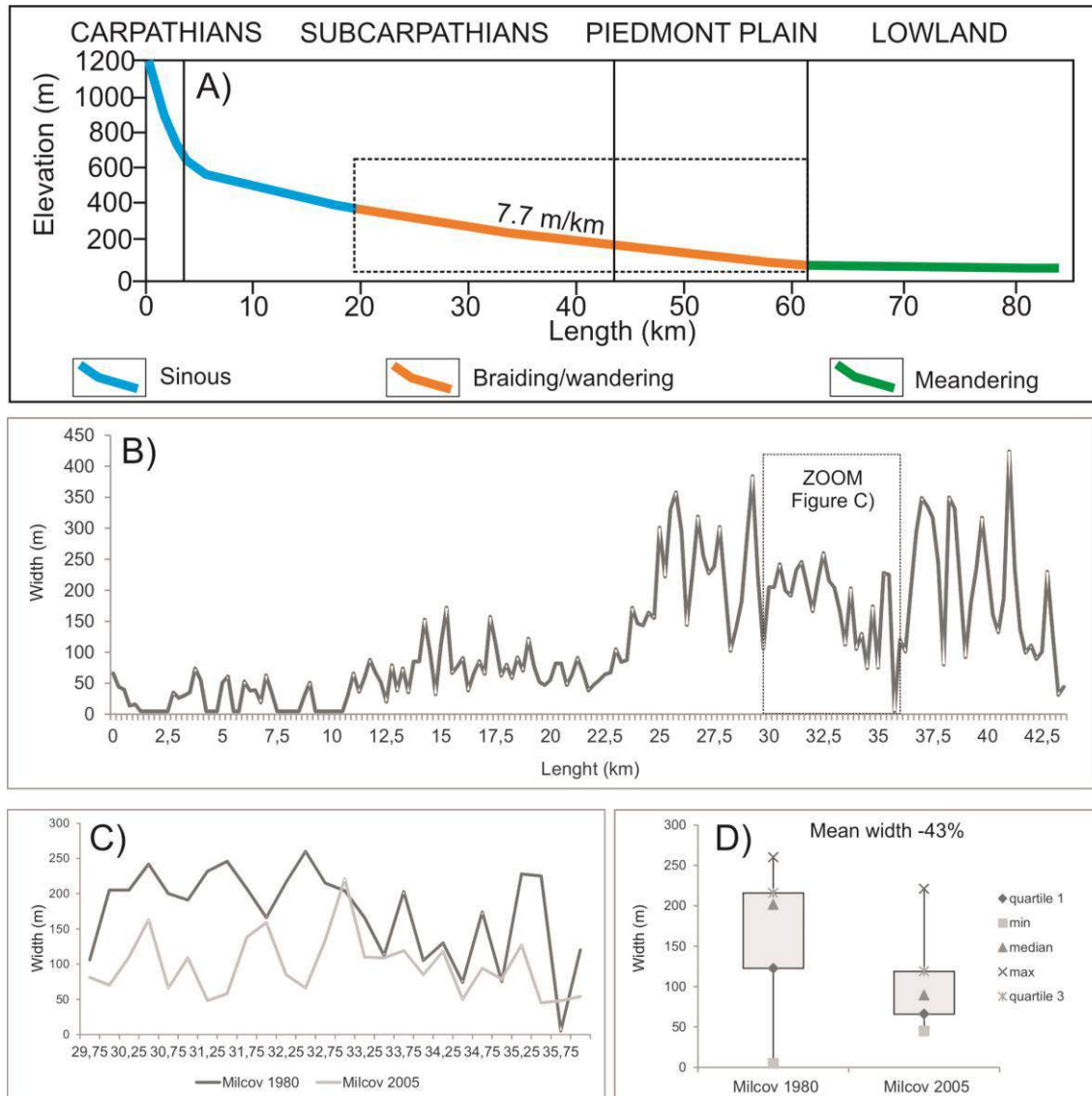


Fig. 8. Milcov River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel in 1980, measured every 250 m. C) Width variations of a river reach between 1980 and 2005. D) Active channel narrowing of the river reach from figure C between 1980 and 2005

6. Conclusions

The rivers crossing the study area form a unique, sinuous channel in the Carpathians and just locally in the Subcarpathians. They form braiding and wandering channels in the Subcarpathians and in the piedmont unit of the Romanian Plain; their origin, length and width depend on the water and sediments resources of each watershed. Downstream, crossing the lowland units of the Romanian Plain, they form meandering channels. In conclusion, channel pattern is related to morphological units and the majority of the rivers respect these patterns.

All the investigated braided rivers adjust to external changes and suffer a narrowing process of different intensities. A fluvial metamorphosis does

not occur, but this process is possible in the near future as the narrowing continues at the present rate. It is difficult to establish the role of each external factor in this evolution, because their actions are synchronous and simultaneous. We notice that gravel mining is an important activity in Romania and it probably plays an important role in channel's evolution. Beside these common aspects, the analysis of each river needs to be detailed, because each river is a unique example. These are only a few examples, which show that it is necessary to conduct the same study on all the major braided rivers.

This study is important because it fills a lack of studies on braiding activity of Romanian rivers and it highlights the general process of narrowing of

channels in the Subcarpathians and piedmont sectors of their courses. Moreover, it could contribute to the geoconservation of braided rivers which the narrowing process, almost caused by human activity, is progressively destroying.

This paper was presented at the 16th Joint Geomorphological Meeting on Morphoevolution in Tectonically Active Belts, Rome and Central Apennine Mountains, Italy, 1-5 July 2012.

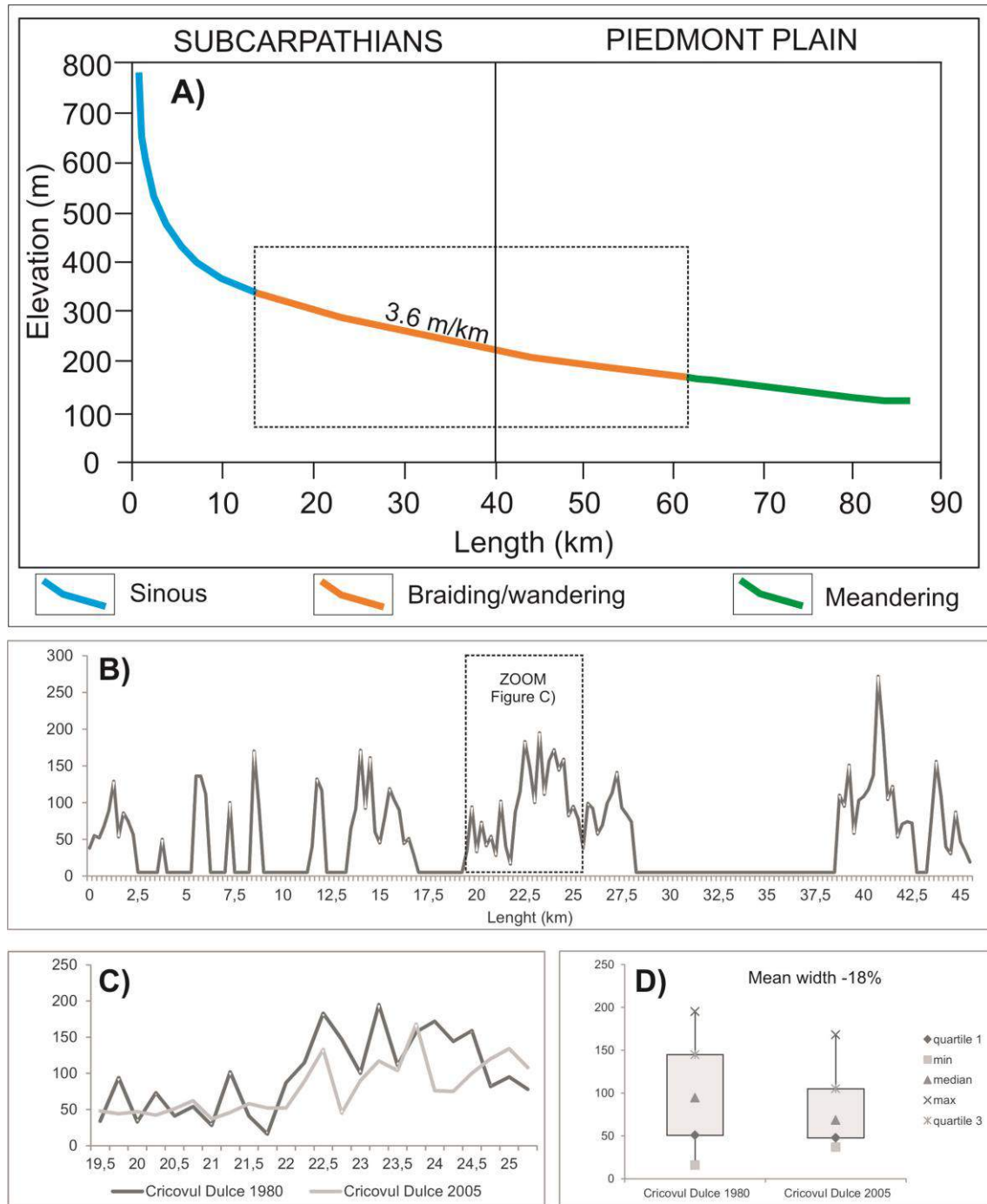


Fig. 9. Cricovul Dulce River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel in 1980, measured every 250 m. C) Width variations between 1980 and 2005 on a river reach. D) Active channel narrowing of the river reach between 1980 and 2005. E) Active channel narrowing of the river reach from figure C between 1980 and 2005

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Dendrogeomorphological reconstruction of past debris flow activity along a forested torrent (Retezat Mountains)

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Abstract. Applying dendrochronological principles and techniques in geomorphological studies proves to be a veridical method for spatio-temporal reconstruction of processes occurring in mountainous regions. Analysis of tree ring growth data provides valuable information on past geomorphic activity, especially where there is a lack of archival records regarding them. Trees affected by the manifestation of geomorphological processes reveal morphological and anatomical disturbances through which we can date and assess these former events.

This study is an attempt to reconstruct temporal debris-flows activity by determining and dating various ring disturbances as growth responses of the trees which have been affected by these processes. The study was conducted on a torrent located in the southern slope of Retezat Mountains. In this analysis we used 122 increment cores extracted from 60 Norway spruce (*Picea abies* (L.) Karst.) that allowed us to reconstruct more than a century of debris flow activity. Past events dated through tree ring analysis reveal a good correlation with meteorological and hydrological data recorded in the vicinity of the studied area. The results obtained can equally serve to complete the archival data regarding natural hazards specific to this area and to establish the frequency and the magnitude of the processes with a useful role in taking early measures so as to prevent negative consequences.

Keywords: dendrogeomorphology, temporal reconstruction, debris flow, anomalies, Retezat Mts.

1. Introduction

Debris flows are the most frequent kind of rapid mass movements occurring in the mountainous regions of the earth, except for avalanches (Strunk, 1991). Debris flows, as being described by Takahashi (2007), are massive sediment transport phenomena that manifest themselves in the channel of mountain streams, consisting of a large variety of solid material. In order for a debris flow to occur, there has to be a sufficient amount of loose rock and soil deposits (Bovis & Jakob, 1999) and a large amount of water. In addition to this, the morphometrical parameters of the area have an important role in debris flow triggering, as they usually occur in torrents characterised by steep slopes and high values of fragmentation depth (Slaymaker, 1988; Wilford et al., 2004).

In Romania, though there are some mentions about past debris flow occurrences (Bălțeanu et al., 2004), only recently a few studies are concentrated on this type of mass-movements (Pop et al., 2008, 2010, Ilinca, 2009, 2014). The debris flows which occurred in Retezat Mountains area, caused a lot of damage to infrastructure (400000\$ damages in 11-14.07.1999), determined negative ecological consequences and even fatalities (13 deaths registered in the last event).

The debris materials, formed mainly by rocks and boulders of all sizes, hit the trees adjacent to the stream drainage channel, causing them many disturbances (Fig. 4). Any mechanical disturbance causes morphological changes in trees cell structure (Schweingruber, 1996). After the event occurrence, visible scars and marks remain on the stem of the affected trees, all of the disturbances being recorded in the tree's growth (Alestalo, 1971). As it has widely been described in the literature (Shroder, 1980; Braam et al., 1987; Schweingruber, 1996, 2007; Strunk, 1997; Stoffel & Bollschweiler, 2009 etc.) the trees react differently, depending on the type of the disturbance (scars and marks on the stems, tilting of stems, uprooting, decapitation etc.) by formation of callus tissue, tangential rows of traumatic resin ducts, compression wood, growth release, growth reduction, etc.

Due to the high sensitivity to any geomorphological disturbance, tree species like Norway spruce (*Picea abies* (L.) Karst.), are considered extremely suitable for dendrogeomorphological reconstruction. Using trees' reaction to physical injuries one can precisely date debris flow activity and assess the spatial extent of each individual event with annual or even seasonal resolution (Stoffel, 2008).

The main purpose of this study is to reconstruct debris flow activity by dendrogeomorphological methods on a small catchment situated on the southern slope of Retezat Mountains (Romanian Carpathians). In this study, 122 increment cores extracted from 60 Norway spruces (*Picea abies* (L.) Karst.) were used. It is very important to know whether the frequency of debris flows affecting an area is increasing or is stable over time, as this aspect determines what kind of measures should be taken in order to prevent negative consequences (Braam et al., 1987).

1. Study area

The study site ($45^{\circ}19'01.2''$ - $22^{\circ}47'19.3''$) is represented by a small catchment located on the southern slope of Retezat Mountains (Fig. 1). The main collector is a right tributary of the Lăpușnicul Mare River, which drains an area of 128 ha, extending from an elevation of 2100 m a.s.l. to 1160

m a.s.l., corresponding to the confluence with the Lăpușnicul Mare River. The torrent surface is mainly built of deposits of granodiorites, with the exception of the lower sector, where conglomerates with sandstone intercalations are dominant, forming the base for the depositional cone of the torrent (Fig. 3). At the elevation of 1550 m a.s.l. there is a structural breakout and a waterfall of 5 m, at the bottom of which there can be observed blocks of over 3 m in diameter. The forest standing on the cone and along the channel mainly consists of Norway spruce (*Picea abies* (L.) Karst.). The permanent stream flow of the torrent initiates at the elevation of 1850 m a.s.l., reaching the cone after 2.2 km where it flows into the Lăpușnicul Mare River.

The debris material which can be observed along the torrent stream is heavily fractured, starting from blocks of a few meters in diameter to fine sand that can be easily mobilised during heavy rainfall and incorporated in the debris flow mass.

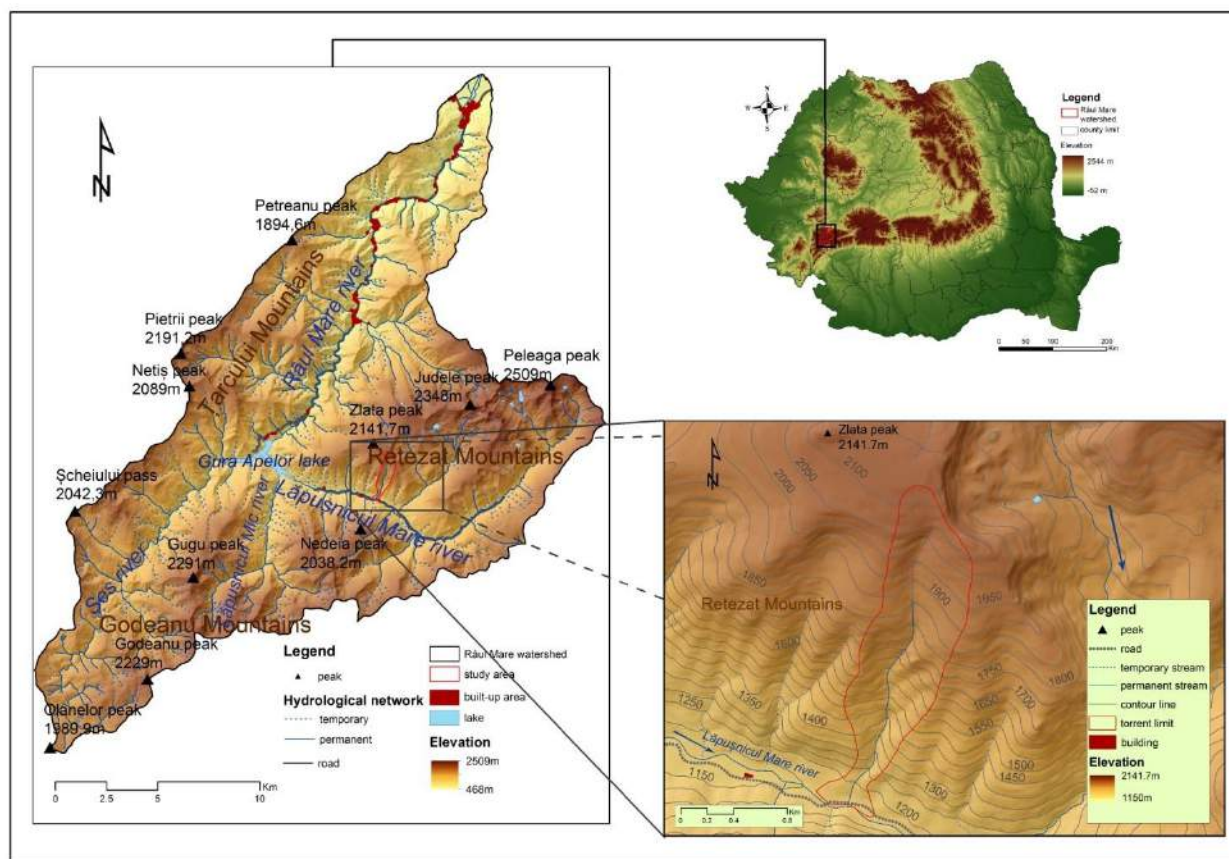


Fig. 1. Geographical position of the study site

The studied torrent has a mean slope of 24° , most of the slopes ranging from 17° to 31° (Fig. 2). Due to the steep slopes and impermeable substrates there is a fast response to heavy rainfall. The events which occurred in 11-14 July 1999 on almost all of

Retezat Mountain's torrents were triggered by intense rainfall during a period of three days (241 mm in 20.4 hours), causing enormous economic damages (≈ 800000 \$) and 13 human life losses.

As it is a part of the Retezat National Park protected area, the study site has not been under a high anthropogenic influence. The torrent cone is crossed by the only access road to this area which connects the Poiana Pelegii site to the Gura Apelor Lake. After the event in 1999, many sectors of the

road have been repaired and even moved and many streams were consolidated near the confluence (through deflection dam and reinforced-concrete frame constructions). In the lowermost part of the cone a small bridge was built as the road had been frequently destroyed by repeated debris flow events.

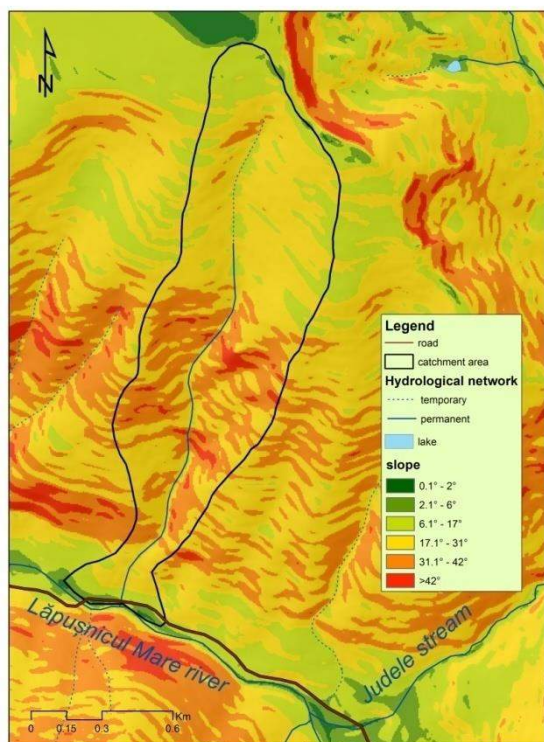
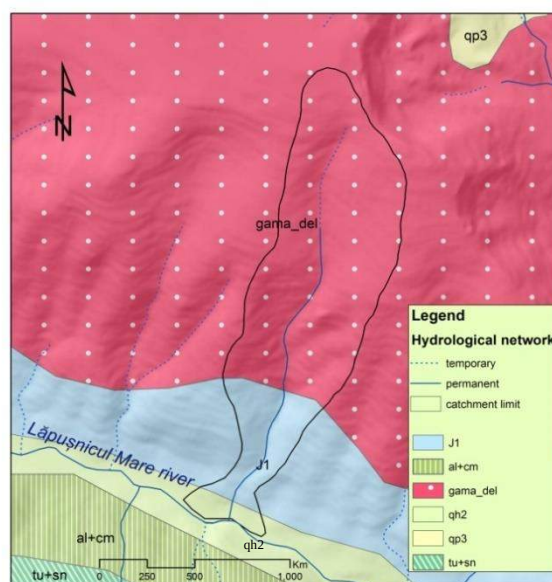


Fig. 2. Declivity map of the catchment area



J1 – conglomerates, sandstones, clays; **al+cm** – limestones, calcareous-marls, sandstones; **gama_del** – granodiorites; **qh2** – gravels, sand, claysh-sand; **qp3** – glacial deposits; **tu+sn** – sandstones, conglomerates.

Fig. 3. Geological map of the catchment area

3. Methodology

In a first analytical step, we used different cartographic materials (topographic map 1:25000, orthophotoplans 1:5000, etc.), field observations and other expertise, in order to gather detailed information about the study site. Based on the acquisition of a detailed database, the use of GIS techniques provided the thematic maps necessary for the analysis. For a more accurate representation of the geographical features and for a more precise observation of the value changes which arise in reality, the main morphometrical characteristics of the terrain surface were calculated based on a DEM with a 5 m resolution.

In addition to this, archival records were consulted to gain data regarding previous occurrences of major events at the study site or in the nearby area.

A number of 122 increment cores from 60 affected trees bordering the transport channel of the torrent were extracted in this study (Fig. 5). Using a Pressler increment borer, two increment cores were usually extracted per tree, except for the ones which presented multiple injuries. All of the sampled trees exhibited obvious evidence of debris flow impact on the stem but also on the roots and crown (Fig. 5, b and c). Most of them presented visible scars on the stem, especially on the waterside part. Two cores were extracted per tree, one close to the edge of the wound and the other on the opposite side of the stem. In the case of tilted trees, the samples were also taken from both sides at the height of the inclination. Moreover, for each sampled tree, additional data was gathered including description of the type of disturbance, its position, tree diameter, tree height and other useful information for the analysis.

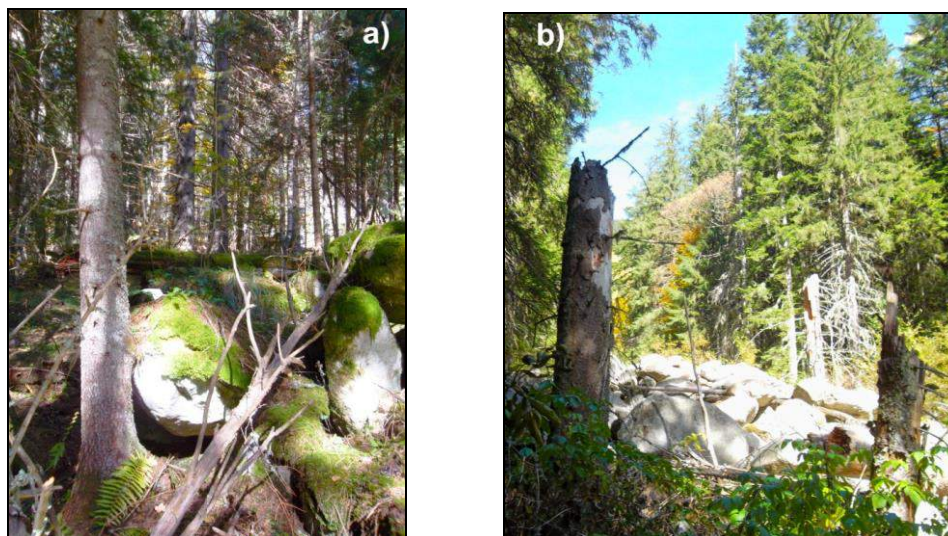


Fig. 4. a) Damaged tree due to boulder impact;
b) decapitated trees by mechanical impact and debris storage on the streambed

In addition to this, 20 undisturbed *Picea abies* trees were sampled which have not been affected by debris flow activity or other geomorphological processes. According to the procedure, the undisturbed trees were sampled at breast height, parallel to the contour line.

In the laboratory, samples were prepared and analysed according to the procedure described by Stokes and Smiley (1968), Braker (2002) and Stoffel & Bollschweiler (2008). In a first stage the samples were fixed on wood mountings, dried up and sanded in order to obtain a clear surface

necessary for detailed anatomical observations. After counting the rings of each core, tree ring widths were measured with 0.001 mm precision using a LINTAB measuring station and TsapWin™ software. Growth curves of the affected trees were cross-dated with a reference chronology of undisturbed trees so as to obtain a normal growth condition of the investigated site. Afterwards, each sample was visually examined using a binocular microscope device in order to identify the growth anomalies and the year in which they appeared.

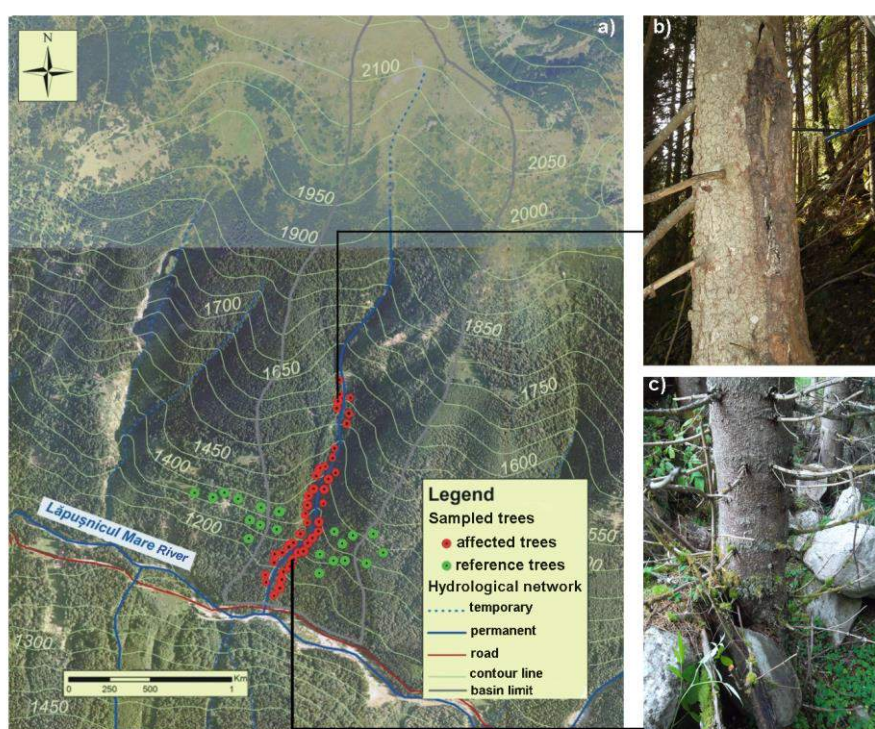


Fig. 5. a) Position of the sampled trees; b) and c) - severe disturbances at the stem and roots level

4. Results

The sampled trees have an average age of 76 years, the oldest one having 188 years, while the youngest one is only 28 years old (Fig. 6). The age structure of the sampled trees is heterogeneous and, therefore, we could not establish a spatial distribution of them. All sampled trees responded with different types of disturbances (Table 1). In total 556 growth anomalies were identified, the most frequently encountered being abrupt growth changes figured either by suppressed or released ring width in 316 and 42 cases, respectively. Another 172 anomalies were formed in the form of tangential rows of traumatic resin ducts (TRD), while compression wood (CW) was only occasionally found, in 26 cases.

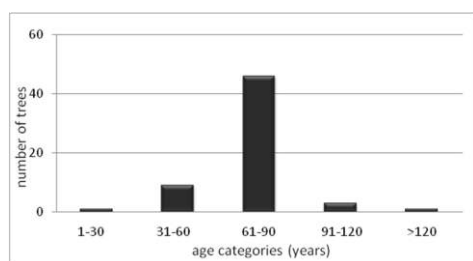


Fig. 6. Representation of the age categories of the sampled trees

Growth disturbances	total	%
Growth suppression	316	57
TRD	172	30
Growth release	42	8
Compression wood	26	5
Total	556	100

Table 1. The total number of growth disturbances found in the sampled trees

The event chronology attained through these reactions of the affected trees allowed us to reconstruct the following chronological sequence of debris flow occurrences in the investigated area. In 2000 a number of 30 trees reacted, from which there were 18 cases of tangential rows of traumatic resin ducts and 23 severe growth reductions. In 11 cases, the anomalies were both in form of TRD and in form of growth reduction. In the following 3 years another 49 anomalies were found. Another reconstructed year event was 1989, when 11 growth anomalies were encountered most of them being represented by growth suppression in 10 trees and traumatic resin ducts in 1 tree. Between 1962 and 1968, various types of anomalies such as traumatic resin ducts and growth reductions were identified in each year. This was considered a peculiarity, as in most cases after an event trees can react in the same

year or in the following years, but not so far in time. In 1965 only 5 anomalies were discovered, but in the next year 10 anomalies were found. Also in 1961, 4 trees reacted through growth ring suppressions and compression wood. In the next 3 years, there were discovered in total other 15 reactions. In 1954, 7 trees reacted in form of 5 tangential rows of traumatic resin ducts (TRD), 1 growth reduction and 1 case of compression wood. Further in time, in 1949, 7 growth anomalies were discovered, mostly in the form of suppression wood, in 6 trees, 1 TRD and 1 case of compression wood. In the following year, 9 additional disturbances were identified, from which 7 cases of TRD and 2 suppression growths.

After almost a decade of reduced activity, in 1938, 5 trees presented TRD as growth anomalies. Earlier, in 1935, some growth anomalies were identified in the form of TRD in 6 cases and one case of growth suppression. Also related to this event can be considered other 7 anomalies found in 1936, from which 4 cases of TRD and 2 growth reductions. In 1929, 7 trees presented various forms of disturbances as TRD, growth suppression and growth release. To this event year the next two years can be also added, in which other 12 disturbances were found; in all 3 years in which trees reacted, in total 19 growth ring disturbances were counted.

As we go further in time, there are less available tree-ring data for the reconstruction, due to the young age of the majority of the sampled trees. The oldest disturbances identified were in 1866 via TRD, which continued to form even in the next year. Despite that, because of the limited number of trees available for the reconstruction, this year cannot be introduced in the review.

To this event chronology, another 3 events which might have been at a much smaller scale were added, as there were only few trees which reacted to them. Accordingly, the years 2010, 1992, and 1982 were also introduced in the analysis as there could be found some disturbances, many in the form of TRD and abrupt growth changes and a few cases of compression wood. In 2010, 6 TRD, 2 growth suppression and 2 growth releases were revealed as well as 4 other anomalies found in the next year. In 1992 and 1993, 13 anomalies were found, from which 4 TRD and one growth suppression for the first year and 4 TRD, 2 growth reductions, 1 growth release and one compression wood for the second year. In 1982, 8 anomalies via 7 growth suppression and one TRD were encountered, while in the next year 10 trees reacted by forming 7 growth reductions, one TRD, one growth release and one compression wood. In 1980, 7 anomalies were identified, out of which 3 TRD and 4 growth suppressions of the rings.

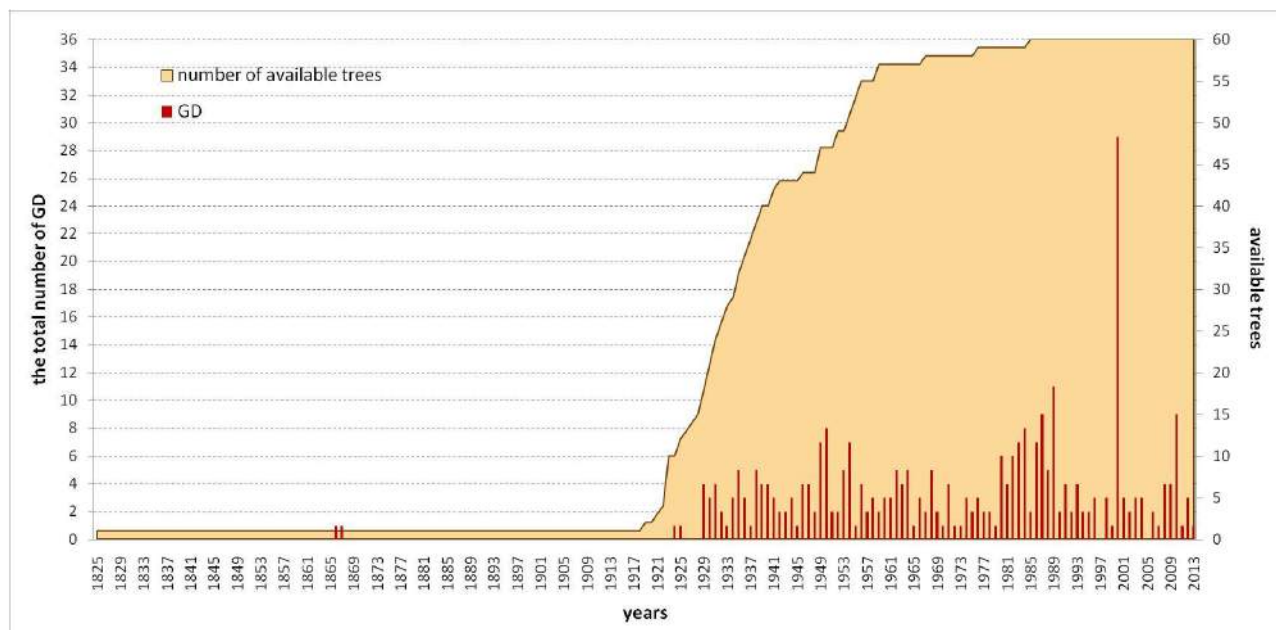


Fig. 7. Representation of the total number of disturbances found in each year and the number of available trees

The analysis of the 556 growth anomalies found in the 60 *Picea abies* sampled allowed the dating of 9 major debris flow events and another 3 of much smaller magnitude. The oldest event identified and introduced in the analysis was in 1929 and the newest occurred in 2010. As one can notice, debris flow activity is quite uniformly distributed, periods of repeated occurrences are followed by phases of no activity or at a much smaller-scale. According to Jakob *et al.* (2005), the channels of the torrents need to be recharged with debris supply in order to allow the debris flow development. Furthermore, the reconstruction of events dating prior to 1920 is limited by the absence of tree-ring data, due to the young age of the sampled trees.

5. Discussions

Using dendrogeomorphological methods for the temporal reconstruction of debris flow activity which regularly manifests itself on a torrent situated in the southern slope of Retezat Mountains, 9 major past events and other 3 smaller ones have been identified. The dendrogeomorphological reconstruction of debris flow occurrence was limited by the young age of the sampled trees and by the deprivation of other ones which were severely affected by rot or dryness. There were few trees which exceeded 100 years, the average age of the sampled trees being only 76. As a consequence, all the disturbances found prior to the 1920s could not be used in the assessment.

This temporal reconstruction has to be seen as a minimum frequency of past debris flow activity, as

it depends on the probability of a tree being affected by the manifestation of a particular event in the past. According to this, only those trees which were directly hit by boulders and rocks transported by the mass-movement of the debris flow could react by forming different kinds of growth disturbances. Moreover, as debris flow magnitude decreases and the material remains in the channel, fewer trees can be affected and may, therefore, not be identified by dendrogeomorphological methods.

Comparing tree-ring data with local archival records one can notice a quite confident relationship between them. During the reconstruction period, six major flood events were registered which occurred in the vicinity of the studied area. Most of them were caused by massive amounts of rainfall of high intensity. The availability of a massive amount of loose rock, corroborated with the preponderance of steep slopes and a large amount of water make excellent conditions for the debris flow to be configured. Summer thunderstorms which are considered to be one of the main triggering factors of debris flows are frequently recorded in this site (135.8 mm in 7 hours, 11-12.07.1999). Earlier registered events in the neighbourhood area were noted in archives as they had caused major damages to infrastructure or even life losses. However, smaller scale events might not have been registered.

Tree-ring data coincide very well with archival records of the event which occurred in July 1999, but most of the trees affected then reacted only in the next year of vegetation. Given the high number of growth disturbances identified in 2000 to which another 49 anomalies found in the next 3 years of

vegetation were added, one can deduce that the event had a high magnitude which caused severe damages to the riparian vegetation.

Between 1962 and 1968 there various types of growth anomalies were discovered in each year, which was considered a peculiarity due to the long period of reactions. As the available archival data were investigated for this period of time in what concerns debris flow or flash-flooding records in adjacent rivers, two major events were found, one in 07.09.1961 and another in 04.06.1965. As observed so far almost in every case, anomalies continued to be formed in the following years of vegetation after a major event. In the case of the event which occurred in September 1961, it is presumed that many growth disturbances of the affected trees appeared only in the following year, because the event manifested at the end of the vegetation period.

The last archival record found on flooding in the vicinity of the studied area was from 18.08.1948, when a major flood on Râul Mare River occurred. Related to this event might be the growth anomalies which were found in the next years of vegetation, in 1949 and 1950.

As additional archival data on major events occurring in this area could not be found, dendrogeomorphological methods may be the most precise and accurate way for dating geomorphological processes.

The trees which grew up near the streamline were either decapitated or eliminated, as their rotten and dry trunks and branches can still be seen in the channel or on the cone. Anthropogenic activity was not detected along the torrent channel, but some interventions have been observed in the lowermost part of the cone. After the event in July 1999, different protection measures have been taken, especially at the bottom of the torrent, so as to prevent the destruction of the road which crosses the cone. The bank of the active debris flow channel was reinforced at the apex of the cone, near the confluence with the Lăpușnicul Mare River. In addition to this, the road was consolidated and a bridge was built to protect it against any geomorphological or hydrological phenomena. Other necessary defensive works were not taken into consideration. In order to prevent the triggering of debris flows, the consolidation of sediment deposits needs to be considered as well as torrent bed reinforcements, dams and debris flow breakers, to hold back large boulders.

In conclusion, debris flow activity in the studied area appears to be rather influenced by meteorological events, as debris supply cannot be considered a limiting factor, due to the high

availability of loose material. Therefore, particular characteristics of some weather events might trigger a debris flow. As it was pointed out by Armanini (2005), the concomitance of a period of successive rain events or an intense rainfall preceded by a long period of sediment saturation are favourable conditions for debris flow initiation. Unfortunately, this aspect decreases the predictability of this kind of phenomena, posing as a real threat to human safety. These processes have been causing many fatalities and economic damages and other negative ecological effects and, therefore, should not be underestimated.

6. Conclusions

The dendrogeomorphological analysis used in this study allowed the reconstruction of 12 events, covering almost a century. The study was conducted on a torrent located on the southern slope of Retezat Mountains. The results of this study reveal that the temporal reconstruction of past debris flows based on the interpretation of tree-ring data, coincide with archival records of meteorological and hydrological events. Since 1948, almost all of the event-years reconstructed through dendrogeomorphological means were confirmed by major events recorded in the archival data.

Despite the young age of the trees available for analysis, which limited the reconstruction of debris flow activity, the dendrogeomorphological method proved to be a reliable and valuable tool in the acquisition of data on former events at the study site.

The low predictability of debris flow occurrences, associated with their high destructive power, led to some unfortunate events which caused many economic damages and even human losses in Retezat Mountains area. Even if the event from 1999 led to the application of some measures which consolidated the torrents and the road, there are still some other actions that need to be taken into consideration. Smaller scale events manifesting within the channel are often neglected by the authorities. The temporal reconstruction of debris flow activity is important for establishing the process frequency required for hazards and risk assessment databases. In addition, a better understanding of past and potential future debris flow occurrences is necessarily imperative, in order to take early measures and to prevent negative consequences.

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GEMAS : une application Visual C# pour la gestion automatisée du découpage de l'espace en mailles régulières géoréférencées

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Résumé. Traditionnellement, les facteurs de changement du paysage sont étudiés par élaboration de carte de synthèse à partir de photo-interprétation de documents divers, par extraction d'informations à partir de traitements de l'imagerie satellitale ou par combinaisons d'informations extraites de documents variés dans un SIG ; ces combinaisons, basées sur l'élaboration de couches d'informations extraites à partir de documents divers, ne permettent pas toujours d'aboutir à une analyse fine de tout point de l'espace. Pour pallier à ces inconvénients, est apparue récemment l'application à la géographie de l'analyse inspirée du concept d'automate cellulaire utilisée en électronique digitale essentiellement dans la commande des panneaux d'affichage. C'est le principe du découpage en mailles régulières (ou analyse de grille) utilisée d'abord pour le suivi de l'occupation de l'espace urbain utilisée par E. Dubos-Paillard et al. (2003) qui considèrent que la croissance urbaine, mais aussi de nombreux autres processus géographiques, peuvent s'expliquer par des règles spatiales simples, formulées à partir de nos connaissances empiriques mais néanmoins explicatives de la dynamique spatiale si elles résultent de la pratique sociale. Les premières utilisations de l'analyse de grille ne donnent pas la possibilité de générer un découpage en grille à partir d'un fond cartographique ou image géoréférencée ; ils ne permettent pas en particulier de récupérer de façon automatique l'information contenue dans l'image résultant d'un traitement numérique sur couches raster (NDVI par exemple, combinaisons, classification). Une première solution est proposée par A. Abdellaoui et al. (2010) consistant à transformer l'image résultat en couche vectorielle de résolution égale au pixel de l'image. Cette solution présente encore quelques difficultés d'application, en particulier le fait que la résolution est imposée par la résolution de l'image et peut ne pas correspondre à des thèmes de travail où cette résolution n'est pas adaptée (trop grande ou trop petite). Dans le présent travail, nous avons développé sous Visual C# un algorithme de lecture des composantes RVB d'une image géoréférencée (résultat d'un traitement numérique d'une image satellitale multispectrale) sur laquelle est construite une grille avec une maille choisie par l'utilisateur. Ces valeurs sont récupérées dans un fichier Excel qu'il est possible d'intégrer à un SIG.

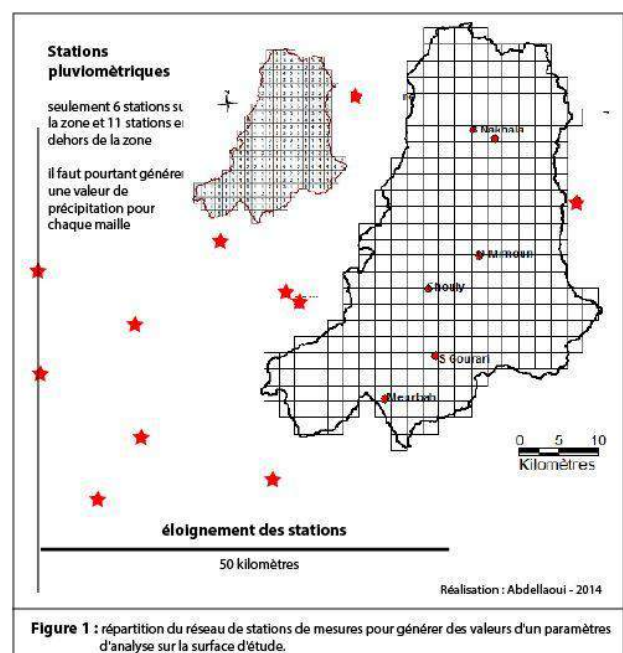
Mots clés : analyse de grille, analyse du paysage, image satellitale, SIG.

1. Introduction

Traditionnellement, les facteurs de changement du paysage sont étudiés i) par élaboration de carte de synthèse à partir de photo-interprétation de documents divers, ii) par extraction d'informations à partir de traitements de l'imagerie satellitale ou iii) par combinaisons, dans une solution SIG, d'informations extraites de documents variés ; ces combinaisons, basées sur la réalisation de couches d'informations, ne permettent pas toujours d'aboutir à une analyse fine et régulière de tout point de l'espace.

L'élaboration de carte de synthèse à partir de documents divers est généralement confrontée à deux types de problèmes :

i) l'échelle des documents sources induit automatiquement une absence d'information pour un nombre de points de l'espace d'autant



disponibles en téléchargement avec un pas de 1 kilomètre sur la France entière et 200 mètres sur chaque région. Le Muséum National d'Histoire Naturelle propose également une grille-type pour effectuer un calcul, par carreau de 5 ou 10km, du nombre d'espèces d'un certain type de plantes ou d'animaux.

Notons enfin qu'Arrouays et al. (2001) affirment, dans un travail dont l'objectif est de tester différentes configurations d'implantation d'un réseau de surveillance des sols, que la sélection de type grille systématique est la seule qui permette d'atteindre les objectifs tout en offrant la garantie de ne pas être biaisée *à priori*. Ils ajoutent cependant qu'elle présente un inconvénient majeur du à son coût ; pour optimiser la mise en place d'un tel réseau, il convient donc de déterminer la densité minimale acceptable et d'en chiffrer le coût.

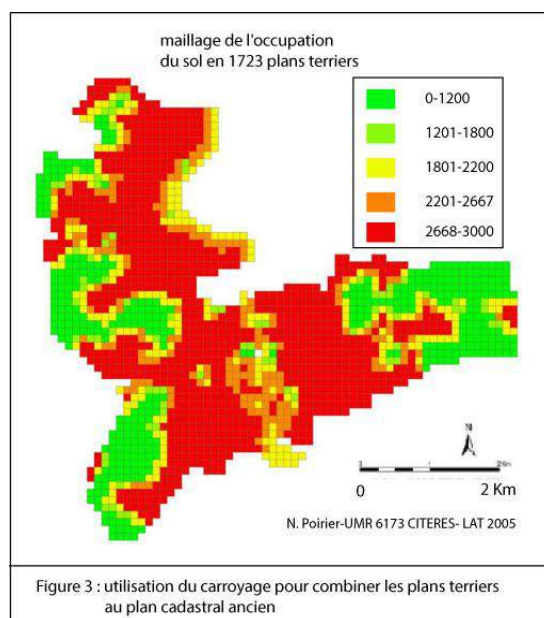
Le découpage en mailles offre de nombreux avantages dont nous citons les trois principaux suivants :

- i) Bien que le format vecteur soit généralement choisi comme base de traitements car plus familier pour les utilisateurs SIG, les calculs sur raster sont parfois plus appropriés car le carroyage permet de transcrire au format vectoriel des méthodes rasters ; Il est en effet tout à fait possible d'effectuer des dénombrements, de calculer des moyennes, des écarts-types au niveau de chaque carreau, ce qui s'apparente aux calculs focaux utilisés sur les rasters.
- ii) La transformation de données fines, précises sous la forme de carreaux permet de vulgariser la donnée et de la simplifier. Les mailles peuvent alors être confrontées à la fois à un niveau spatial (un carreau par rapport à ses voisins : analyse par clusters), de même que dans le temps (état d'un carreau dans un état antérieur et dans un état actuel ; par ex. étude de l'évolution de la population). Par ailleurs, il s'agit d'un mode de visualisation efficace qui "élimine le bruit" et découpe le territoire en unités égales et comparables.
- iii) Avec le carroyage il est possible d'associer plusieurs dimensions aux carreaux, comme autant de colonnes ou d'attributs. On pourra alors adjoindre à chaque carreau des valeurs issues de différents domaines : environnement, transport, habitat, et de différents types : quantitatif, qualitatif, ordinal. On pourra faire apparaître différentes thématiques sur les choroplèthes au gré des besoins.

2. Quelques exemples d'analyse du paysage par mailles

2.1. Le découpage du territoire par mailles pour combiner les plans terriers (1723) au cadastre ancien (1829)

Pour ce travail deux types de sources primaires de documents sont utilisés : les plans terriers et le cadastre napoléonien, tous deux non géoréférencés ; de plus la géométrie des plans terriers n'est pas adaptée à une solution SIG (caractère schématique et approximatif des plans dressés en 1723). Après vectorisation des documents (format polygonal des objets géographiques) puis divers traitements de préparation des données (dont le géoréférencement), il a fallu découper le parcellaire napoléonien selon l'emprise spatiale des plans terriers, conformément à la figure 3. Cette opération a consisté en considérant la couche représentant l'espace documenté par les plans terriers comme « pochoir » aux limites duquel le cadastre ancien a été découpé. On obtient ainsi deux couches vectorielles de surface et d'emprise rigoureusement superposables. Les résultats de cette approche globale paraissent en contradiction avec le schéma généralement admis d'un recul des espaces boisés au profit des espaces cultivés.



Pour dépasser cette approche globale, l'auteur a réalisé une analyse par mailles qui permet une « modélisation et discrétisation de l'espace en mailles géométriques régulières, carrées de 100 m de côté. Ce découpage a l'avantage de réduire la variabilité parcellaire observable sur chacune des deux couches à une grille standardisée exactement superposable pour chacun des deux états du paysage.

2.2. Le modèle SPACELLE : analyse de l'évolution urbaine par automate cellulaire

On fait généralement remonter l'histoire des automates cellulaires aux années quarante et à Stanislas Ulam. Ce mathématicien s'est intéressé à l'évolution de constructions graphiques engendrées à partir de règles simples. La base en était un espace à deux dimensions divisé en « cellules », soit une sorte de feuille quadrillée. Chacune des cellules pouvait avoir deux états : allumé ou éteint. Partant d'une configuration donnée, la génération suivante était déterminée en fonction de règles de voisinage. Par exemple, si une cellule donnée était en contact avec deux cellules allumées elle s'allumait sinon elle s'éteignait.

L'expression « automate cellulaire », en tant qu'ensemble constitué d'un ensemble de cellules régulières liées par des lois topologiques et couvrant un espace géographique d'analyse, ne doit pas nous renvoyer à la seule idée de découpage de l'espace en mailles régulières ; elle doit par contre nous renvoyer également vers le concept de fonctionnement non mathématique, mais plutôt spécifiquement informatique. L'objet de la théorie des automates est de produire le fonctionnement de l'automate suite à l'exécution d'une série d'instructions écrites dans un certain *langage* et produisant des *actions* élémentaires d'une *machine* virtuelle ou réelle.

Pour Wolfram (1984) un automate cellulaire est un « système dynamique de cellules interagissant localement de manière simple avec un comportement global complexe ». Les automates cellulaires, basés sur un découpage du paysage en mailles, ont deux caractéristiques principales : i) une topologie définie par leur arrangement dans un espace linéaire, surfacique ou volumique, et ii) des effets de voisinage et une sémantique décrits par la liste de leurs états et les règles de transition d'un état à l'autre.

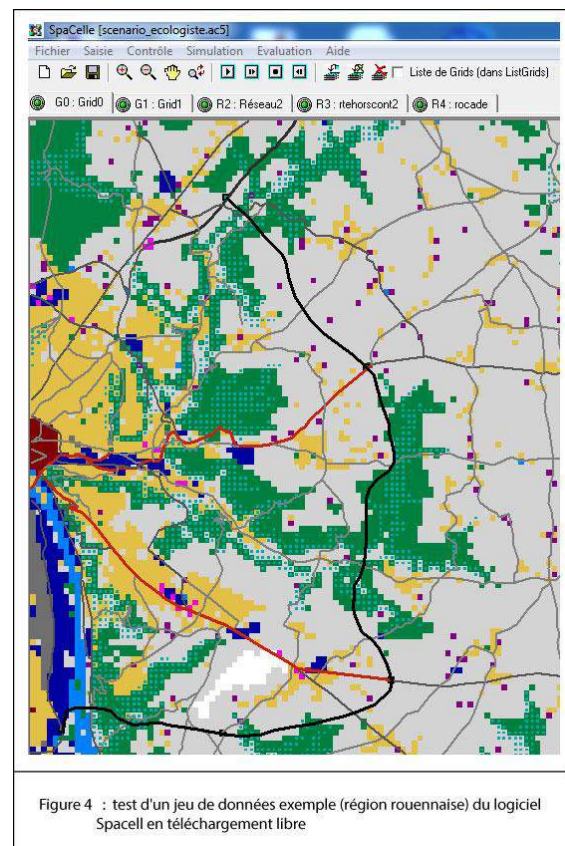
De nombreux travaux ont montré la pertinence de l'utilisation des automates cellulaires dans des domaines aussi variés que la physique fondamentale, la croissance végétale, la biologie, la robotique, la dynamique des fluides, etc (Wolfram, 2002).

Le modèle SpaCelle (Dubos-Paillard et al. 2003) est inspiré, d'une part, de l'automate du jeu de la vie qui définit la naissance et la mort des cellules et, d'autre part concernant la modélisation géographique, du modèle de White et Engelen (1993) pour la ville de Cincinnati. Dans ce modèle, l'état de chaque cellule évolue en fonction des états présents à l'intérieur d'un disque autour de la cellule concernée. De ce fait, seules les cellules les plus fortes, confrontées au hasard des combinaisons environnementales, survivent.

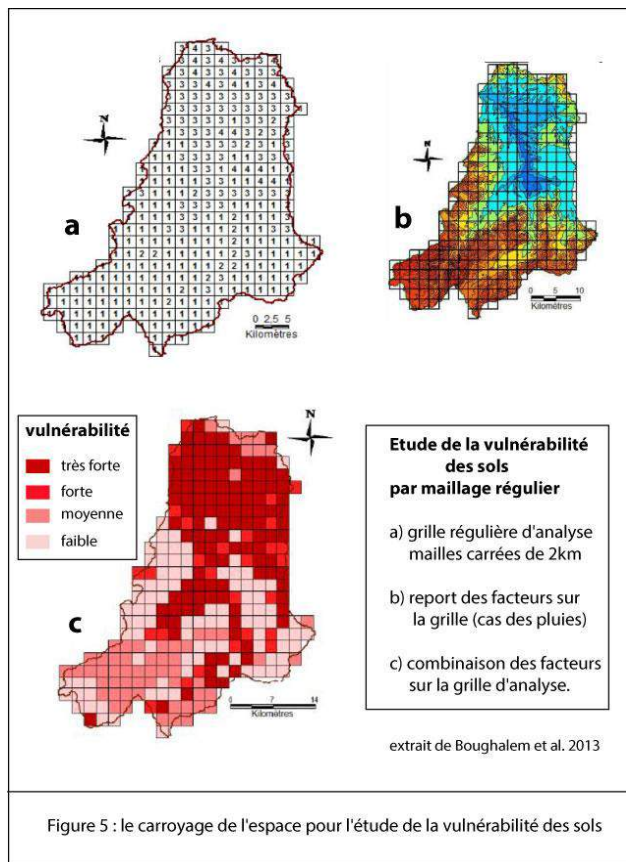
L'ensemble S des états (ensembles des valeurs descriptives de l'espace de la cellule, par exemple un type d'occupation du sol) est défini par l'utilisateur. Une cellule possède, à chaque instant, au plus un état, sinon elle est *vide* et donc éliminée dès le départ du domaine d'étude. Les cellules (non vides) sont regroupées en *classes ayant un même état*. À chaque classe C est associé son *état de vie* s , mais aussi une *espérance de vie*, et un *état de mort*. Pour chaque classe, l'état et la durée de vie ainsi que la mort sont définis à travers une *règle de vie* exprimée par l'utilisateur.

De façon pratique, l'occupation du sol est numérisé en 15 postes à partir de carte au 1/25000^e avec zonage du SDAU sur trois dates d'étude ; puis un carroyage (grid) précis doté de mailles de 150 m de côté est construit sous ArcView. L'état de chaque cellule est défini en fonction de l'occupation prépondérante, excepté lorsque la cellule contient un élément linéaire (route, voie ferrée ou cours d'eau majeur) qui prévaut sur les modes d'occupation surfaciques. Enfin les cellules initiales de l'automate représentant les situations observées aux dates choisies sont générées par importation dans SpaCelle du carroyage d'ArcView.

La figure 4 donne une idée de résultat sur l'espace rouennais.



2.3. Analyse de l'érosion du sol par mailles régulières



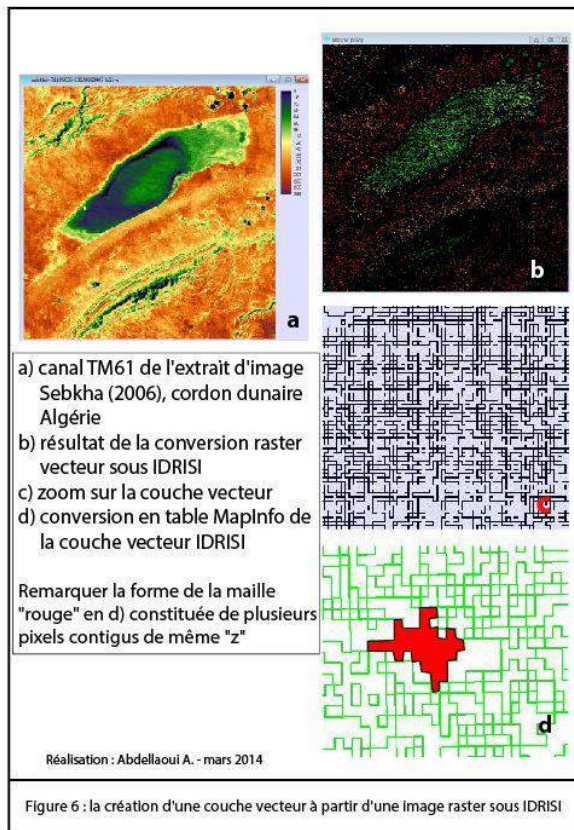
Le phénomène d'érosion des sols fait intervenir plusieurs facteurs estimés à partir de plusieurs sources de données à des échelles et des résolutions très différentes conduisant, après vectorisation, à la génération d'objets géographiques de formes complexes et de superficies variées. Afin de réaliser une analyse homogène sur l'espace, Boughalem et al. (2013) ont proposé un découpage en mailles carrées régulières de 2000m de côté ; tous les logiciels dédiés SIG permettent par la suite de créer une grille vectorielle (polygones) correspondant au découpage choisi. Chaque maille est affectée de quatre variables V_i ($i=1,4$) correspondant aux quatre facteurs f_1, f_2, f_3, f_4 , pris en compte dans l'analyse ; les valeurs des variables traduisent l'importance du facteur dans le phénomène. La combinaison des facteurs se fait alors aisément à partir d'une solution SIG classique ; dans ce cas d'étude, les auteurs ont utilisé MapInfo. Les valeurs des variables sur les mailles sont ici saisies de manière semi manuelle qui rend le travail de préparation légèrement fastidieux. Mais la grille une fois remplie, toutes les combinaisons de couches et analyses deviennent rapides. Les résultats sont très facilement interprétables comme on peut le constater sur la

figure 5 qui donne en (c) la vulnérabilité des sols en quatre classes (très forte, forte, moyenne et faible).

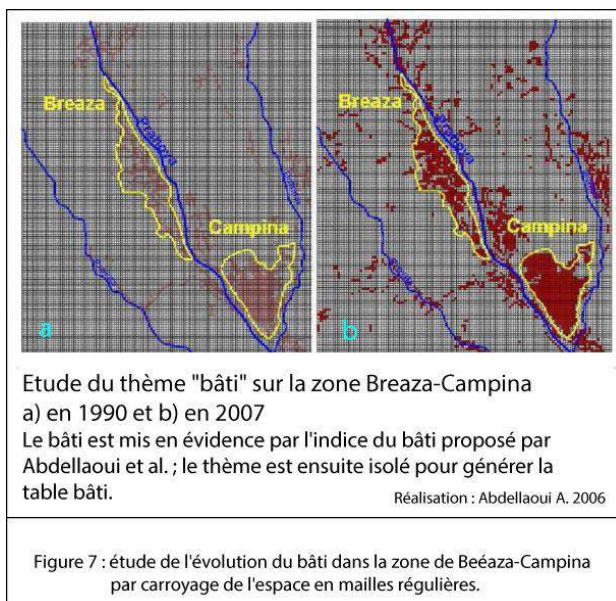
2.4. Le passage du pixel à la maille

Certains logiciels de traitement de l'image satellitale offrent des modules de conversion d'une couche raster (image) en une couche vecteur points (1 objet point pour chaque pixel), lignes ou polygones (théoriquement pour chaque pixel est généré un polygone ; concrètement, une agrégation est opérée sur la valeur du pixel : si deux pixels contigus ont même valeur, ils donnent lieu à la création d'un polygone unique. Cette propriété représente un handicap sérieux dans la génération d'une grille régulière à mailles carrées de longueur de côté fixe. La figure (6) montre la forme de grille générée par cette méthode. Il est facile de comprendre que deux thèmes différents (végétation à deux dates ; végétation et sol) génèrent deux grilles complètement différentes impossible à combiner. Pour pallier à cet inconvénient, Abdellaoui et al. (2010) ont proposé une chaîne de traitements en sept étapes :

- i) rééchantillonnage de toutes les images concernant la zone d'étude en utilisant comme image pivot celle de meilleure résolution ; en réalité, il ne s'agit pas d'une opération classique de rééchantillonnage car, en plus du fait que les images n'ont pas la même résolution, on observe un décalage spatial entre les pixels de d'images à des dates différentes comme on le voit sur la figure 6 pour les extraits d'images de la zone de Breaza de 1990 et 2007.
- ii) création d'une image « init » (raster) de même propriétés (même résolution, mêmes nombres de lignes et de colonnes) que l'image rééchantillonnée ; dans l'image « init » chaque pixel est affecté d'une valeur z différente de celles de ses 24 plus proches voisins ;
- iii) création d'une couche vecteur G_{init} à partir de l'image « init » en utilisant le module de conversion de raster en vecteur (polygone) ;
- iv) chaque image Ω , résultat d'un traitement est remplacée par son produit avec l'image « init » selon la formule suivante : $\Omega \rightarrow \Omega * \text{«init»}$;
- v) création d'une couche vecteur G_Ω à partir de chaque image Ω en utilisant le module de conversion de raster en vecteur (polygone) ; la figure 6 montre en exemple les couches « bâti » de 1990 et 2007 ;
- vi) conversion des couches « vecteur » $V_{init}, V_{\Omega i}$ aux formats adéquats SIG (mif, shp) ;
- vii) mise à jour de V_{init} à partir des $V_{\Omega i}$; traitements. La figure 7 montre une synthèse des thèmes « bâti » et végétation entre 1990 et 2007.



Ce travail avait permis d'introduire une séquence d'automatisation d'affectation des valeurs des variables aux mailles par transformation du raster (ensemble des pixels) en une grille où chaque pixel devient une maille du carroyage. On obtient ainsi un carroyage de même résolution que celle des images satellitaires initiales ; il faut cependant noter qu'il est toujours possible d'opérer un rééchantillonnage si l'on décide d'opter pour une dimension de maille différente. La difficulté de l'algorithme réside dans la génération de la grille de départ.



3. Le modèle GEMAS

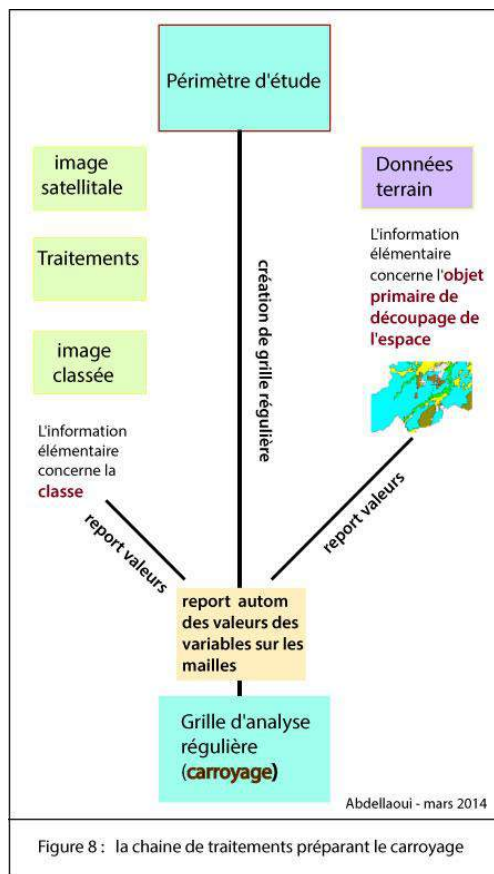
3.1. Rappels méthodologiques

Dans ce qui précède nous avons montré, en nous appuyons sur de nombreux travaux, que :

- L'analyse par maille est intéressante à plus d'un titre pour l'étude du paysage car cette approche permet, en particulier: i) un balayage régulier de l'espace géographique de travail ; ii) une combinaison et une comparaison faciles des couches, c'est-à-dire des variables descriptives de l'espace ; iii) d'effectuer sur les variables les opérations classiques des rasters, une maille de découpage pouvant être assimilée à un pixel et les variables à des composantes d'une image multibande.
- L'analyse par mailles est déjà utilisée par plusieurs auteurs sur des thèmes très variés.
- Cependant, le problème essentiel qui persiste pour rendre cette approche totalement opérationnelle concerne le remplissage mailles des mailles par les valeurs des thèmes à partir d'un résultat de traitements d'images satellitaires.

Dans une approche opérationnelle, on devrait pouvoir mettre en place une chaîne de traitement se rapprochant du schéma de la figure 8. Cette figure met en évidence les deux voies principales d'acquisition des informations de base sur le territoire d'étude : i) l'imagerie satellitaire d'une part qui permet d'obtenir des couches chacune constituée de classes d'un thème donné ; ii) les données terrain collectées à partir de mesures ou d'enquêtes extrapolées ou moyennées sur des zones géographiques d'un découpage particulier de l'espace (thématique ou administratif). Le schéma montre également l'étape indispensable de report des valeurs d'appréciation des divers facteurs d'analyse sur les mailles du carroyage. Il n'y a pas encore de module spécifique permettant de réaliser cette étape de manière automatique dans les logiciels de traitement d'images satellitaires ou de SIG.

Des algorithmes particuliers sont développés ici ou là pour répondre à des problèmes spécifiques. Les grandes institutions publiques fournissent, quant à elles, des données sur un découpage de l'espace en mailles ; mais les agences de cartographie ou de SIG ne fournissent pas encore des carroyages susceptibles de remplacer ou de compléter les découpages administratifs traditionnels (découpage à la commune, au département, au pays).



3.2. Stratégie de l'algorithme GEMAS

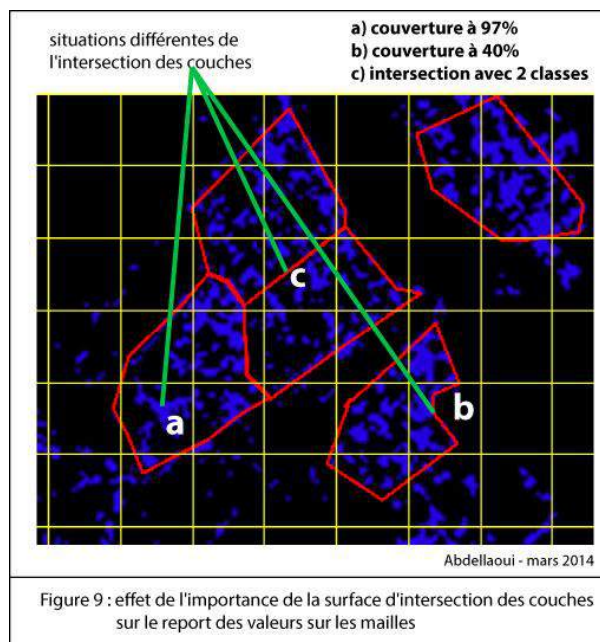
Lorsque les informations nécessaires pour l'étude envisagée sont issues d'enquêtes, il est généralement possible de s'adapter aux découpages administratifs conventionnels ; il est alors possible de reporter les valeurs des objets géographiques du découpage sur les mailles d'une grille particulière d'analyse. Il y a lieu de noter cependant que ce report de valeurs dépend grandement des surfaces d'intersection des mailles du carroyage avec les objets géographiques de la couche thématique (ou administrative) ; on se trouve alors devant le dilemme du choix de seuil d'affectation : à partir de quelle couverture, la maille prend-elle la valeur de l'objet ? La figure 9 illustre ce problème : en a), il n'y a pas d'ambiguïté, la maille prend la valeur de l'objet ; en b) on peut hésiter avec une couverture à près de 40% ; en c) il y a ambiguïté totale car la maille intersecte deux objets différents avec pratiquement un taux égal à 50%.

Si les informations sont issues de points de mesures (données climatiques par exemple), il est également possible d'interpoler sur un carroyage ou un ensemble de points à l'intérieur de la zone d'étude ; il est alors relativement aisé de construire un algorithme de balayage de l'espace de travail par une fenêtre de dimensions égales à celles de la

maille de carroyage pour calculer une moyenne des valeurs des points à l'intérieur de cette fenêtre mobile et d'affecter cette moyenne à la maille recouverte par la fenêtre.

Dans l'algorithme GEMAS, nous nous intéressons surtout au cas où les informations à introduire doivent être extraites du résultat d'un traitement d'images satellitaires. Ce résultat est généralement obtenu sous l'une des formes suivantes :

- Une image classée où les pixels sont affectés à l'une des N classes (N thèmes) présentes
- Une image où un thème particulier est mis en évidence avec un algorithme spécifique (indice de végétation, indice du bâti, indice du voile sableux par exemple) ; le thème (thème global végétation) peut apparaître avec plusieurs « nuances » traduisant la réalité de plusieurs sous-thèmes (différentes essences végétales, différentes densités d'espace construit) ; ici nous ne sommes pas en présence d'une image classée avec un nombre fini de classes prédéterminées mais plutôt d'un ensemble continu de « gradations » sur un intervalle de valeurs
- Une image binaire traduisant la présence (pixel à 1) ou l'absence (pixel à 0) d'un thème



Dans chacun des trois cas, il est possible de récupérer une valeur pour chaque pixel (numéro de classe, valeur du sous-thème ou présence-absence du thème).

En réalité ce n'est pas la valeur d'un pixel qui nous intéresse mais une valeur significative d'un ensemble de pixels présents dans une fenêtre d'image équivalente à la maille du carroyage. Pour

cela plusieurs stratégies peuvent être adoptées, parmi lesquelles :

- Moyenne des valeurs des pixels présents dans la maille ou
- Valeur du pixel central de la maille

Dans cette première version de GEMAS, nous avons adopté la seconde stratégie.

3.3. La plate forme de programmation

Pour développer GEMAS, nous avons utilisé la plate forme C#. Cette plate forme a été utilisée par plusieurs auteurs dans la production d'atlas interactifs. A titre d'exemple, P. Apparicio et V. Petkevitch proposent en 2006 une approche simple basée sur le SVG, le C# et l'ASP.Net pour déployer rapidement et efficacement des atlas électroniques et interactifs sur Internet. Cette approche repose sur le langage de programmation C# afin d'utiliser trois technologies : le SVG, l'ADO.Net et l'ASP.Net. ; elle a ainsi deux avantages majeurs : une production cartographique souple et rapide et la possibilité de développer rapidement et efficacement des fonctionnalités de cartographie interactive. Le modèle de déploiement des atlas interactifs qui est présenté ici

Rappelons que C# est un langage de programmation orienté objet à typage fort, créé par la société Microsoft afin que la plate-forme Microsoft .NET soit dotée d'un langage permettant d'utiliser toutes ses capacités. Il est très proche de Java dont il reprend la syntaxe générale ainsi que les concepts ; la syntaxe reste cependant relativement semblable à celle de langages tels que C++ et C. Un ajout notable au C# est la possibilité de surcharge des opérateurs, inspirée de C++. Le C#, langage phare de Microsoft, fait partie d'un ensemble plus important qu'on appelle le « **Framework .NET** ». La compilation en C# ne donne pas un programme binaire, contrairement au C et au C++ ; le code C# est transformé dans un langage intermédiaire (appelé CIL ou MSIL), non exécutable lui-même mais que l'on peut ensuite distribuer. Cependant il faut installer la machine CLR sur l'ordinateur qui peut alors lire les programmes en C# et les compiler "à la volée" en binaire.

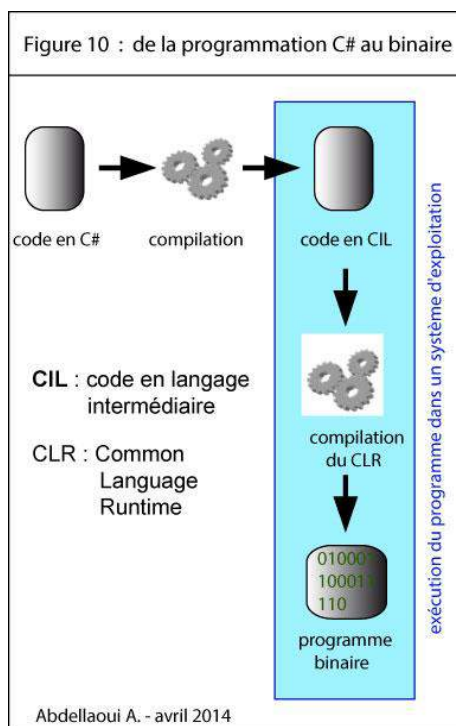
Avantage : le programme est toujours adapté à l'ordinateur sur lequel il tourne. La figure 10 montre le cheminement du passage du C# au programme « binaire ».

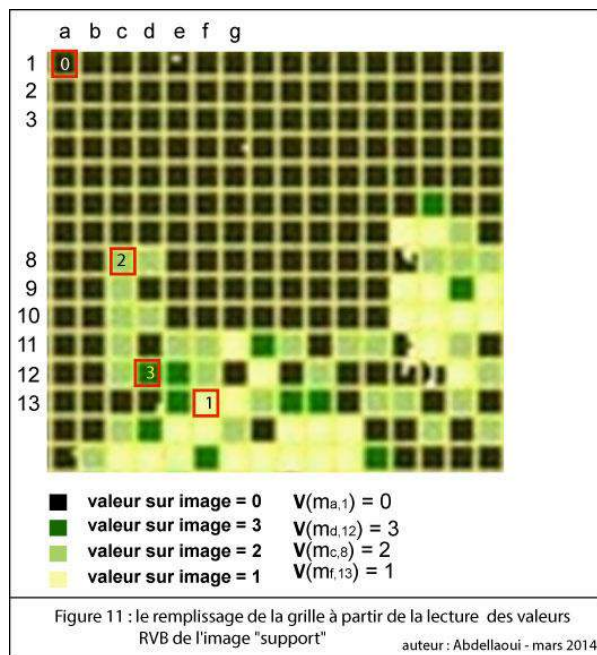
3.4. Présentation de GEMAS

Le problème est à résoudre consiste à générer une grille G sur une zone géographique, dans un premier

temps de forme rectangulaire simple dont les limites sont connues par leurs coordonnées dans un système de projection cartographique ; cette grille est constituée d'un ensemble de $n \times p$ mailles M_{ij} ($i=1, n$ et $j=1, p$) ; elle est par ailleurs superposée à une image de référence géoréférencée dans le même système de projection cartographique ; à la grille est ensuite associée une variable « couleur » ; puis à chaque maille de la grille est ensuite associée une valeur de la variable « couleur » obtenue par lecture des composantes RVB de l'intersection de la maille avec l'image de référence. La figure 11 illustre le principe du remplissage des valeurs des mailles à partir de l'image de référence, ou image support. Sur cette figure, l'image de référence est une image NDVI dans laquelle apparaissent trois seuils de coupure de végétation. Le reste de l'espace est occupé par tous les thèmes présents dans l'image différents du thème « végétation » ; les pixels, et donc les mailles correspondantes, sont à 0. La chaîne de traitements de l'algorithme GEMAS est constituée de 6 étapes schématisées par la figure 12 :

1. La première étape consiste à charger l'image de référence ; dans cette première version, l'image est sous le format bmp ; nous envisageons d'étendre à d'autres formats de lectures tels que : jpeg, tiff/géotiff
2. La seconde étape consiste à définir les limites de l'image exprimées dans le système de projection cartographique utilisé pour géoréférencer l'image de travail (nous utilisons généralement UTM wgs 84).



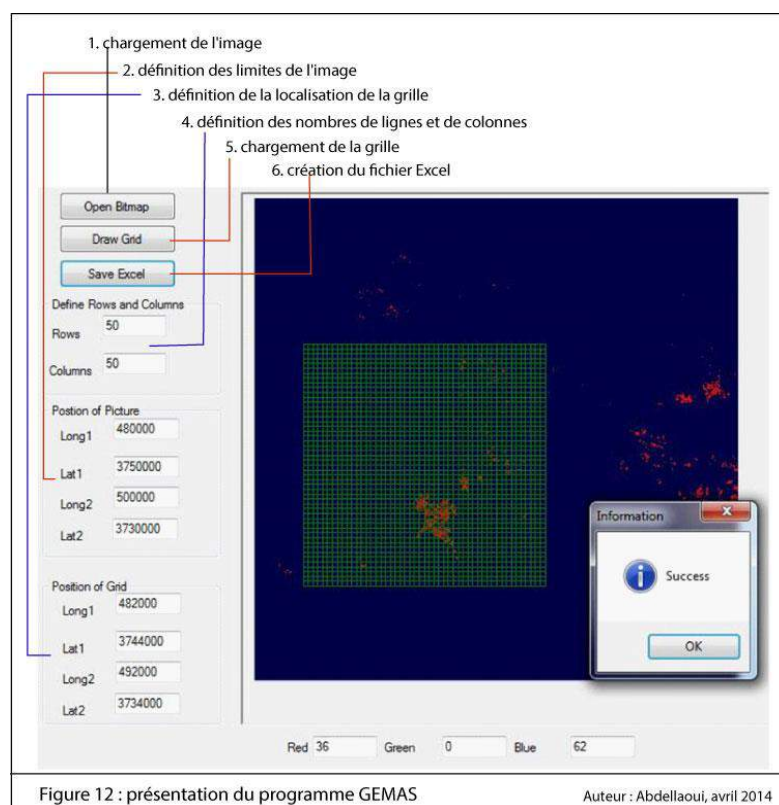


3. La troisième étape consiste à localiser la grille à créer sur l'image ; les limites sont bien sur exprimées dans le même système de projection cartographique.
4. La quatrième étape concerne la définition du nombre de lignes et du nombre de colonnes de la grille ; il faut noter ici que :
 - a. Les nombres de lignes et de colonnes influent directement sur les dimensions de la maille, donc sur la résolution d'analyse et donc sur la

précision des traitements et des interprétations.

- b. Les nombres de lignes et de colonnes doivent être déterminés de façon à avoir des dimensions entières de mailles : 100 m, 500 m, 2 km.
- c. Enfin il est inutile d'entrer de très grands nombres de lignes et de colonnes ; on se rapprocherait dans ce cas de mailles de la taille du pixel ; l'analyse par mailles deviendrait inutile.
5. La cinquième étape consiste à créer concrètement la grille ; celle-ci apparaît immédiatement sur la fenêtre de visualisation
6. La sixième et dernière étape concerne la création du fichier Excel nommé de façon automatique « solution » et enregistré dans le répertoire à partir duquel a été récupérée l'image de référence. Ce fichier comporte colonnes :
 - a. Une colonne « compteur »
 - b. Deux colonnes « col » et « row »
 - c. Trois colonnes « R », « G » et « B » représentant les trois composantes de l'image dans l'espace RVB
 - d. Une colonne « screen coordinate »

Et deux colonnes correspondant aux coordonnées du centre de la maille ; ces coordonnées peuvent servir à géocoder les centres de mailles et donc à rattraper les éventuels erreurs de superposition de l'image et de la grille.



3.5. Exemple d'application de GEMAS

A titre d'exemple, nous présentons l'application de l'algorithme à l'analyse de la végétation pour l'oasis de Laghouat à partir d'une image Landsat ETM de 2000.

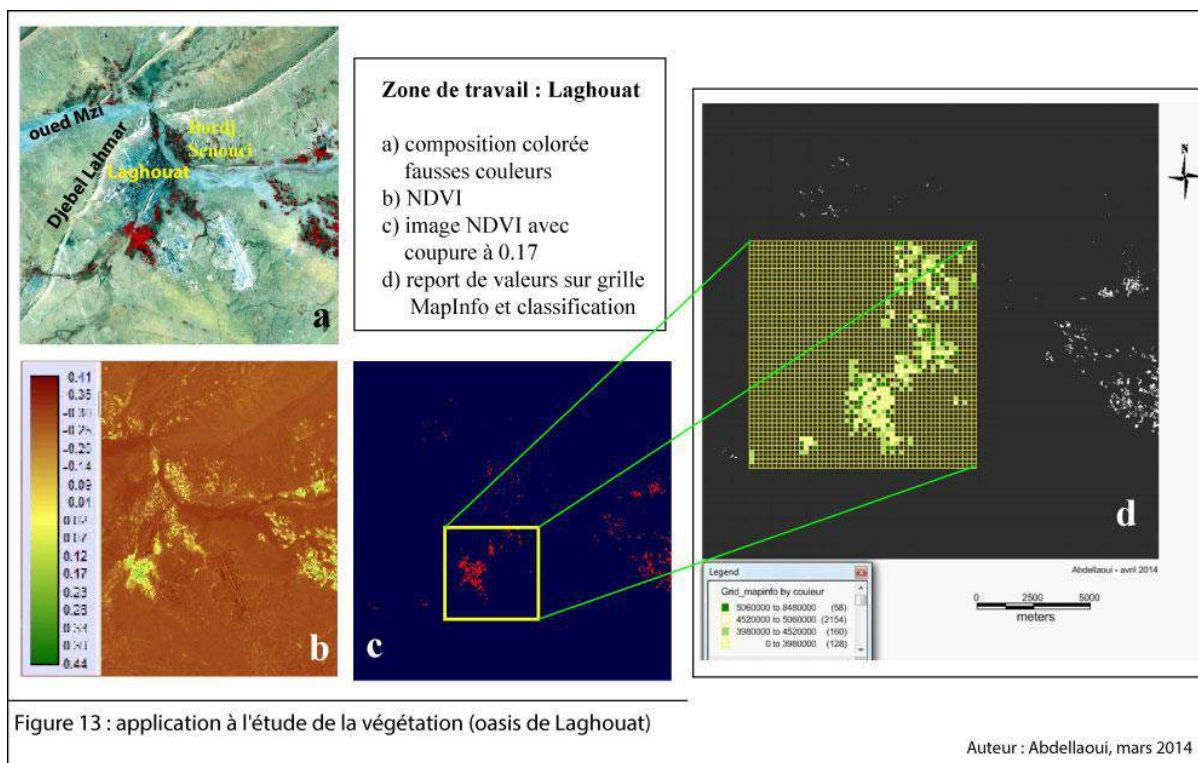
Nous avons d'abord extrait de la scène 195-037 du 6 avril 2000 une fenêtre correspondant à la ville de Laghouat et ses environs proches ; nous avons appliqué le module NDVI qui nous a permis de localiser la couverture végétale présente à cette date. Nous avons par la suite éliminé toutes les valeurs de NDVI inférieures à 0.17 pour ne conserver que les pixels « végétation » avec cependant des teintes différentes pour différentes classes comme nous pouvons le voir sur l'image b) de la figure 13 ; notons ici que les pixels « autres que végétations » ont été mis à 0. La lecture de l'image par GEMAS a

bien fonctionné et a fourni les différentes nuances de « couleurs » que nous retrouvons dans le fichier

4. Conclusion

Le programme GEMAS nous permet désormais de récupérer de façon automatique les valeurs RVB d'une image .bmp géoréférencée à travers un découpage régulier de l'image par un ensemble de mailles carrées. Le programme laisse beaucoup de latitude à l'utilisateur. En effet, celui-ci fixe les nombres de mailles en lignes et en colonnes. La taille de la grille d'analyse et sa localisation sur l'image sont également définies par l'utilisateur.

Le passage à MapInfo, à travers un fichier Excel de report de valeurs, ne pose aucun problème et l'analyse peut ainsi se poursuivre sur un logiciel dédié SIG.



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Landslide susceptibility in Zalău Municipality

Andreea Maria VÂTCA, Ioan Aurel IRIMUŞ, Sanda ROŞCA

Abstract. Due to the city's geographical context and human intervention, landslides occur in Zalău Municipality on extended areas. With a medium reactivation potential, some of these processes repeatedly affect dwellings, elements of infrastructure or agricultural terrains. The main purpose of this paper is to identify and locate the landslide prone areas from Zalău based on the landslide susceptibility assessment performed with the help of the semi-quantitative method included in the Governmental Decision 447/2003 – Mapping methodology and content of landslide and flood risk maps. The estimation of the value and the geographical distribution for each susceptibility coefficient was performed separately for the lithologic, geomorphologic, structural, hydrologic and climatic, hydrogeologic, seismic, silvicultural and anthropic factors. Using GIS techniques, the thematic maps representing the contribution of each factor to landslide occurrence and evolution were used to determine the map of average susceptibility coefficient. The validation was achieved by comparing the results with the location of active landslides identified in the field and through cartographic analysis of topographic maps and satellite images. Identifying landslide prone areas is a necessary stage in the process of landslide prevention and mitigation of negative effects.

Keywords: landslide, susceptibility, Zalău, GIS, validation rate

1. Introduction

Landslides are mass movement processes affecting the stability of slopes and included in the category of geomorphologic hazards. In Zalău municipality there are both areas affected by landslides and areas susceptible to landslide activity. The landslide causes in this urban area are related both to natural processes and anthropic activities.

2. Data and methodology

The objectives of this paper are represented by landslide identification and landslide susceptibility mapping in Zalău built-up area, using the semi-quantitative method described by the legislative document H.G. 447/2003 and GIS techniques.

Several thematic maps were created considering the landslide susceptibility coefficients and the contribution of each factor to landslide activation and evolution led to the final map of the average hazard coefficient.

Susceptibility refers to spatial probability or to what extent a territory is prone to a specific extreme phenomenon and is based on the presence of a set of known causing factors or the history of events affecting a specific area (Crozier & Glade, 2005, Irimescu et al., 2005, Rădoane & Rădoane, 2006). It

can be represented through various classes describing the occurrence probability which characterises a specific territory (Surdeanu, 1998, Irimescu, 2006, Măguţ, 2013).

The susceptibility assessment of any process can be performed by applying a variety of spatial analysis models using GIS techniques, which statistically or heuristically combine causing factors represented through thematic maps and the map describing the spatial distribution of the analysed process (Fabbri et al., 2003; Guzzetti et al., 2006; Rossi et al., 2009; Kouli et al., 2010 cited by Măguţ, 2013). This can also be achieved directly through expert opinion, when experts use mapped inventories of the process or previous knowledge related to causing factors and the studied area in order to delineate hazard zones (Van Westen et al., 1999; Cardinali et al., 2002, cited by Măguţ, 2013, Fell et al., 2008, Petrea et al., 2014).

Landslide susceptibility research has recently been represented by a series of scientific papers applying this type of analysis among which Manea & Surdeanu (2012) and Măguţ et al. (2012) have analysed the landslide susceptibility at administrative level.

The landslide susceptibility assessment was done using the semi-quantitative method described in the Romanian legislation H.G. 447/2003 – Mapping methodology and content of landslide and flood risk

maps, including a series of work stages illustrated in Figure 3: data base generation for the landslide susceptibility coefficients, susceptibility assessment and validation of results using the map of active landslides.

Using GIS techniques, the thematic maps representing the contribution of each factor (coefficient) to landslide activation and evolution were generated. The estimation of value and spatial distribution of each coefficient was made individually for the lithologic, geomorphologic, structural, hydrologic and climatic, hydrogeologic, seismic, sylvic and anthropic factors. These were eventually used to generate the map of the average hazard coefficient.

3. Results and discussion

Zalău Municipality, the capital city of Sălaj County, is located at the contact of the Meseș Mountains with Silvaniei Hills in the southern part of the Zalău Depression (Fig.1). The administrative territory of Zalău has a total area of 90.09 km², including the settlement Stâna which is located south-eastern from the Meseș (Nicoară & Pușcaș, 1999). The municipality is limited to the south-east by the steep slope of Măgura Stâni (716 m), to the east by Peringar Hill, to the north by Ceacă Hill (410 m), to the south-west by Labului Hill (403 m) and to the west by Zalău Vest Hill (400 m).

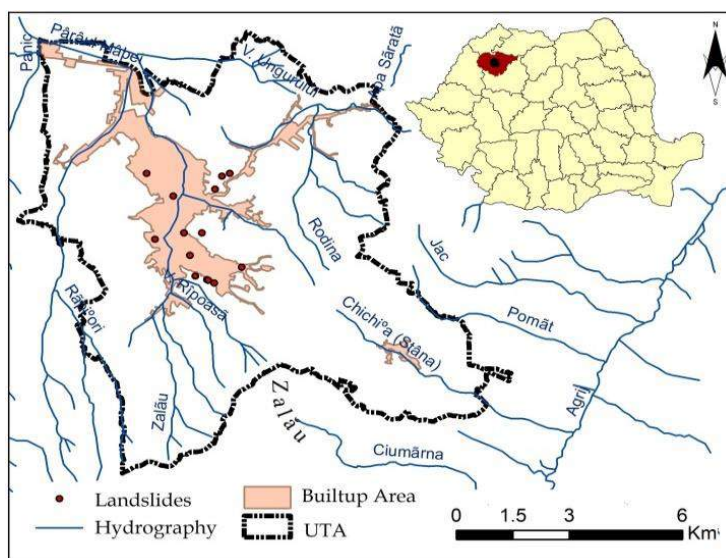


Fig. 1. Geographic location of study area

The study area has the form of a depression which is crossed from south to north by the Zalău River. The territory on the right side of the valley includes the north-western steep slopes of the Meseș with streams cutting down into friable Neogene sediments. The territory on the left side of the Zalău Valley has a wavy landscape with rounded hills being fragmented by streams with longitudinal profiles having a smaller slope angle (Popșe et al., 2010).

The fluvial topography, which includes floodplains, terraces and alluvial fans, is characterised by sedimentary formations found on vast areas. These are represented by marls, sand and gravel, with local clays, conglomerates and sandstones. All these sediments are geomorphologically susceptible to downslope movement through landslide processes. The slopes flanking the Zalău River and its tributaries have been constantly being affected by gravitational processes, including landslides (Mac and Hosu, 2010).

The cause leading to landslide activation in Zalău Municipality is related both to natural conditions and anthropic activities. Thus, one of the areas affected by landslides is the neighbourhood Ortelec. The landslide causing factors in this area are represented by water accumulation in the clay strata as well as the clay exploitation performed by SC Cemacon SA. Although a variety of measures have been undertaken over the years, including giving up the water pipe of the water distributor SC Publiserv SA, the building of taluses by Cemacon, these were not able to prevent a landslide affecting 10 Ha. This landslide caused damages to the road (Porolissum Street) connecting Zalău and Ortelec (DJ 191C) and the water tanks used for supplying the neighbourhoods Brădet and Stadion (Fig. 2).

3.1 Susceptibility coefficients

Using the method described in the H.G. 447/2003 and the factorial coefficients, the average

susceptibility coefficient was calculated for the area of Zalău municipality (Fig. 3).



Fig. 2. Landslides in Ortelec area

The lithologic coefficient was determined using the geological map 1:200 000 (1970) where the lowest coefficient value (<0.10) was attributed to massive rocks, while the highest value (0.51-0.80, >0.80) was attributed to saturated clays, to silt and to small and average aerated sands

The geomorphologic coefficient was calculated starting from the topographic map 1:25000 (1970), which was used to generate the digital elevation model, the hypsometric and the slope angle maps needed for determining the spatial distribution of the geomorphologic coefficient.

The structural coefficient, $K_c=0.35$, corresponds to a medium-high probability.

The hydrologic and climatic coefficient (K_d) was determined using the multiannual average precipitation map of the Romanian Climatic Atlas (2010). According to the meteorological data, the average precipitation is around 600 mm/year, corresponding to a coefficient value of 0.6 and a high probability of landslide occurrence.

The hydrogeologic coefficient has been attributed the value $K_e=0.4$ due to a predominance of areas where the phreatic level is up to 5 m, corresponding to a medium-high probability of landslide occurrence.

The seismic coefficient (K_f) has the value 0.7 and is correspondent to high landslide probability as the study area is included in a 6° MSK seismic intensity area.

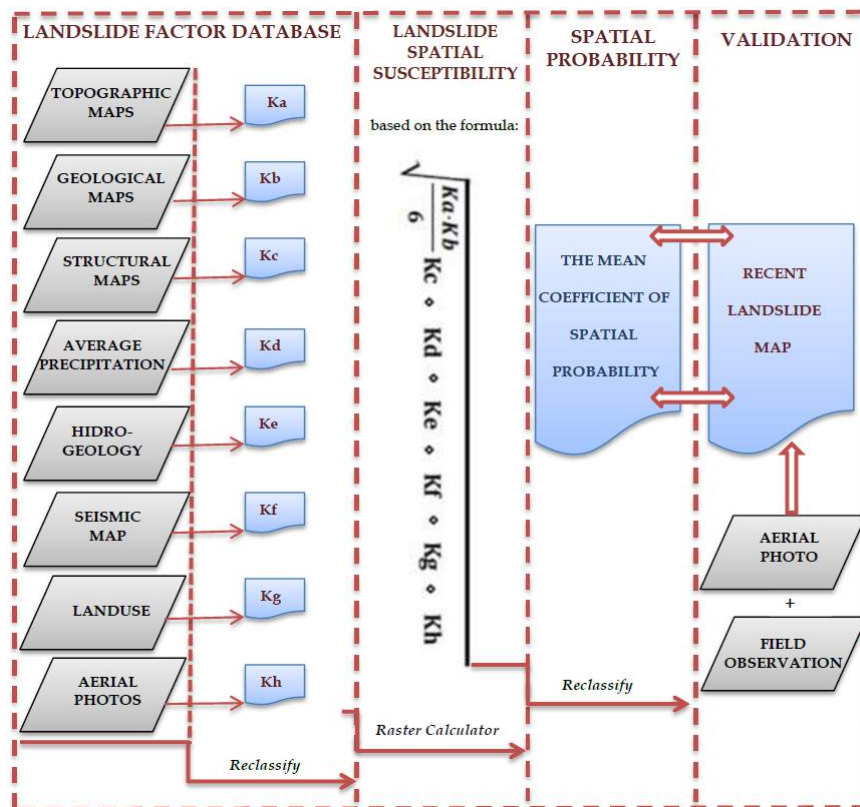


Fig. 3. Model schematics for landslide susceptibility assessment

The sylvic coefficient (K_g) was determined starting from the Corine Land Cover data: the areas covered with broad-leaved forests received the value 0.1, orchards and vineyards – 0.5, complex

agricultural areas – 0.5, non-irrigated arable lands – 0.9 and deforested areas and pastures received the highest value of the coefficient - 0.95.

For the anthropic coefficient (K_h) a value of 0.1 was attributed to areas without any infrastructure, while the other areas, occupied with different constructions, received a high value of 0.95, corresponding to a high probability of landslide occurrence.

$$K(m) = \sqrt{\frac{K(a) \times K(b)}{6}} \times [K(c) + K(d) + K(e) + K(f) + K(g) + K(h)]$$

in which: $K(m)$ – average susceptibility coefficient, $K(a)$ – lithologic coefficient, $K(b)$ – geomorphologic coefficient, $K(c)$ – structural coefficient, $K(d)$ – hydrologic and climatic coefficient, $K(e)$ – hydrogeologic coefficient, $K(f)$ – seismic coefficient, $K(g)$ – sylvic coefficient, $K(h)$ – anthropic coefficient.

Depending on the values of the average hazard coefficient, the probability of landslide occurrence was determined (Fig. 5) through reclassification, the study area being described as having:

- A *low probability* of landslide occurrence when the average landslide susceptibility coefficient has the values between $K(m) = 0.01 - 0.10$;

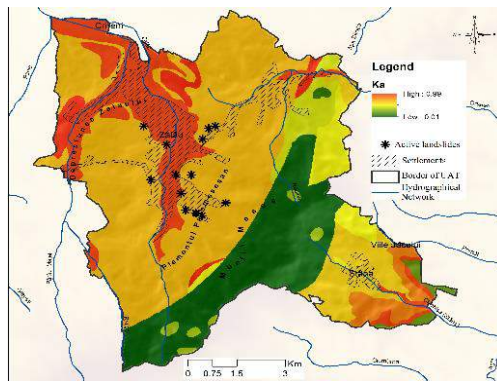
3.2 Probability of landslide occurrence

After analysing each factorial coefficient (Fig. 4), by using ArcGis 9.3, they were combined in order to generate the average hazard coefficient using the expression:

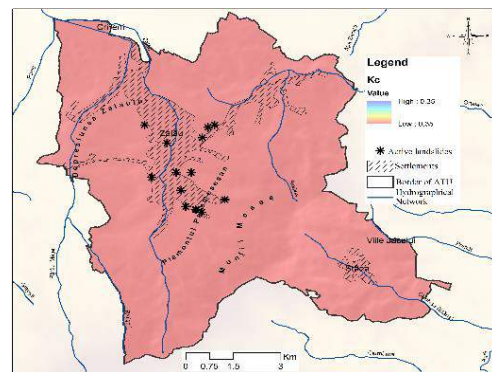
- A *medium probability* of landslide occurrence when the average landslide susceptibility coefficient has the values between $K(m) = 0.11 - 0.26$.

The average hazard coefficient (Fig. 6) has values between 0.003 and 0.26, the highest values characterising the built-up area of Zalău, in the north-eastern part of the city (Dealul Malu, Dâmbul Ciobanului), in the western part (Zalău west), as well as in the south-eastern part of Zalău.

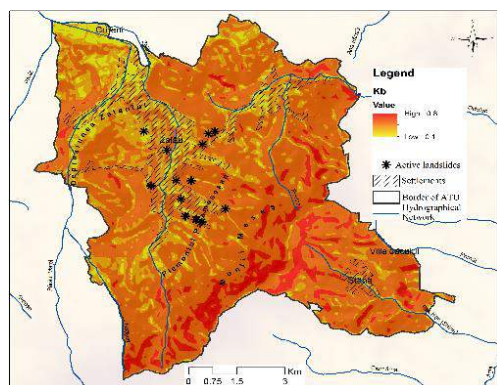
The Meseș Mountains and the north-western part of Zalău municipality are characterized by low values of the average hazard coefficient, due to the stable lithology and the forested areas which determine a high stability of the slopes.



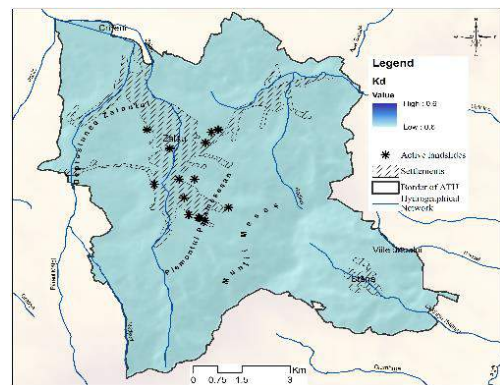
a. Lithologic coefficient map



c. Structural coefficient map

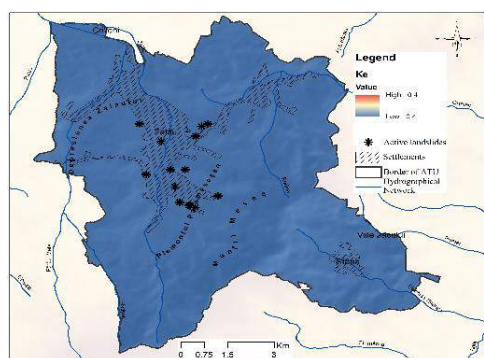


b. Geomorphologic coefficient map

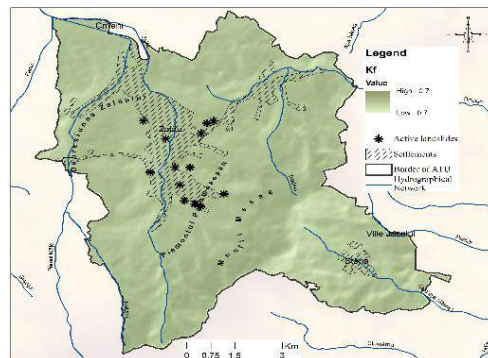


d. Hydrologic and climatic coefficient map

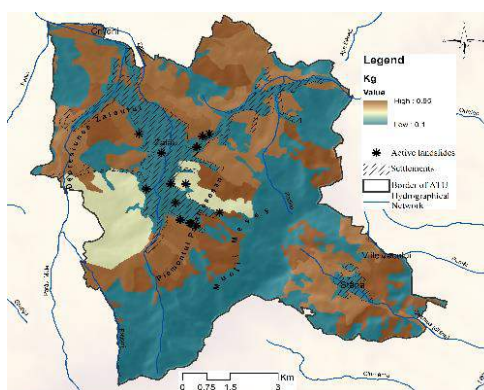
Fig. 4. Maps of factorial coefficients



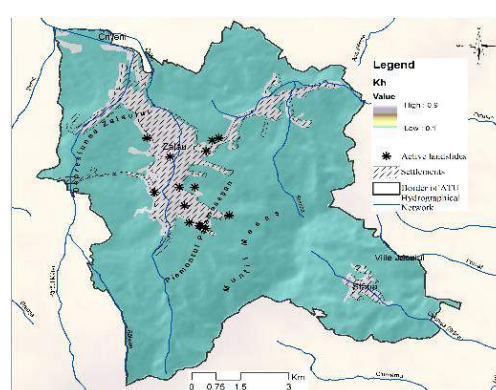
e. Hydrogeologic coefficient map



f. Seismic coefficient map



g. Sylvic coefficient map



h. Anthropic coefficient map

Fig. 4. (continued)

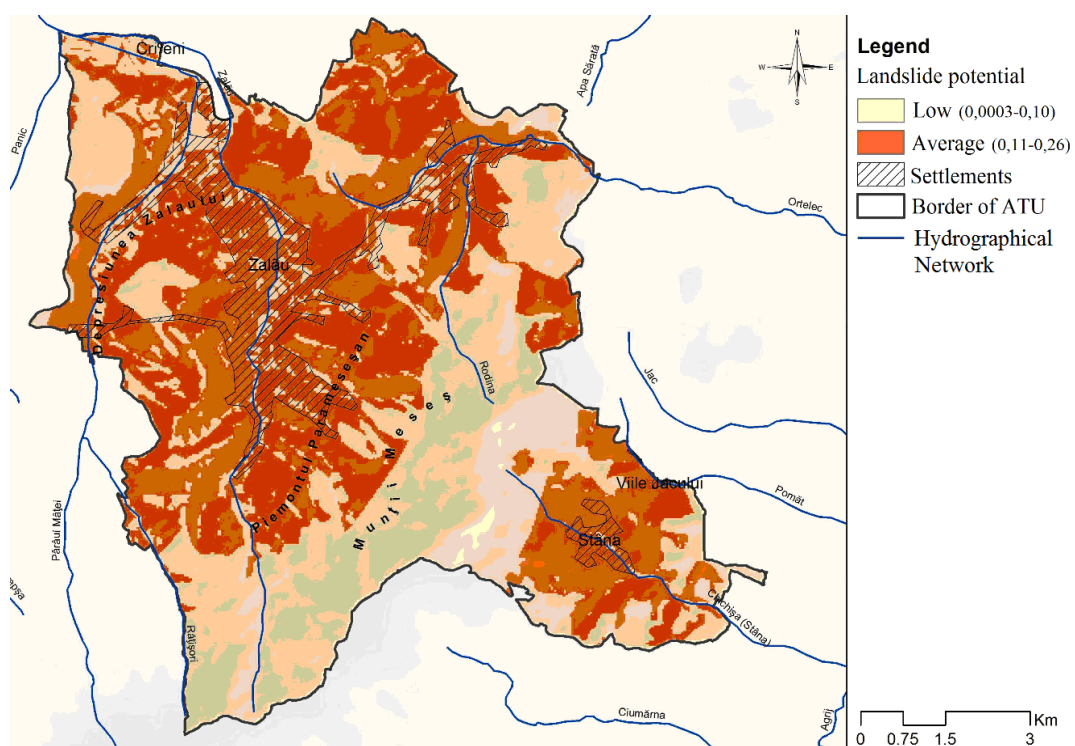


Fig. 5. Probability of landslide occurrence

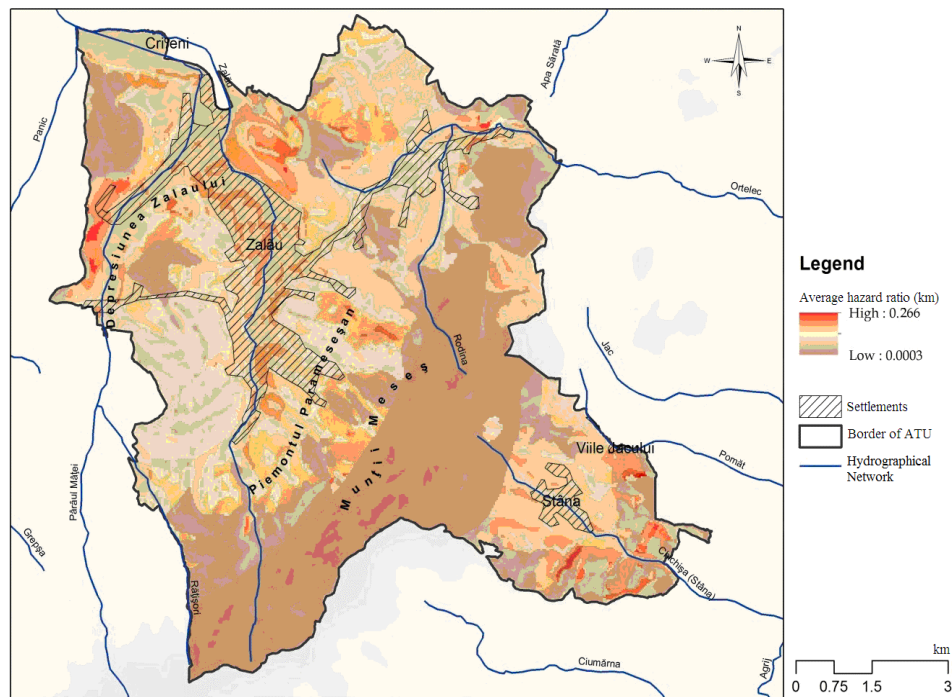


Fig. 6. Map of average hazard coefficient

3.3 Validation rate

After applying the landslide susceptibility model described in the legislative methodology H.G. 447/2003, an average value of the hazard coefficient was determined, ranging between a minimum of 0.0003 and a maximum of 0.260.

The territory characterised by a very low probability of landslide occurrence represents the largest percentage in the study area, 40% or 36 km². The medium probability characterises 37.08% of the area, which represents 33.1 km², while the smallest

surface (23.19%) is characterised by low probability and is represented by 20.8 km² (Table 1).

In order to determine the success rate of the landslide susceptibility model, according to the H.G. 447/2003 methodology, the total area of landslides was compared for each probability class (Fig. 7). Thus, the medium susceptibility class is validated by 79.09% of the mapped landslides, while only 22% are located in the low susceptibility class. The susceptibility analysis is considered to be successful as less than 25% of the landslide area is located outside the class of highest susceptibility, according to the recommendations of Carrara (1995).

Table 1. Spatial extension of probability classes

Probability	Class area		Landslide area	
	Km ²	%	m ²	%
Very low	36.006	40	0	0
Low	20.875	23.19	15571	22
Medium	33.133	37.08	51537	79.09

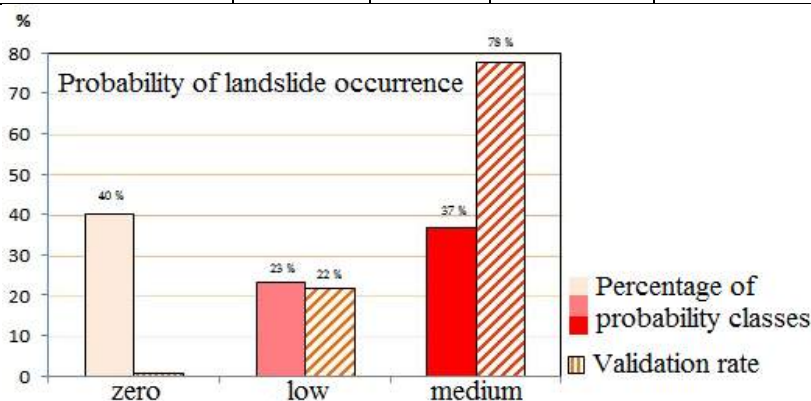


Fig. 7. Percentage of each landslide susceptibility class and of the mapped landslides (1-zero, 2-low, 3-medium)

As a result, the model and the factors included in the analysis successfully illustrate the situation from the field, as most of the mapped landslides are located in the areas with the highest susceptibility.

The areas with *active landslides* from Zalău Municipality, which are associated with geomorphologic risk situations, include: the right slope of the Meseş Valley in the neighbourhoods

Brădet and Stadion, Gheorghe Lazăr Street, the Central Park, the cemetery, the Courthouse; the right slope of the Zalău Valley in the Ortelec neighbourhood (water tanks, clay quarry), the People's Park, Traian-Vișinilor area, Dumbrava II area. All these territories are included in the medium susceptibility area (Fig. 8).

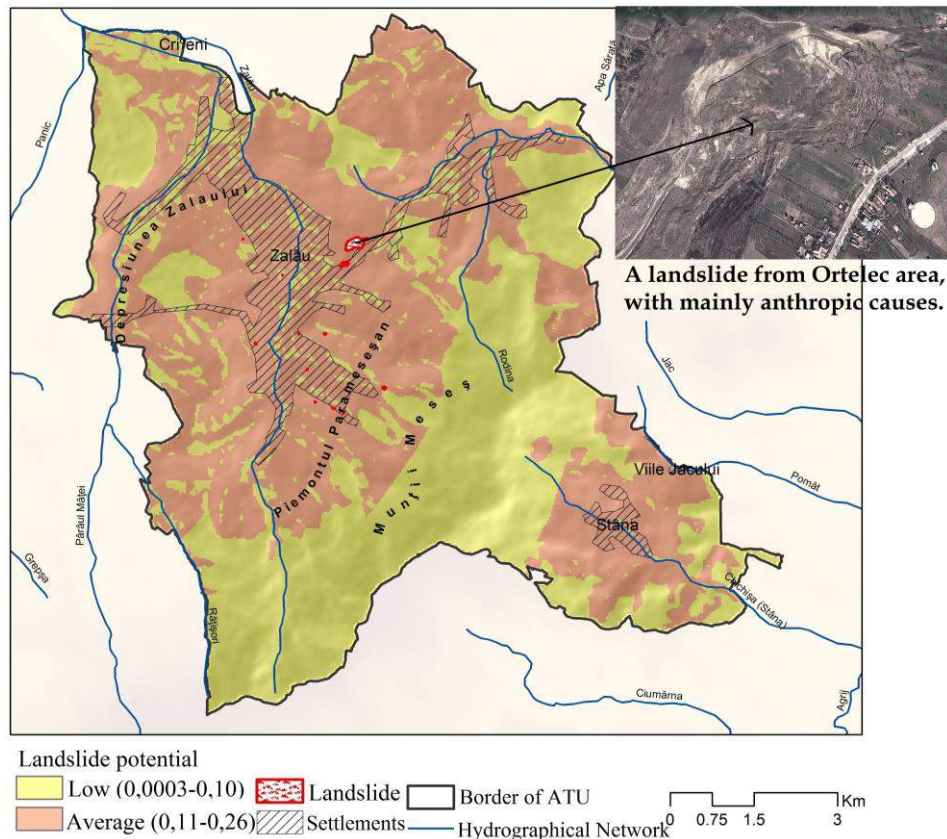


Fig. 8. Map of active landslides, classified on landslide susceptibility intervals

The landslides in Ortelec neighbourhood have visible effects in Zalău (Fig.8), mainly affecting the road infrastructure and the built-up area. Covering approximately 10 hectares, these landslides and have also affected agricultural terrains, water tanks, as well as the connecting road DJ 191C (Porolissum Street). Landslides of similar intensity affected also the Brădet and Stadion neighbourhoods, from the Meseş foothills.

4. Conclusions

Applying the semi-quantitative methodology, the landslide susceptibility in the Zalău built-up area has been determined and confirmed by previously mapped landslides. The medium probability of landslide occurrence was validated by 79.09% of the landslides mapped in the field, while the areas with

low probability include only 22% of them, thus the model has a good success rate. In the low and medium susceptibility classes the average hazard coefficient ranges between 0.003 and 0.026 in the north-eastern part of the city (Dealul Malu, Dâmbul Ciobanului), in the western part (Zalău west), as well as in the south-eastern part of Zalău.

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Using Spontaneous Potential (SP) as a Geophysical Method for Karst Terrains Investigation in the Mărghitaş Plateau (Banat Mountains, Romania)

Laurențiu ARTUGYAN, Petru URDEA

Abstract: Mărghitaş Plateau is the name of a karstic plateau situated in the karstic area called Anina Mining Area, in Anina Mountains (Banat Mountains). This plateau is located in the North part of Anina Mining Area and it is characterized by sinkholes doline valleys and independent sinkholes, but also by the missing of surface water and springs. Anina Mining Area is defined by Vasile Sencu (1977) as the area that is surrounded Anina town and it may be exploited by mining activities. The studied area presents many landforms specific for karst terrains. These features belong to the exokarst forms (sinkholes, poljies, karrens, gorges, karstic springs), but also to the endokarst forms (caves, shafts). Because of the geomorphology and the absence of surface rivers, this plateau is very interesting to study, both surface and underground. Geophysical methods are an option to study the subsurface in connection with the surface landforms. One of these methods, which is also used in the analysis of the groundwater, especially in karst areas, is spontaneous potential (SP). Spontaneous potential (SP), also called self-potential method, is a passive and an electrical geophysical method, which quantifies natural electrical fields that are passing along the Earth's surface. We developed measurements in 7 sinkholes, during different periods of the year to take in terms of comparability. We chose approaches, naming here profiles and grids. The method involves two non-polarizing electrodes, a fix electrode and a mobile one. Each electrode was introduced in a hole, approximately at 10 cm deep in the soil and after 1 minute we noted the value - measurements were made in mV- showed on the voltmeter and then we move the mobile electrode. In most of the situation the distance between the electrodes was 3 m, or if the field was larger we take 5 m distance between electrodes. The purpose of this work is to present our preliminary results obtained using the spontaneous potential method to characterize the surface and subsurface drainage in a karstic plateau. The results showed in most of the cases negative values, suggesting a direction in the water circulation, but we also obtained positive values during the dry season, most of them being measured in August and September, after large dry periods. Besides, we note that atmospheric conditions and the quantity of precipitations have a significant influence on our outcomes. In our study, we intend to obtain more field data using spontaneous potential to compare with our first results, but we also to validate the SP results with other geophysical methods such as Ground Penetrating Radar and Electrical Resistivity Imaging.

Keywords: karst terrain, sinkholes, spontaneous potential, Anina Mountains.

1. Introduction

Karst terrain is the meaning of a distinct relief, which is a result of rock masses dissolution, having as consequences an effective underground flow (Waltham *et al.*, 2005). To understand karst topography, we must recognise the nature and that factors that are defining dissolution processes in karst soluble rocks and the drainage resulted from these processes (Ford, Williams, 2011).

Anina Mining Area is defined by Sencu (1977) as the area that is surrounded Anina town and it may be exploited by mining activities and later, in 1978, Sencu included this study area in a tourist guide. He established the limits of this area as a rectangle with the large side oriented North-South (Fig. 1a).

Tacking into account the main marks of the geomorphological landscape, we established the geomorphological limits of the study area, using the topographic maps 1:25000 (Fig. 1b).

Mărghitaş Plateau is the name of a karstic plateau situated in the karstic area called Anina Mining Area, in Anina Mountains (Banat Mountains). This plateau is located in the North part of Anina Mining Area and it is characterized by sinkholes valleys and independent sinkholes, but also by the missing of surface water and springs. The studied area presents many landforms specific for karst terrains, both exokarst forms (sinkholes, poljies, karrens, gorges, karstic springs) and also endokarst forms (caves, shafts).

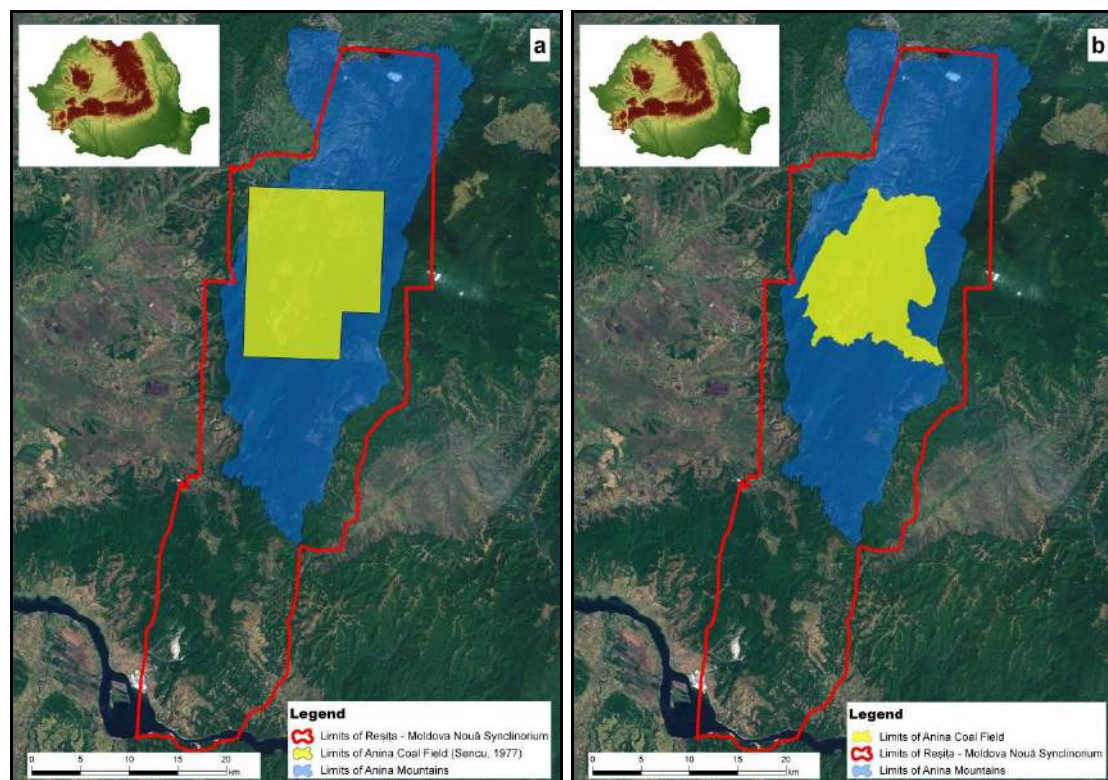


Fig. 1. Location of Anina Mining Area and the limits established by Vasile Sencu, 1977 (a) and in our study (b).

2. Study area

Our study area is situated in the largest and most compact area of carbonate rocks in Romania, in a typical structural area, Reșița-Moldova Nouă Synclinorium (Orășeanu, Iurkiewicz, 2010), where the Paleozoico-Mesozoic formations are overlapping fundamental crystalline domain (Bucur, 1997). This overlapping was explained by Oncescu (1965) as a consequence of the fact that the Paleozoic and Mesozoic sedimentary deposits were deposited either before main tectonic meso-Cretaceous phase or in the phase that followed the meso-Cretaceous phase. From tectonic point of view this area is part of Supragetic Unit which consists mainly of crystalline formations, overlain in place by Paleo-Mesozoic sedimentary rocks, affected by the Austrian and Iaramian paroxysmal phases (Năstăseanu et al., 1981).

The Reșița - Moldova Nouă Zone is regarded as the classic area for sedimentary domains, even if sediments that covered a significant part of the sedimentary field were largely removed by erosion. Even so, sediments remained in the area due to the fact that Reșița - Moldova Nouă Zone had the status of sedimentary depression in which succession and erosion of sedimentary cover was complete (Mutihac, Ionesi, 1974).

The study area is representative for the suspended karst plateaus, due to presence of wide

and flat interfluvies separated by deep valleys, and characterized by a high degree of karstification (Onac, 2000).

Mărghitaș Plateau (Fig. 2) is delimited by a ridge and some peaks with altitudes reaching 700 meters in the Western part, and, by the Buhui valley in the Eastern part. The general aspect of this plateau is a flat area (Fig. 3a) with many sinkholes (Fig. 3b), sinkholes valleys, a number of small caves and vertical shafts. Another characteristic for this karstic plateau is that the surface water is missing and also the springs are present only along the Buhui valley.

3. Methods

The characterization of karst regions requires specific knowledge of both surface and those forms of underground, and application of the geophysical methods are an option to study the subsurface in connection with the surface landforms. One of these methods, which is also used in the analysis of the groundwater, especially in karst areas, is spontaneous potential (SP). Spontaneous potential, also called self-potential method, is a passive and an electrical geophysical method, in which detect and quantifies natural electrical fields that are occurring on the Earth's surface. The spontaneous potential method is not a new one, being used before in many

karstic areas (Stevanovic, Dragisic, 1998; Lange, 1999; Rozycki et al., 2006; Guichet et al., 2006; Jardani et al., 2007; Jardani et al., 2009; Jouniaux et al., 2009; Robert et al., 2011).

The spontaneous potential method involves two non-polarizing electrodes, a fix electrode and a mobile one. Each electrode has to be introduced in a

hole, approximately at 10 cm deep in the soil and after the value - in mV- showed on the voltmeter is stable, we note it and then we move the mobile electrode. The length between the electrodes was 3 m, or if the field was larger we take 5 m distance between electrodes.

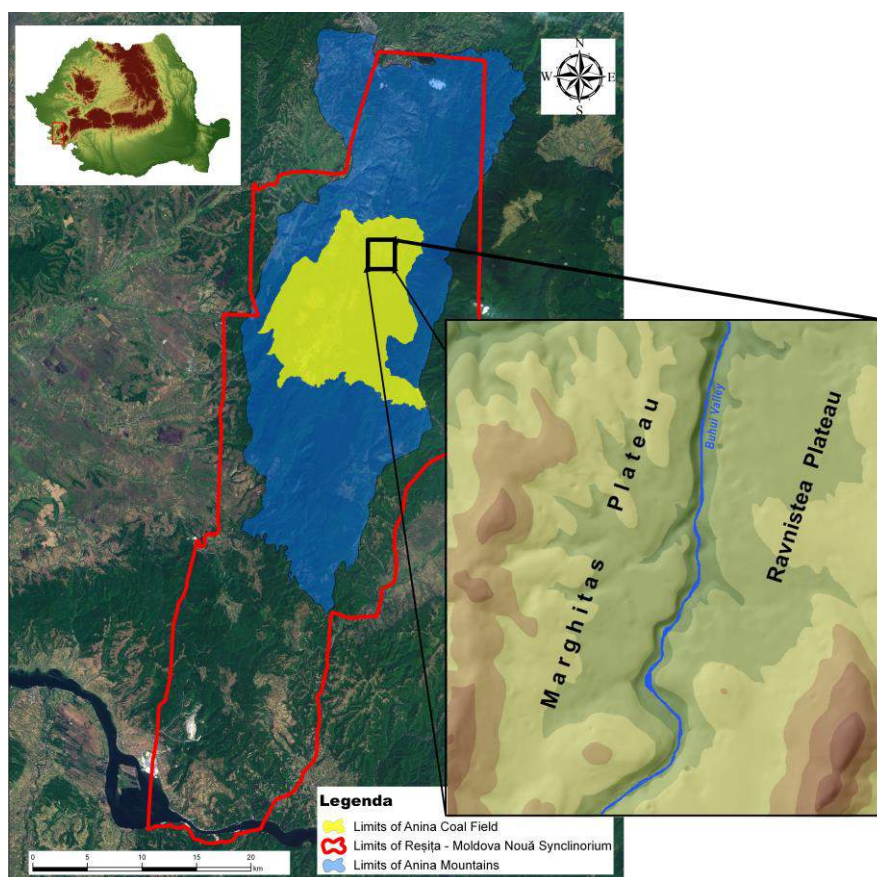


Fig. 2. Location of Mărghitaş Plateau



Fig. 3. General aspect of Mărghitaş Plateau (a) and a large sinkhole (b)

In Mărghițaș Plateau we measured SP in 10 sinkholes. These data campaigns were made during different points of the year to take in terms of comparability. Those measurements were realized as profiles and grids. These measurements give the results of 3 grids (in 2 sinkholes, meaning that in 1 sinkhole we repeated our measurements in a different period) and 28 profiles (2 profiles per each sinkhole measured, N-S and W-E).

Our campaigns started on 1st of May 2013 in this area and our last campaign of measurements was in 27th of October 2013. During this period we could observe the difference in SP values during three different seasons, starting from the spring and finished in the autumn. The results of these

measurements will be presented in the next section of this paper.

4. Results and discussions

A first finding is that the results showed in most of the cases negative values, suggesting a direction in the water circulation, but we also obtained positive values during the dry season, most of them being measured in August and September, after large dry periods. Besides, we note that atmospheric conditions and the quantity of precipitations have a significant influence on our outcomes. Four of our sites measurements are shown in Figure 4.



Fig. 4. The localization for Sinkhole 1, 2, 3 and 7

4.1. Grids study case

We developed 3 grid measurements, in 2 sinkholes. The first one is located near other 4 sinkholes, and the other one is located in a plane area bordered by karrens.

The first sinkhole, Sinkhole 1 (Fig. 5a) was measured in 1st of May 2013, after a large dry period and during a day with high temperature, from SW to NE direction. Also, measurements of SP show that in the centre of this sinkhole the water is retained more and the ground moisture is higher than on the sinkhole's slopes. The negative values point out that

the water is flowing from SE and from NW toward the bottom of this sinkhole. If we compare the outcomes from this sinkhole with the outcomes of the measurements of the second sinkhole, Sinkhole 2, studied in the same campaign (Fig. 5b), we may observe that the SP values range is similar, with larger values on the boundaries of those two sinkholes, both of them being surrounded by karrens. In both sinkholes our measurements show that in the centre of these landforms, where the aspect is flatter the water is retained more than on the sides of the sinks.

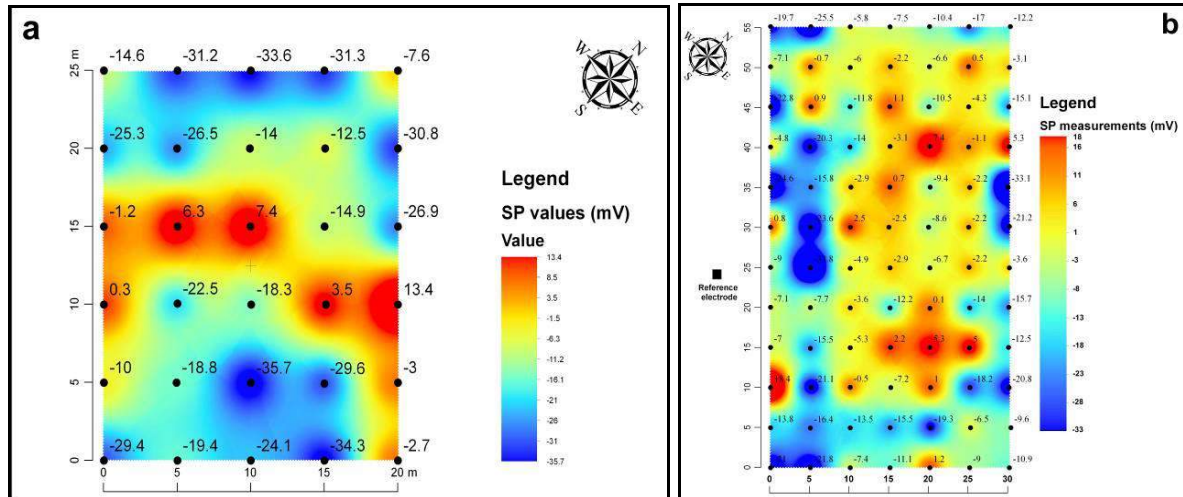


Fig. 5. Sinkhole 1 SP values in 1st of May 2013 (a) and Sinkhole 2 SP values in 2nd of May 2013 (b-Artugyan & Urdea, 2014)

4.2. Profiles study case

We choose for exemplifying our studies 5 sinkholes for which we realized 10 profiles of spontaneous potential measurements, by two perpendicular profiles, one oriented E-W and one oriented N-S.

Sinkhole 3

This sinkhole is a large one, with a diameter of almost 70 meters on E-W orientation and of 60 meters on N-S orientation, having a circular form, with a very flat bottom and very steep slopes sprinkle with large karrens. SP measurements show that on E-W orientation (fig. 6a) the negative values indicate a direction of water flowing to the underground, but the larger values located in the bottom of these sinkholes point out that there the soil moisture is higher as the water stagnation. On the other side, for the N-S orientation (fig. 6b) the profile is more fluctuating, alternating larger values with small values for the entire profile.

The next 3 sinkholes, Sinkhole 4 (fig. 7a), 5 and 6 (fig. 7b), are located in the same area, being as a

chain of 3 sinkholes. The choice of these sinkholes are certainly determined by the fact that these sinks are located in a forested area, and, being late autumn - measurements were created on the 27th of October 2013, leaves retain more humidity even if the measurements were taken in after a large period without precipitations. This is the reason for which nearly all the values measured are negative, with only 2-3 positive anomalies. These sinkholes are not already marked with the GPS.

Sinkhole 4

This sinkhole has circular form based on the two diameters, presents greatly forest vegetation and it presents not very steep sides. The N-S orientation (fig. 8a) is relatively homogenous in the profile, but on the E-W orientation (fig. 8b) the values decrease from East to West, as the slope decrease also and at the end of the profile the values are more homogeneous. This suggests that the water flowing direction is from the East to the West, being determined by the slope gradient.

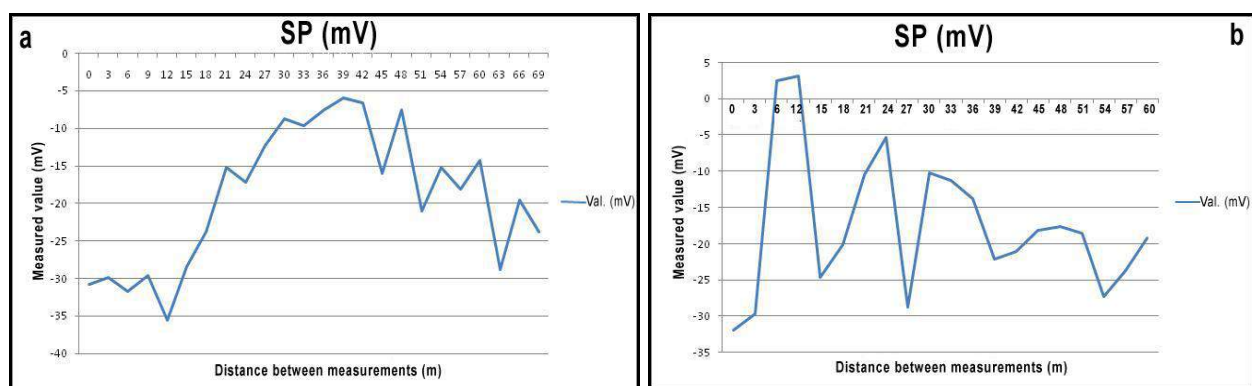


Fig. 6. Two profiles of Sinkhole 3 (26th of October 2013) on E-W orientation (a) and N-S orientation (b)



Fig. 7. Sinkhole 4 (a) and Sinkhole 6 (b) located in the wooded area of Mărghițaș Plateau

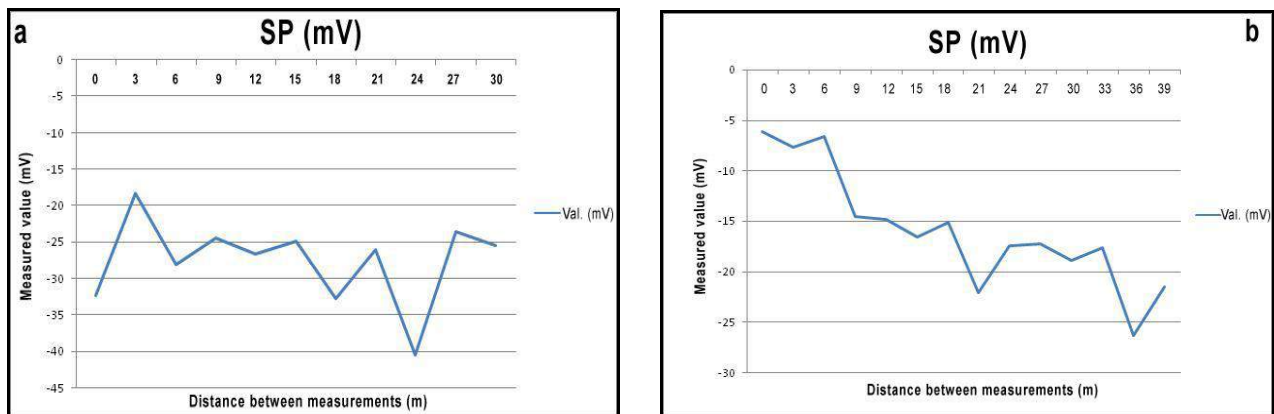


Fig. 8. Two profiles of Sinkhole 4 (27th of October 2013): North-South orientation (a) and East-West orientation (b)

Sinkhole 5

Along the North-South orientation (fig. 9a) presents a sinuosity at the bottom of the sinkhole, with larger negative values in the North side and positive values to the Southern part, as a result of the steepest slopes located in the Northern part. On

the other hand, the E-W orientation (fig. 9b) presents a large negative anomaly right in the middle of this sinkhole, meaning that at that point may be important cracks network drainage to underground.

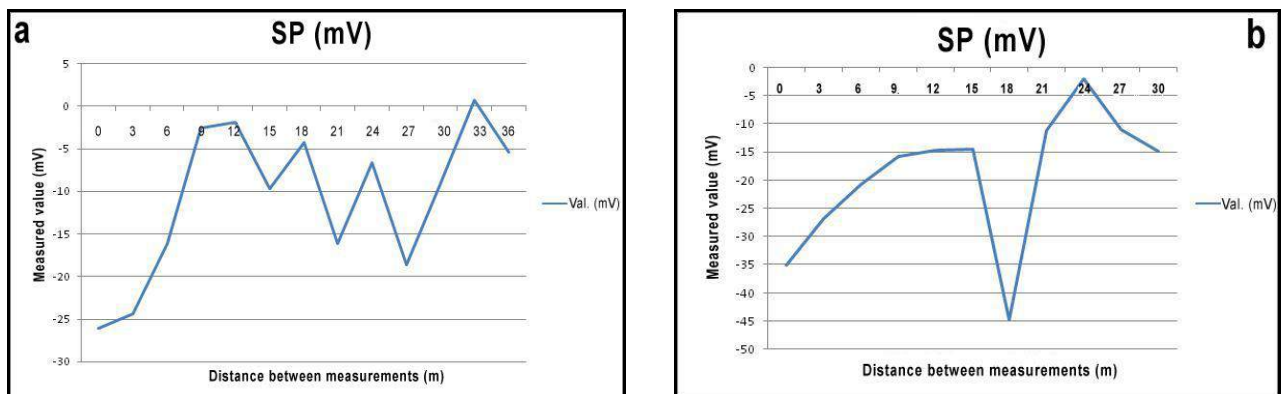


Fig. 9. Two profiles of Sinkhole 5 (27th of October 2013): North-South orientation (a) and East-West orientation (b)

Sinkhole 6

This sinkhole is the last one situated in the continuation of the two previous sinkholes, deepen in the forest. Again, the North-South orientation (fig. 10a) is relatively sinuous, but without large anomaly values. On the other side, on East-West orientation (fig. 10b) our measurements indicate 2

large anomalies at the West end of the profile, a negative and a positive one. But, besides these anomalies, this profile indicates that at the bottom of the sinkhole the water is retained more (higher values of SP measurements) and again the slope configuration determine the drainage to the bottom of the sinkhole.

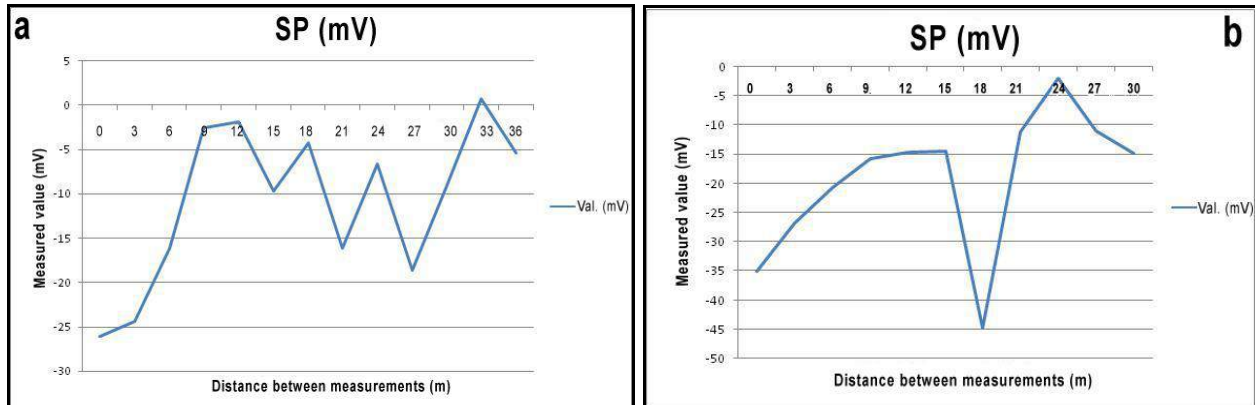


Fig. 10. Two profiles of Sinkhole 6 (27th of October 2013): North-South orientation (a) and East-West orientation (b)

Sinkhole 7

This sinkhole is the only one located on this karstic plateau for which we managed to obtain results in two different campaigns. The results presented in fig. 11 shows that even if the two campaigns were made in different seasons (first one during the spring and the second one during the autumn), the general aspects of these profiles are

almost the same. In May the results indicate well de bowl-shaped as a doline, but reversed, because the larger values indicate the water stagnation more in the bottom of the sinkhole, while in October, the values are more homogeneous, as the consequence of a large period without precipitations that preceded this measurements (Artugyan & Urdea, 2014).

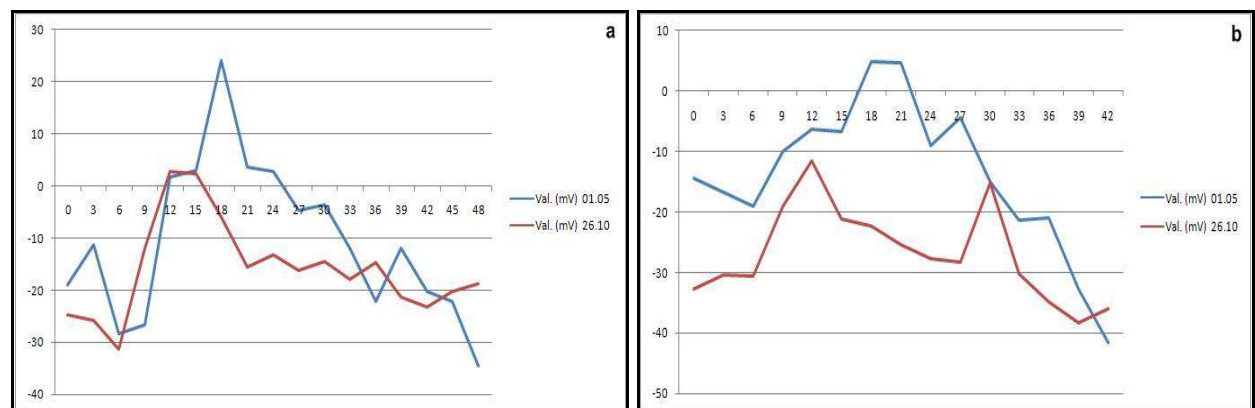


Fig. 11. Comparison for Sinkhole 7 self-potential measurements in 1st of May 2013, North-South orientation (a) and in 26th of October 2013, East-West orientation (b) (by Artugyan & Urdea, 2014)

5. Conclusions

Spontaneous potential measurements helped us to obtain data regarding water drainage at the surface in a karstic plateau situated at altitudes between 580 and 740 meters. Our approaches involved grids measurements and profiles measurements. Grids measurements are more representative because it

reveals values for the entire area, both boundaries and the bottom of these sinkholes. But, profiles are also useful because they show relatively well if there is a certain direction in water drainage and if the bottom of studied sinkholes presents a higher level of moisture.

SP measurements show that the temperature and the precipitations are factors that are really

important values, interpretations because the SP values are strongly correlated with those atmospheric conditions. Another factor that influences our results is the vegetation. Most of our results are obtained in forested areas, or even if the sinkhole were not situated in a forest, almost all the sinkholes located in these karstic plateaus present many trees and shrubs because these landforms are the places with the highest moisture degree, so are the sites where vegetation may find more humidity due to the characteristic of these features to retain water in karstic areas.

From this self-potential measurements we may point out that in most of the sites where we developed measurements the characteristics are similar, meaning that most of the sinkholes presents a water flowing direction from the boundaries toward the bottom, and, also the bottom presents the property of retaining water and humidity for a longer period due to the soil thickness which is larger in the middle of the doline.

Based on our study, we may conclude that sinkholes are those features which are the last point where water is retained on the surface of this karstic plateau. Besides, these sinks may be the link between water percolation surface drainage into the underground. This hypothesis must be determined using other geophysical methods, as Electrical Resistivity Tomography (ERT) which will offer the image for the bedrock and soil thickness, and, also

will help us to identify if there are some voids where the water is flowing to the secret.

In the following months we aim to repeat SP measurements in those sinkholes presented above, to get more data to compare and to point out certain charges of water drainage in Mărghitaș Plateau. Besides, our approach involves other sinkholes that were placed near those already presented to be included in our geophysical measurements.

In our study, we intend to obtain more field data using spontaneous potential to compare with our first results, but also to validate the SP results with other geophysical methods such as Ground Penetrating Radar and Electrical Resistivity Imaging.

Acknowledgements

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Aspects regarding the evolution of slope processes in the Izvoru Alb – Bicz territory (Neamț County) during 2005 – 2014

Costică BRÂNDUȘ¹, Claudiu GAMAN²

Abstract: Izvoru Alb brook enters Izvoru Muntelui – Bicz reservoir on its right side, approximately 10 km from the dam. Its hydrographic basin is affected on both its sides by slope processes in different evolution stages. Dominant in terms of affected area are processes in a relative stable state, yet reactivations on local areas are quite frequent. During August 2005 a large landslide occurred in the lower part of the valley, on the right, partially affecting Izvoru Alb village. A debris flow of large dimensions has blocked the brook floodplain and caused the formation of a lake with a surface of 2.5 ha and depths of 2-3 up to 8 meters. Numerous households, terrains, electric power lines and roads have been flooded and destroyed. The research conducted in 2013 had as purpose establishing the later evolution of slope processes, the way in which the lake evolved, the environmental consequences as well as those social and natural inflicted upon the rural settlement. It was concluded that slope processes are in a relative stable state, but with a high potential of reactivation. The water from the lake has been almost completely evacuated following works of deepening the brook (only small ponds have remained). The affected households have been abandoned, the number of inhabitants in the village decreasing. Due to a lack of reparatory measures and financial support, the village can soon lose the character of permanent settlement.

Keywords: natural dam lake, effects on settlements, present state of landslides

1. Introduction and local characteristics

The study area coincides mostly with the territory of Izvoru Alb village, situated in the lower sector of Izvoru Alb valley, brook which flows into the Izvoru Muntelui – Bicz reservoir 10 km upstream the dam. Before the construction of the large dam reservoir in 1960, the village was situated almost completely in the area where the brook flew into Bistrița River. That area is now situated under the lake surface, the inhabitants being forced to relocate in the current position (Fig. 1).

Slope processes on the two sides of Izvoru Alb brook have been mentioned by locals from the beginning of the 20th century, described as a large landslide occurred in 1914 accompanied by the formation of a small temporary lake. Landslides have been later mentioned by Băncilă (1958) and studied by Donisă (1968) and Surdeanu (1975). More recently they have been studied by Brânduș et al. (2006) as a consequence of the reactivation of the landslides on the right slope of the brook and the formation of a natural dam lake in the village area. In fact the local reactivation of slope processes on both sides of the brook at different time spans and with different intensities is specific for the entire

Izvoru Alb basin. This is due to some extremely favorable natural (petrographic, morphometric, climatic) and anthropic factors (mainly the presence of the Izvoru Muntelui – Bicz reservoir).



Fig. 1 Geographic location of the study area

Among the natural favorable factors, mentioned also by Brânduș et al. (2006), we consider the lithological, morphometric and climatic ones as being the most important. The lithology is represented by a shale-clay-sandstone facies belonging to the Albian-Vraconian curbicortical

flysch (Izvoru Alb brook reaches in the spring area the base of the Ceahlău conglomerates). Considering the influence of morphometry, important are the relative relief, with mean values of 300 m on the territory of the village, and the high slope angle, with mean values of 7-15% and 15-

30% (Fig. 2). The mean annual rainfall exceeds 900 mm in the rainy years, while absolute maximum rainfall quantities can reach in the warm period of the year values that can sum up to 100-150 mm in 3-4 days (Fig. 3).

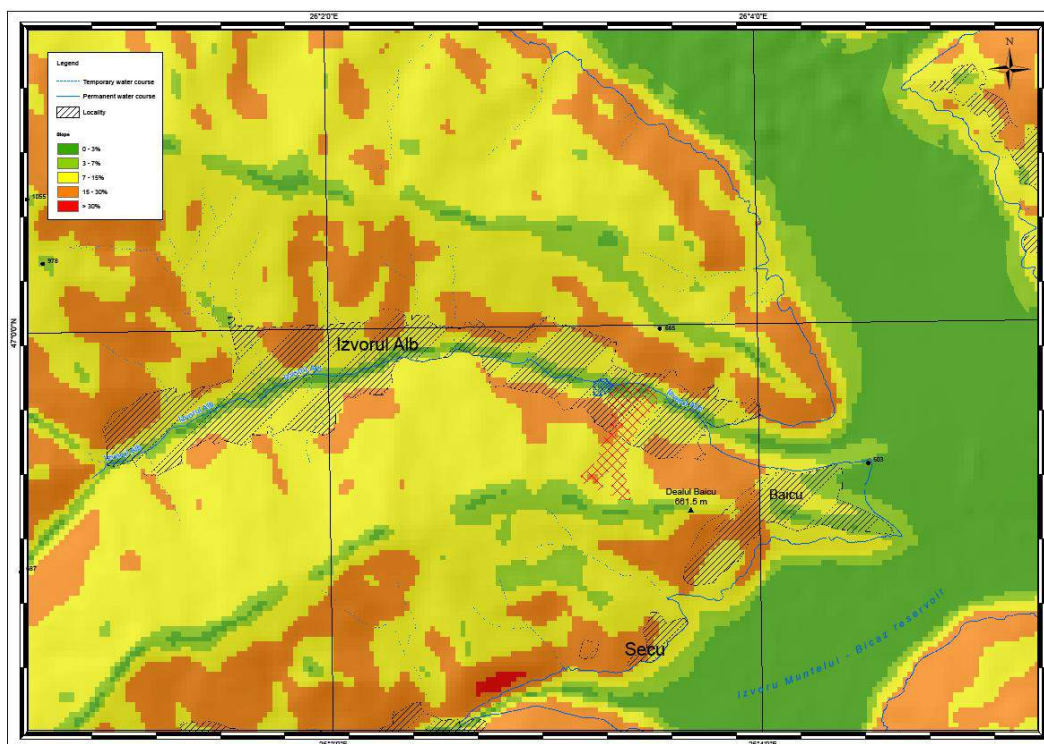


Fig. 2 Slope angle map

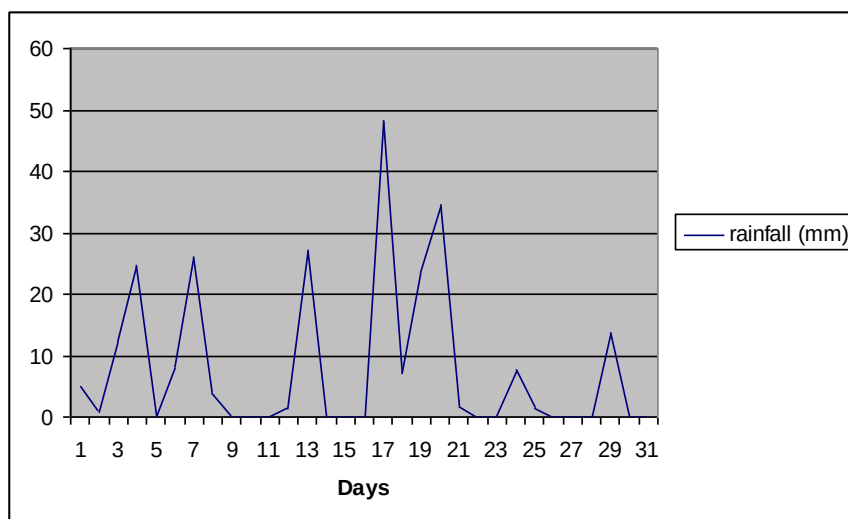


Fig. 3 Rainfall quantities recorded during August 1st -31st at Izvoru Alb

The anthropic favorable factors have become more varied and have intensified starting with the works at the Izvoru Muntelui - Bicăz reservoir in the 1950s and especially after the lake filling up to the maximum level from 1960. Among these factors the most important ones are the construction of new

roads on the slopes, without corresponding measures for preventing and mitigating slope processes, the intensification of deforestation in the Izvoru Alb basin, the diversification and intensification of irrational land use following the relocation of inhabitants and the extension of the

village territory upstream, the occurrence on slopes of buildings and insufficiently consolidated embankments etc. Also worth mentioning are the hydrotechnical works (valley steps, small dams etc.) executed in the lower sector of Izvoru Alb floodplain, with the purpose of stabilizing the thalweg and reducing solid discharge. These works have determined in the first decades a stabilization of the slope processes, but later, because of their degradation and getting out of use, they have caused the rapid deepening of the river thalweg and the occurrence of bank erosion processes that have led to landslide reactivations.

2. Materials and methods

Reinitiating the researches in the Izvoru Alb basin in 2013 had as main purpose the analysis of the way in which slope processes have evolved after their sudden reactivation of high intensity from 2005, as well as of the most important negative consequences.

Among the main geomorphologic processes that have taken place during 2005 and 2006, on August 16th-22nd 2005 have been registered abundant rainfall, when in the Izvoru Alb brook has been recorded a summed quantity of 125 mm. This led to a deepening of the brook's channel, followed by bank erosion on the right side with a level difference of 1 – 3 – 5 m (in different sectors of the floodplain). In the night of August 22nd at 2-3 PM (according to the information given by local people), a debris flow of large dimensions (length of 350-500 m, width of 100–150 m and a thickness of the landslide mass of 3–5–8 m) detached from a scarp situated in the upper third of the slope and suddenly collapsed, reaching with its forehead the brook floodplain. Blocking the floodplain, it determined the formation of a lake (in a period of 72 hours according to the locals), with an estimated surface of 2.5 ha, a mean depth of 2–3 m and maximum of 8 meters, and flooded households, agricultural terrains and roads (Fig. 4). According to the information from the inhabitants, in 2006 have taken place landslide reactivations locally, on small areas, as well as some material losses.



Fig. 4. The landslide that formed the natural lake in Izvoru Alb, August 2005

3. Results and Conclusions

Based on the detailed analysis, since May 2013, of the evolution of slope processes on the right side of the valley and of the effects on the micro-landforms especially in the inhabited sector of the Izvoru Alb village, of the changes in the brook's floodplain and of the evolution of the lake formed in 2005, as well as of the negative social and economical effects generated by the respective phenomenon, the following conclusions have been drawn:

- Regarding the slope geomorphological processes, a relative stability of the main debris has

been noted mass, which blocked the floodplain in 2005 causing the formation of the lake. By repeated measurements of some landmarks it was concluded that on the overall the main debris mass does not register movements. Yet, on areas of different dimensions situated in its vicinity have occurred new small depressions with temporary humidity excess and even ponds (hygrophilous and swamp vegetation), as well as micro-landforms such as furrows, small secondary scarps, cracks and bumps which are proof of small local horizontal and vertical movements (Figs. 5 a and b);



Fig. 5a. Hygrophilous vegetation on the right bank of Izvoru Alb brook, August 2013



Fig. 5b. Secondary scarps in the debris mass, August 2013

- The scarp area of the main debris mass is in a relative stable state, with new vegetation growing. The entire surface of the slope presents micro-landforms such as lenses and furrows, landslide mounds, cracks and small scarps, which demonstrate a real potential for slope processes reactivation in the debris mass, including a possible landslide similar to that of August 2005 (Fig. 6);

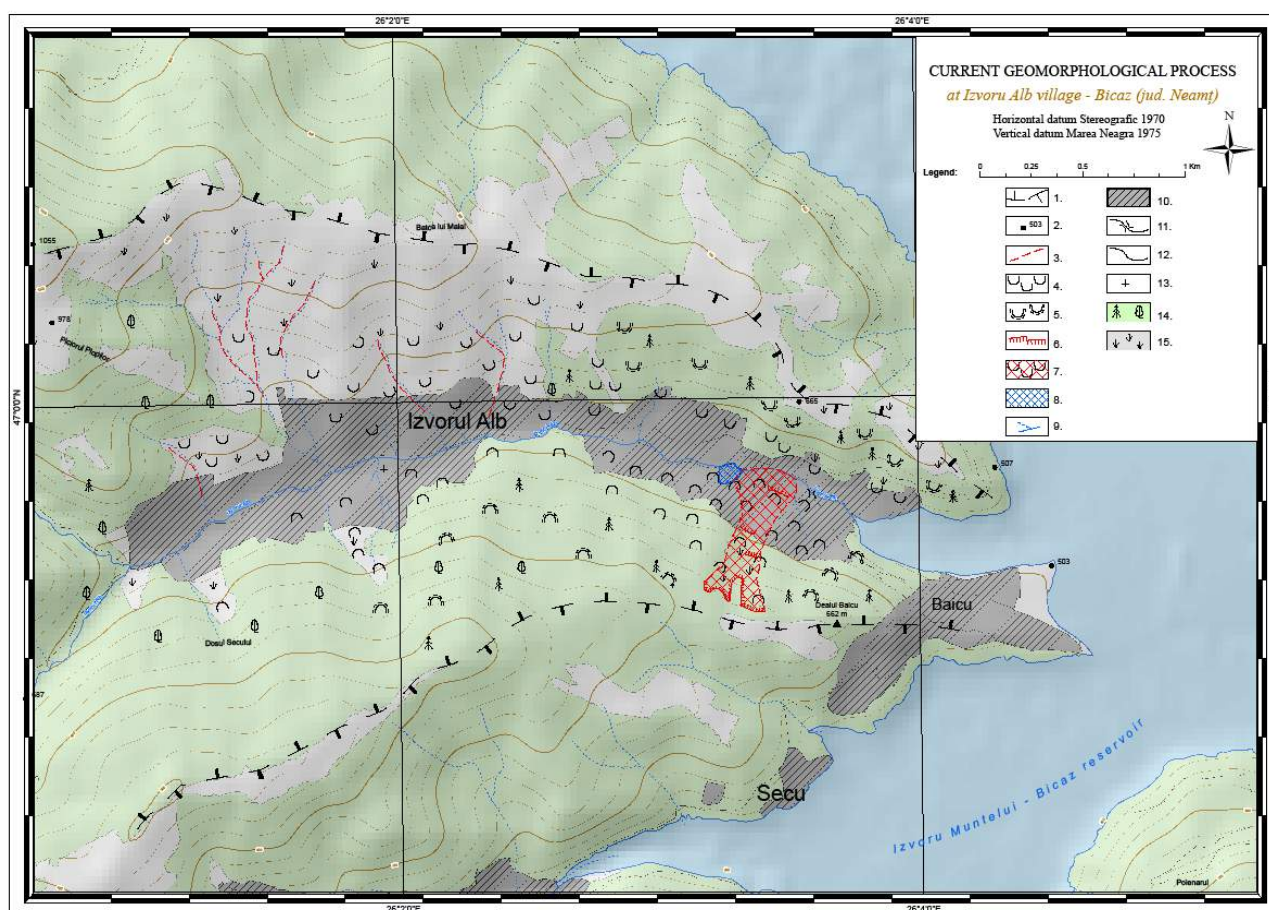


Fig. 6. Map of present geomorphological processes

Legend: 1 – interstream area, 2 – altitude mark, reactivated linear erosion, 3 – relatively stable landslides with periodic areal reactivations, 4 – relatively stable landslides evolving under forest vegetation, 5 – reactivated scarps, 6 – debris mass that blocked the floodplain of Izvoru Alb brook, 7 – the area of the previous natural dam lake formed in 2005, 8 – permanent and periodic river network, 9 – village limit, 10 – bridges, 11 – village road, 12 – church, 13 – broad leaved / coniferous forests, 14 – pastures and hayfields.



Deserted house on the right bank of Izvoru Alb



Lake depth in 2005



Village road under-passed by Izvorul Alb brook in the area of the previous lake

Fig. 7. Present situation of the study area / affected buildings (August 2013)

- Regarding the evolution of the lake and of its surface, we need to point out the total evacuation of the lake water (except some small ponds and areas with swamp vegetation) as a consequence of the locals digging an evacuation channel in the debris mass. The 2.5 ha previously occupied by the lake has been eliminated from any utilization. Also, most of the previous households and terrains are in the same situation (Fig. 7);

- Regarding the negative social and economical effects, it is important to mention the deserting by locals of 13 households in 2005 and another 4 in 2006, due to their flooding or damage by the landslides. Here are also included the inhabited

space, the terrains around the households used for crop growing, electrical network, fountains etc. Thus, Izvoru Alb, mentioned for the first time in 1458 in a document issued by Ștefan cel Mare as a group of houses situated at the confluence of Izvoru Alb with Bistrița, and then on the maps of Cantemir in 1717 and Bauer in 1772, is presently registered at the Bicaz mayor (of which it depends) with 129 households and an ageing population in a constant decline. According to some information from the locals, only 70 families are now permanently living in the village (Fig. 8).



Fig. 8. Inhabited households on the left bank of Izvoru Alb brook, August 2013

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Air versus ground temperature data in the evaluation of frost weathering and ground freezing.

Examples from the Romanian Carpathians

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Abstract: Air temperature is frequently used in frost weathering studies for the assessment of freeze-thaw cycle frequency and freezing intensity on different scales, although ground thermal behaviour is more relevant. In this paper we compare the estimations made by meteorological daily data with the results of continuous field measurements of air, soil and rock thermal regime in intra-mountain depressions, on mountain interfluvies and steep rockwalls. The results show that air temperature alone can be used only as an indicator of diurnal freezing potential interval and of seasonal freezing duration, and is not a reliable proxy for assessing frost weathering magnitude, as it lacks the integration of ground cover by snow and of relevant topographic features like exposure and slope. For illustrating the depression units, which have the highest climatic potential of diurnal freezing (> 100 potential freeze-thaw days/year), we presented the case of Poiana Șampeii (the theoretical maximum freeze-thaw potential, 124 cycles/year, derived on air data), where only 2% of this interval corresponds to active freeze-thawing, while in the rest of the winter the ground is subject to snow-cover insulation. Moreover, the snow-free rock walls from those depressions record only 1/2 freeze-thaw cycles in comparison with the in situ air measurements, while only 35% of them are efficient (> 15 h°C per diurnal cycle). The ratio between active diurnal freezing, seasonal frost and snow cover interval modifies with altitude and is highly influenced by the degree of surface exposure. The high-altitude interfluvies and plateau areas in the Bucegi Mountains show a much higher persistence of deep seasonal freezing due to a more unstable condition of snow cover and to constant low temperatures, while diurnal cycles keep a moderate frequency. The thermal regime in rockwalls highlights and documents the effect of direct solar radiation on exposed (snow-free) surfaces, with the clear distinction of diurnal and seasonal freezing on north and south-oriented steep slopes. Air is shown to be less sensitive than rock surfaces to opposite exposures and largely underestimates the diurnal freeze-thaw processes on the southern slopes. Direct solar radiation on the rock surfaces induces high amplitude diurnal oscillations which do not correspond to those of air, neither as frequency nor intensity. Nevertheless, air temperature derived indices are still relevant for the northern slopes directly connected to heat exchanges with the atmosphere. If snow cover duration proves to be the most important parameter to be included in frost weathering studies on typical horizontal surfaces (especially depressions and valley couloirs), the analysis of the thermal behaviour on mountainous rocky areas with various exposures and complex topography requires detailed ground temperature calibration of air values for good confidence results and estimations.

Keywords: air temperature, ground temperature, frost cycles, weathering, the Carpathians

1. Introduction

It is widely acknowledged that weathering by cryogenic action has a great contribution to the shaping of high altitude mountain environments (Goudie, 2004; Washburn, 1979; Williams and Smith, 2008). Both climatic and geomorphologic studies have attempted to evaluate and quantify the characteristics of frost processes and their impact on mountain surfaces, advancing monitoring approaches and investigation methods with increasing complexity and accuracy degrees. Although many classical studies use air temperature

alone to make supposition on the very intensity of weathering, most of the recent works show that temperature is only one dimension of the process and even the general threshold of 0°C may be misleading (Hall et al., 2012; Hall and Thorn, 2011; Matsuoka, 2001, 2008; Matsuoka and Murton, 2008). A thorough perception and large-scale modelling of thermal weathering intensity cannot be made without the unequivocal understanding of frost penetration mechanisms and ground thermal behaviour, which follow air tendencies, but may largely differ (Hall and André, 2001).

Laboratory experiments were made to evaluate the immediate effect of induced freezing in variable conditions, observing the volumetric changes and the occurrence of new joints and fractures (Washburn, 1979; Hallet et al., 1991). Nevertheless, the necessity of in-situ monitoring has lately been highlighted (Hall, 1999; Matsuoka, 2001; Sass, 2004, 2005; Amitrano et al., 2012) as field conditions (scale, control factors, climate) can hardly be reproduced in the laboratory. The development of new devices and data recording solutions has significantly eased the investigations in steep alpine areas. Thus, continuous measurements of ground (rock or soil) temperature and other parameters (water availability in rock, rock joints dynamics, snow cover, thermal conductivity and electrical resistivity of the ground surfaces) are now regularly performed in regional or country-level monitoring networks (Matsuoka 2008; Magnin et al., 2011; Gruber et al., 2004) at different spatial scales, the data being useful for more precise models and evaluations of climatic scenarios (PermaNET report) or modelling of rockfalls occurrence (Matsuoka and Sakai, 1999; Krautblatter et al., 2013).

In the context of these methodological developments and recent implications, it is more obvious that air temperature can be used at most as a proxy for frost weathering, because it cannot express the actual ground thermal behaviour but only the potential climatic conditions for frost occurrence (Hall and André, 2001). However, ground temperature data are available in a limited number of locations, thus for the purpose of large-scale studies (at mountain-range level) meteorological air temperature data are still to be used, with the existing limitations: the stations are frequently too widespread, the resolution of the data is poor and calibration with ground temperatures is not always possible. These issues can now be partially overcome by the use of multispectral and high resolution satellite images (Cheval et al., 2011; Bogdan, 2009).

The Romanian studies focusing directly on the problem of frost weathering are very few, most of the references using air temperature data available from the meteorological stations, of which only 11 are distributed within the periglacial belt (above 1800 m) of the Romanian Carpathians. Within these works, frost potential is presented for specific mountain valleys, sectors or massifs (Michalevici-Velcea, 1961; Urdea, 2000; Oprea, 2005; Nedelea, 2006; Andra, 2008). Special attention to surface temperatures is given by Stoenescu (1951) who performs in-situ measurements and describes in detail the seasonal frost in a high mountain area.

Two contributions (Posea et al., 1974; Vespremeanu-Stroe et al., 2004) are dealing with the particular distribution of frost potential at the scale of the Romanian Carpathians at different altitudes, while only one study presents systematic ground temperature measurements in relation to freeze-thaw processes (Vespremeanu-Stroe and Vasile, 2010). Onaca (2013) also relates to this topic in discussing the periglacial processes in the Carpathians. Most of these give little weight to terrain properties, focusing solely on thermal data (which is the climatic forcing), without a wider perspective on “the real matter exposed to weathering”, i.e. the ground surface characteristics. Thus, we consider that if there is no surface exposed to the action of frost, than the analysis of freeze-thaw weathering comes without any significant present implications for the modelling of landforms in such typical areas and locations.

Considering the scarcity of information on ground thermal regime in the Romanian Carpathians, our general purpose is to offer a reference on the local disparities between air temperature recordings and ground thermal regime based on field data. The main objectives are: i) to evaluate the potential of frost occurrence from air temperature data given by meteorological stations in comparison with simultaneous field ground surface temperatures, ii) to discriminate between in-situ air and ground temperatures relevance with the integration of topographical aspects and surface properties and iii) to assess whether or not is possible to calibrate air data with rock or soil temperatures or other climatic parameters in specific-scale locations and increase its reliability in expressing frost weathering.

This paper is part of a larger study dedicated to multiple aspects of frost processes and their implications in frost weathering in this mountain area based on extensive field monitoring in the last six years.

2. Study sites and methods

Air, soil and rock temperatures were recorded for one to several years between 2008 and 2013, with the use of automatic iButton thermistors (accuracy ± 0.5 °C) set up at a two hours sampling interval. Measurement depth in rockwalls was 3 cm, while in soil the sensors were placed at 3 cm and 13 cm. Data from the meteorological stations Vf. Omu (Bucegi Mountains, 2504 m a.s.l.), Babele (Bucegi Mountains, 2206 m) and Țarcu (2180 m, Țarcu Mountains) were computed. In-situ air temperatures

were also retrieved by the external sensors of RisfoxMini crack extensometers, which measured temperature every 30 minutes.

The locations were set in intra-mountain depressions and valley couloirs between 600 and 1300 m (Poiana Ștampei, Bixad, Joseni), mean-high altitude mountain interfluvies and plateaus between 1100 and 2200 m (Sf. Ana Lake, Clăbucetul Taurului, Piatra Mare and Cocora Mountains, Baba Mare) and in steep rockwalls above 2200 m in Bucegi and Retezat Mountains on southern, eastern

and northern exposures. As the intra-mountain depressions and high-altitude mountains were previously shown to have the highest number of potential frost days based on meteorological air temperature long-term records (Vespremeanu-Stroe et al., 2004), we reported to this study to test its estimations in natural field conditions. The detailed results from three study areas are discussed (Fig. 1) and the characteristics of the locations in each unit are presented as follows.

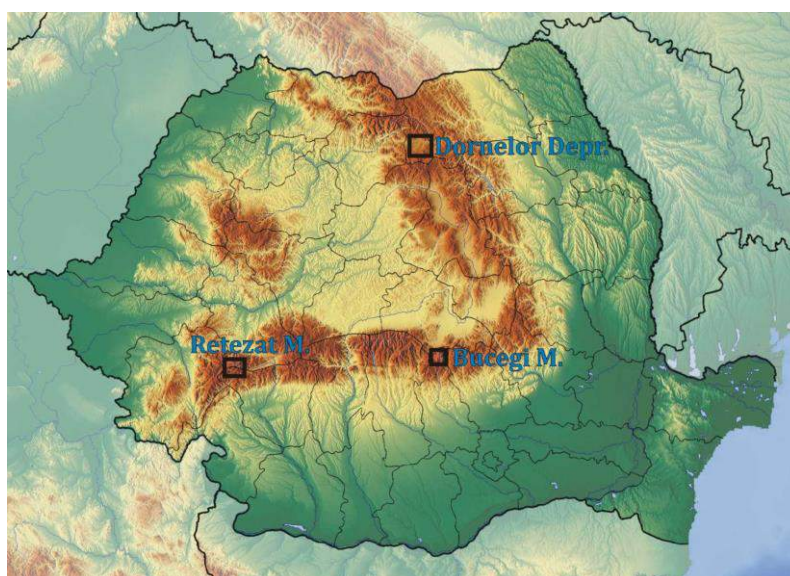


Fig. 1. Main study areas position in the Romanian Carpathians: Dornelor Depression (Poiana Ștampei) in the Eastern Carpathians, Bucegi Mountains (Vf. Omu, Baba Mare, Cocora Mountain, Doamnei Valley) and Retezat Mountains (Turnul Porții) in the Southern Carpathians.

a) Dornelor Depression is situated in the Eastern Carpathians, presents a mean altitude of 750-800 m and it is bordered by Suhard Mountains in North, Rarău Mountains in North-East and Călimani Mountains towards South. Its lithology is dominated by crystalline schist and volcanic rocks. Mean annual air temperatures range around 5 °C and precipitations cumulate 800 mm/year. This depressionary unit presents the longest period with frost occurrence potential from Romanian Carpathians (Vespremeanu-Stroe et al., 2004; Posea et al., 1974), under the specific influence of frequent thermal inversion phenomena. In Poiana Ștampei location, sensors were set up in soil, on an andesitic outcrop and in air, during 2009-2010 at an altitude of 900 m.

b) In Bucegi Mountains, measurements were set near Vf. Omu peak (soil and rock, 2503 m), on the plateau near Baba Mare (soil and rock, 2263 m) and Cocora Mountain (soil, 2043 m, Photo 1) and in the upper part of Doamnei Valley (rock and air, 1929 m). All the sensors measuring soil temperature and

the one measuring rock temperature at Vf. Omu were placed on horizontal surfaces, without obstacles around that would impose shadow effects. At Baba Mare (Photo 2) and Doamnei Valley the sensors were measuring temperature of vertical rockwalls (85-90° slope), exposed southward.

The investigated slopes were limestone outcrops, with medium porosity, which theoretically allows water infiltration at pores level, leading to ice segregation (Matsuoka, 2001; Hales et al., 2011). Multiannual meteorological data indicate mean annual temperatures of -2.4 °C at Vf. Omu (1960-2007) and average precipitation of 1500 mm/year.

c) The location investigated in Retezat Mountains was on Turnul Porții, where air and rock temperatures were registered in a north-exposed vertical rockwall (2113 m a.s.l.). As the location lays on granite and granodiorite rocks, with high macrogelivation potential (Urdea, 2000), there is a visible high frequency of deep joints sets which it is assumed to enhance the detachment of medium and large size boulders.



Photo 1-2: Examples of ground temperature monitoring locations in Bucegi Mts: Cocora Mountain interfluve (top), Baba Mare rock outcrop (bottom).

By selecting these locations, we try to present the behaviour of the ground surfaces with long-lasting snow cover (flat surfaces) and of those surfaces which are at least in part snow-free, due to steep topography and wind action (i.e. the vertical rock slopes). The data from additional locations were used to infer the ratio between the days with snow cover and those with freeze-thaw cycles during the winter season, as well as the difference between oppositely oriented rockwalls.

3. Results

In relation to frost weathering, freeze-thaw cycles may be regarded as both preparing and triggering processes, but in any case their evaluation is based on frequency and magnitude, which enable us to differentiate between diurnal (shallow and small depth) and seasonal (deep freezing) cycles. In the same time, it has been shown that, depending on ground properties, the temperature at which water freezes in rock or soil may vary significantly. Based on the existing models (Matsuoka, 2001; Washburn, 1979), in our previous study we considered a threshold of 12 h°C (hours degrees) for a cycle to be efficient (Vespremeanu-Stroe and Vasile, 2010), and the short oscillations through 0 °C have only a shallow effect which makes them inefficient in promoting intense damage upon ground surfaces. It is obvious that this filter might be reviewed and completed, and we are aware that without clear knowledge of water content and dynamics in

subsurface, even ground temperature can only provide a potential condition for frost to occur. Keeping this in mind, we here use the 0 °C threshold to get a good comparison with the air data, for which a better limit than this one is difficult to establish. Further, different situations are described in order to distinguish between the signals offered by air and ground temperature.

3.1. Poiana Ștampei location

The temperature data available in the meteorological archives cover only daily values of mean, maximum and minimum air temperature. On this basis, the formula presented in our reference study (Vespremeanu-Stroe et al., 2004) uses these parameters, gives the number of days with freeze-thaw occurrence potential (N_g) and refers only to diurnal oscillations:

$N_g = N(T_{min}) - N(T_{max})$, where $N(T_{min})$ = the number of days with the minimum temperature ≤ 0 °C and $N(T_{max})$ = the number of days with the maximum temperature < 0 °C. The result indicates a number of 124 days with frost cycle potential per year at Poiana Ștampei, reporting to the 1961-1990 time-sequence of air values.

For the interval July 2009 - July 2010, our data indicates 97 diurnal oscillations through 0 °C in the air temperature series (Fig. 2), which fits with the meteorological multiannual value standard deviation. During winter, air shows the lowest value (-21 °C), followed by the rock surface (-16 °C) which shows the same variations but much smaller amplitudes, while in soil during the entire season temperatures are close to 0 °C, with no significant oscillations (Table 1). This clearly indicates the presence of an isolating snow layer, which makes the soil to remain at the limit of freezing, without connection to the air fluctuations.

The investigated rock outcrop, which was permanently snow-free as shown by the data (Fig. 2), exhibits 44 cycles, less than half of those counted using the air temperatures (Table 1). Using the 12 °C freezing index as a threshold, 35% of these cycles in rock are actually efficient. This difference shows a more realistic dimension of the process, because it relates the temperature to the surface exposed to weathering and its thermal properties. Our presumption is that the air cycles with reduced amplitude (less than 1.5 °C, for instance) do not materialize into rock cycles, because of the energy modifications during phase change. Therefore, air temperature itself largely overestimates the frequency of frost processes (44 cycles instead of 97) and this may change the presumed intensity and efficiency of gelivation and gelifraction in this specific morpho-climatic units.

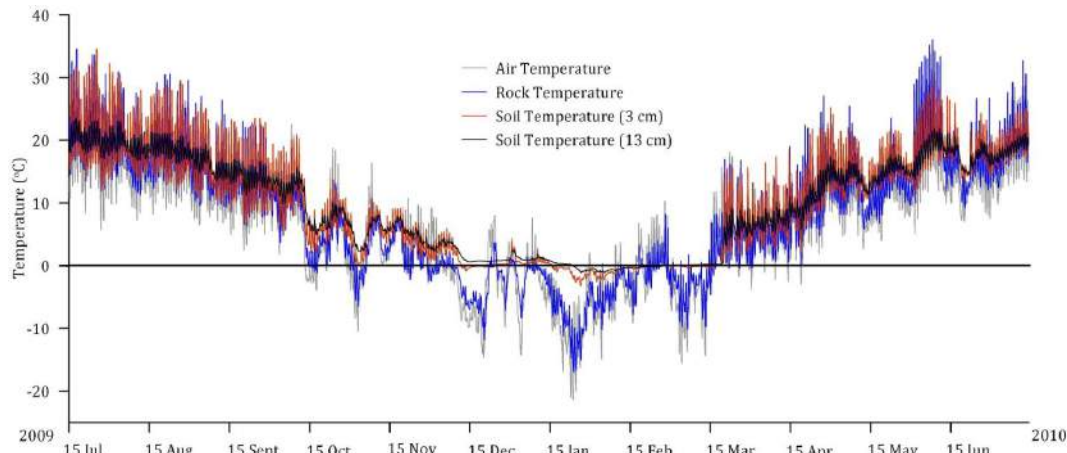


Fig. 2 Air versus ground (soil and rock) thermal regime at Poiana Ștampei location, Dornelor Depression (July 2009 - July 2010; recordings time step of two hours).

Given the morphometric characteristics of Dornelor Depression (low-mean altitude, predominance of flat surfaces, forested slopes) and the results presented above, we could further assume that frost weathering does not have a significant contribution to the present modelling of the relief, although there is a great climatic potential, because most of the ground is covered by snow and the efficient diurnal cycles are less than 10% of the air temperature derived frost cycles. The soil temperature data show that for three months, horizontal surfaces are insulated and get 0 °C equilibrium temperature of thick snow layer. Within the entire frost potential interval given by the air thermal regime (13/10/2009-22/04/2010), there are only 7 oscillations through 0 °C at 3 cm depth and two at 13 cm, while the mean temperature is -1.7 °C and -0.5 °C respectively. This proportion is similar in the additional horizontal surfaces that we investigated and emphasizes the importance of snow cover in such studies. Figure 3B presents the number of days in which frost cycles may occur in comparison with the number of days with snow cover, as shown by two-year data in all the soil temperature monitoring locations. If the number of

frost cycles shows a slight increase with altitude, most probably due to lower temperatures in transitional seasons and to snow redistribution, the maximum duration of snow cover matches the depression and mountain valley units (e.g. Poiana Ștampei in Dornelor Depression – 133 days, Coteanu location on the Ialomița Valley, Bucegi Mountains – 145 days). Consequently, although presenting a high potential for frost weathering, these units are affected most of the winter by snow cover, due to typical shelter conditions and frequent thermal inversions, comparing to the mean-high altitude interfluvies which are more exposed (Baba Mare – 69 days; Cocora – 64 days). There is a very reduced number of efficient cycles that affect horizontal surfaces in depressions (5 to 15 cycles, Fig. 3), which cover approximately 3 to 7 % of the total frost-potential interval defined by air temperature. Nevertheless, a high frequency of diurnal freeze-thaw may be attributed to the steep surfaces in river-cut gorges and defiles, which we did not document here, but which generally cover a small percentage of the surface of intra-mountain Carpathian area.

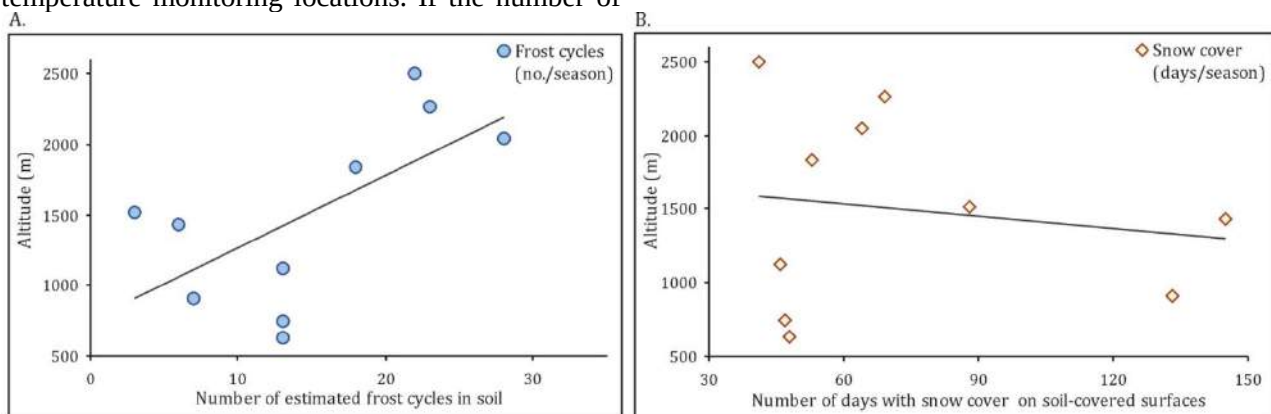


Fig. 3. Efficient diurnal frost cycles (A) and days with snow cover (B) within the interval with frost occurrence potential. The graph is based on two years of soil temperature data in intra-mountain depressions and mean-high altitude mountain interfluvies (2008-2010).

Table 1: Mean annual temperature and the number of frost cycles from in-situ continuous measurements in air, soil and rock at the selected locations (*sensors functioned from December to August exposed South; **sensors functioned from November to September exposed North, meteorological data from Țarcu station were used).

Location	Landforms	Alt. (m)	Meteorologic air data		In-situ measured mean annual temperature			Number of diurnal frost cycles		
			Diurnal cycles	Mean annual	Air	Rock	Soil 3cm	Air	Rock	Soil 3cm
Poiana Ștampei	depression	900	124	5	6.8	7.5	9.5	97	44	7
Vf. Omu	high alt. Interfluve	2500	104	-2.4	-	1.3	1.2	-	80	22
Baba Mare	high alt. plateau and rockwall	2200	96	0.1	-	4.2	3.3	-	130	23
Doamnei*	rockwall	1900	-	-	4.6	5.5	-	41	84	-
Turnul Porții**	rockwall	2200	81	-0.6	0.4	0.6	-	21	24	-

3.2. Ground and air thermal regime at high altitudes in Bucegi Mountains

The locations chosen at high altitudes (~ 2500 m), close to Vf. Omu peak, are facing a large variability of surface conditions, as a consequence of intense wind (average speed of 10-11 m/s in November-March, Vespremeanu-Stroe et al., 2012) which highly impacts the deposition of snow and ground-air connection during potential frost intervals, and overlays the severe thermal conditions at this altitude (mean annual air temperature of -2.4 °C). To evaluate the interval of potential frost occurring, we considered the daily air temperature data from the meteorological record as a proxy, as shown in the Poiana Ștampei case. In this context, soil temperature data at 3 cm depth shows that at Vf. Omu, during 70% of the duration of frost potential interval, flat soil surfaces are covered by snow (Fig. 4A). Complementary, the remaining 30% of the days are affected by diurnal freeze-thaw cycles. The ratio of freezing to snow-covered intervals (30/70) defines the temporal availability of flat surfaces from a location to the manifestation of gelivation processes. As this ratio was 2/98 (2% diurnal freeze-thaw of the ground, to 98% - snow cover effect) in the previous cases from intra-mountain depressions, it is noticeable that changing the altitudes, but especially the landform features, the ground thermal regime changes significantly, and the freeze-thaw cycles frequency as well.

The monitored rock surface at Vf. Omu location (Fig. 4A) was horizontal within the same topographic context as the soil location nearby. The number of

diurnal freeze-thaw oscillations surpasses the one estimated in the air via meteorological records (80 frost cycles in rock *versus* 70 cycles in air, respectively). This can be explained by the higher thermal amplitude of uncovered rock surfaces which are exposed to direct solar radiation. On the other hand, during the monitoring period, a large interval (16 November - 31 March) faced the seasonal (or siberian) frost cycle with a mean temperature of -7 °C. During the first half of this interval, the rock followed the air temperature fluctuations, while in the second, diurnal amplitudes were much diminished, indicating the probable formation of an ice crust (layer) which prevents direct heating during sunny daytime. The ice layer still allows a filtered heat exchange with the atmosphere, as temperatures remain constant much below the freezing point and close by the mean air temperatures. The seasonal freezing appears in the same period at the soil locations from Vf. Omu and Baba Mare. Its intensity and duration recommend it as a major morphodynamic agent, as it deeply affects the ground with significant implications in weathering. If the interval with potential of diurnal freeze-thaw was given by the formula presented above, the duration of seasonal frost coincides with a more or less continuous period of winter days ($T_{max} < 0$ °C) and should be used as well in evaluating frost weathering at a specific location, in order to get a full image of its action.

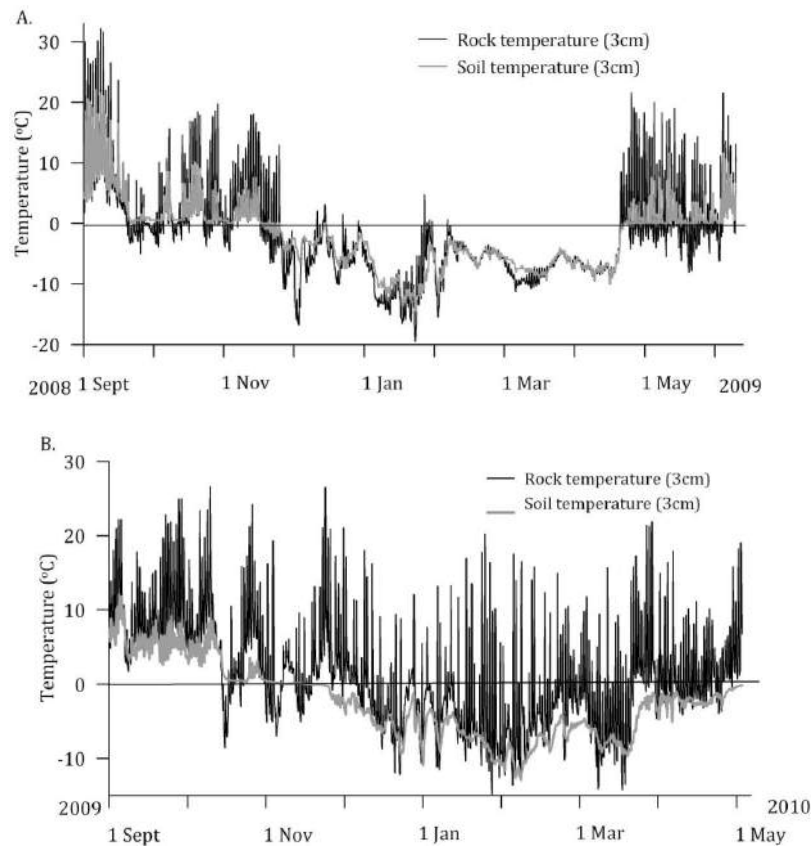


Fig. 4 (A) Thermal regime at Vf. Omu (2503 m) in horizontal rock outcrop and soil, during the cold season 2008-2009; (B) Thermal regime at Baba Mare location (2200 m) in vertical south-exposed rock slope and in soil during the cold season 2009-2010.

Thermal behaviour of snow-free rockwalls was monitored on south exposed sites, besides the air and soil surfaces. The air and rock sensors set at Doamnei Valley location (1929 m) functioned from December 2011 to August 2012. During this period, the frost potential obtained from daily air temperature values (Vf. Omu meteorological station) is 39 days, very similar to the number of air diurnal cycles measured on site, 40 cycles respectively. There are twice as many oscillations observed in the south-exposed rockwalls (84 freeze-thaw cycles) in the same period, with significantly

high amplitudes (Fig. 5) presenting an average freezing index of 35 h°C (hours degrees) for the diurnal freeze-thaw cycles, that imply a very high weathering potential of the rockwall at shallow depths (20 – 50 cm). The rock is on average 1 °C warmer than the air, which indicates again that rocky surfaces are largely influenced by the direct incoming solar radiation. These results give us a first sight of the exposure implications in the context of site-specific assessment of weathering intensity at different scales.

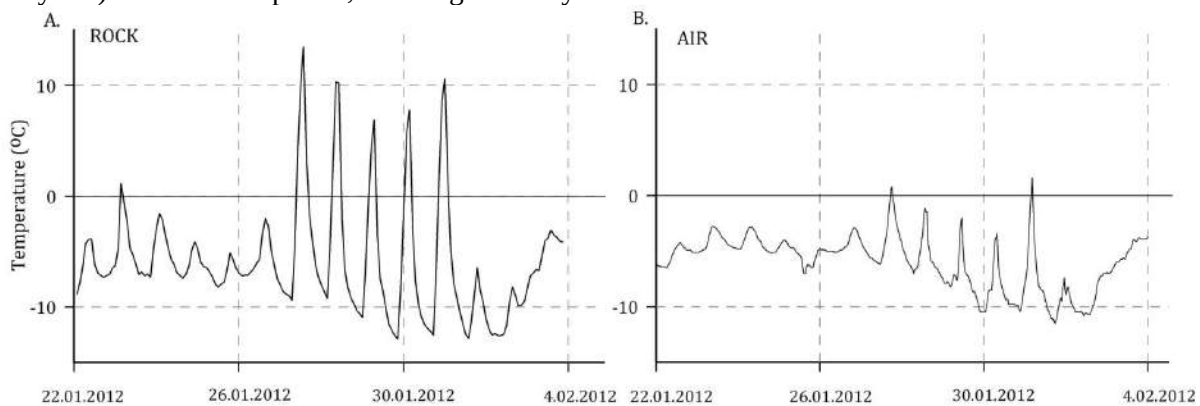


Fig. 5. The co-evolution of temperature in the vertical rockwall exposed to south (A) and in air (B) at Doamnei Valley location in Bucegi Mts (1920 m) during 22 January - 4 February 2012 interval

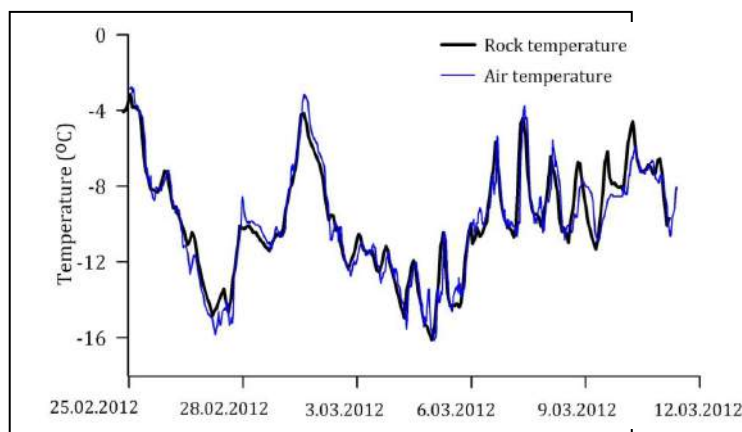
The difference between flat surfaces and steep rockwalls is presented in the data from Baba Mare location (2200 m) by comparing soil and rock temperature (Fig. 4b). This case also highlights the specific conditions of south-oriented surfaces, where 130 diurnal freeze-thaw oscillations occurred in one season (with a mean freezing index of 52 h°C for the diurnal freeze-thaw cycles), compared with the potential number of 69 cycles estimated based on daily air values, while seasonal frost is apparently missing in the very shallow rock layer, due to the intense solar radiation; conversely, the seasonal frost acts at depths of 0.2 – 2.8 m (according to modified Berggren equation). In opposite, the soil covered surface was dominated by the snow covered interval (58 days) and seasonal frost (120 days) and it exhibits a diminished frequency of diurnal oscillations (22 cycles) characterized by low intensity (freezing index equals 2-7 h°C).

3.3. Rockwall thermal behavior at Turnul Porții site

The air and rock sensors from Turnul Porții location (Retezat Mountains, 2130 m) functioned between 11 November 2011 and 1 September 2012. The rock sensor was set on a north-facing vertical slope and

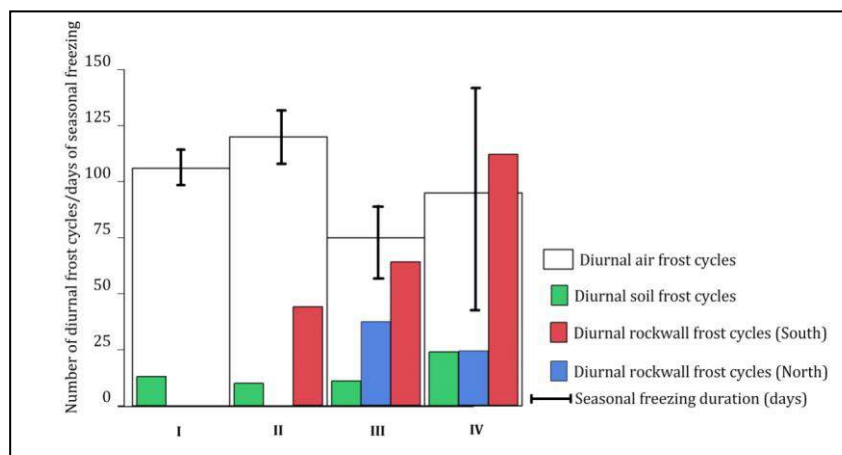
was snow-free except for the interval 5 December 2011 – 23 January 2012, when a very thin snow layer was probably present. The effect of direct solar radiation was clearly absent as the rock kept a similar temperature as the air during the 10 month period (average of 0.6 °C in rock, and 0.4 °C in air) and the number of diurnal cycles is similar (24 cycles and 21, respectively) (Fig. 6). Although these series do not cover an entire year, we can notice the large difference in respect to the multiannual air estimations at the same altitude, based on the nearest meteorological station (81 freeze-thaw potential days at Țarcu station, 2180 m). Thus, except for the ground temperature, air thermal behaviour seems also to be influenced by the northern exposure, but this study cannot give sufficient arguments on this problem.

Seasonal freezing has a significantly long duration on this site, and the mean temperature of this interval is -7 °C, favouring an intense and prolonged action to a potential depth of 7.5 m. The implications of this regime are reflected by the large dimensions of resulting rock fragments. Nevertheless, it is worth noticing the different manifestation of south and north-exposed rock surfaces which cannot be captured by the data gathered on a random meteorological station.



5. The co-evolution of air and rock temperature at Portii north-exposed slope during 25 February – 12 h 2012 interval, under seasonal freezing conditions

Fig. 7. Annual distribution of diurnal freeze-thaw cycle frequency and seasonal frost duration in the investigated mountain units: I) low-altitude depressions and valley couloirs (300–700 m); II) high altitude depressions (700–1300); III) low to mean altitude interfluvies and plateaus (1300–2000 m), IV) high-altitude interfluvies and rockwalls (> 2000 m). Frost cycles number was calculated by measured air values, soil and rock temperature measured at 3 cm depth, on south and north-exposed vertical slopes and seasonal freezing from soil thermal regime.



4. Discussion and Conclusions

Following the in-situ measurements results, it seems that air temperature can be used with reasonable confidence only to estimate the interval for diurnal freeze-thaw cycles occurrence and the seasonal frost duration. The use of air temperature data was found unsuccessful to determine the frequency and the efficiency of the freeze-thaw cycles in different ground types (soil and rock surfaces) based on their intensity (magnitude and duration), especially when remote locations (as usually the meteorological stations) are used, excepting the case of northern rockwalls where feasible estimations are possible. By comparing the mean annual meteorological data with the air values registered in the field, good correspondence resulted in a first phase for both depressions and high-mountain environments, but caution is necessary especially when considering snow-covered areas or south-exposed surfaces with high income of direct solar radiation where the correlations become weaker.

The estimation of freeze-thaw frequency by air temperatures can lead to large inaccuracies when additional ground surface characteristics are not integrated. Using the example of Poiana Șampei location and those of intra-mountain depressions and high-altitude interfluves in the Romanian Carpathians, it can be observed that at ground-level the potential interval for diurnal freeze-thaw occurrence is actually split up in three distinct intervals: diurnal cycles, seasonal frost and snow cover. The duration of each time-sequence is variable and is strictly controlled by the topographical parameters of the setting (slope, soil-covered or free rock surfaces, rockwalls with different orientations) and by altitude, which impose distinct climatic forcings (Fig. 3, Fig. 6). In the analysis of horizontal surfaces, the temporal ratio between active freezing and snow cover intervals is of a great importance for a reliable result, as it can vary substantially from 2-4 / 98-96 in the depressions (persistence and thickness of snow-cover) to 20-30 / 80-70 on the high-altitude mountain interfluves (surface exposed to severe wind conditions and constant low temperatures). Thus, although having the highest diurnal freezing potential interval, snow cover is clearly the dominant regime in the depressions, due to the fact that wind-protected horizontal surfaces are the most extended, while in the plateau area of Bucegi

Mountains above 2000 m, the seasonal frost is active for 2-3 months.

In the case of mostly snow-free rock surfaces, the effect of exposure can lead to very different interpretations of weathering magnitude and mechanisms, especially when comparing north and south-oriented rock facets. Air is shown to be less sensitive than rock surfaces to opposite exposures and largely underestimates the diurnal freeze-thaw processes on the southern slopes acting on shallow depths of 15 – 50 cm (Fig. 5-7). The daily effect of direct solar radiation on the rock surfaces induces an intense activity of high amplitude diurnal oscillations which does not correspond to those of air. Nevertheless, air temperature derived indices are still relevant for the northern slopes which only receive caloric energy from the air, as showed at Turnul Porții location. The most important aspect of north/south distinction is the assessment of seasonal and diurnal freezing weight in the general frost weathering process.

Finally, the reliability of air temperature values highly depends on the purpose of the study and of the capacity of integrating specific characteristics of the surface, especially when confronting with high slopes of opposite orientations. In such cases, more detailed topographic information are needed to get a reliable estimation of the manifestation of the weathering processes and the conversion of meteorological data is complex and requires in-situ thermal data from multiple altitudes, exposures and slope conditions for calibration. Horizontal surfaces such as depressions and large plateau areas should be easier to address, because the data from meteorological stations can provide relative information for the seasonal freezing and active diurnal freezing interval, whereas ground surface thermal measurements are needed for the evaluation of the snow-cover effect and to model the freeze-thaw cycles efficiency.

Acknowledgements

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Variabilité spatiale de l'infiltrabilité sur les versants marneux de l'Isser-Tlemcen (Algérie)

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Résumé. En Algérie du Nord, le phénomène d'érosion hydrique présente la forme de dégradation physique des sols la plus importante affectant les reliefs, la production du sol et la stabilité des versants.

L'objectif de ce travail est d'évaluer l'influence des contraintes naturelles sur quelques propriétés hydrodynamiques des sols sous différents modes de gestion des terres afin d'appréhender les zones contributives du ruissellement et des pertes en terres au niveau du bassin versant de l'Isser (nord-ouest d'Algérie).

Pour réaliser un bon diagnostic des risques de ruissellement et d'érosion sur un versant cultivé, il est nécessaire d'observer le fonctionnement hydrique du terrain au cours de la saison des pluies, ou tout au moins, de tester la capacité d'infiltration des sols soumis à diverses utilisations les plus courantes (Roose, 1996).

La mesure de l'infiltrabilité du sol par les méthodes classiques est cependant assez longue et coûteuse. Nous présentons ici le test d'infiltration au cylindre unique sous charge décroissante (surface = 100 cm²) qui est une méthode simple et de faible coût suggérée par Roose et al. en 1993. Ce test permet non seulement de classer les horizons d'une toposéquence en fonction de leur capacité d'infiltration, mais aussi de visualiser le mode de circulation de l'eau d'un horizon aux suivants par comparaison des taches d'humidité créées par l'infiltration. Un exemple sera décrit sur un versant marneux de l'Isser sur sols bruns calcaires argileux. Les mesures sont effectuées à l'échelle du m², sur un échantillon de six parcelles soumises à différents systèmes de culture. Il en ressort que l'infiltration est très liée à l'état hydrique et structural du sol. Elle augmente de l'amont vers l'aval des versants et est plus élevée sur les versants exposés nord que ceux exposés sud.

Mots clés : Isser, érosion, infiltrabilité du sol, méthode monocylindre, spatialisation.

1. Introduction

La dégradation des sols par l'érosion est l'un des problèmes majeurs auxquels est confrontée l'agriculture à travers le monde en général et en Algérie en particulier. Elle résulte de la conjonction de plusieurs facteurs : agressivité des pluies ; érodibilité des sols ; dissection du relief ; faiblesse du couvert végétal... Ce phénomène contribue non seulement à la réduction de la productivité des sols mais aussi à la pollution des eaux de surface et à l'envasement prématuré des infrastructures hydrauliques.

En Algérie, environ 6 millions d'hectares sont exposés aujourd'hui à une érosion active et en moyenne 120 millions de tonnes de sédiments sont emportés annuellement par les eaux. Les pertes annuelles des eaux dans les barrages sont estimées à environ 20 millions de m³ dues à l'envasement (Remini, 2000). La subsistance des populations est de plus en plus menacée par les pertes en sol. L'identification des zones vulnérables à l'érosion et l'estimation quantitative des risques érosifs est donc

un enjeu important pour les gestionnaires des retenues et pour les aménageurs dans une perspective de conservation des sols.

L'étude des risques de ruissellement et d'érosion sur un bassin versant exige une bonne compréhension du comportement hydrologique du sol et, en particulier, de la capacité d'infiltration qui dépend de ses états de surface et des types de sols (Coutadeur et al., 2002). Dans ce contexte, le présent travail consiste en l'étude de l'infiltration dans le bassin versant de l'oued Isser au nord-ouest algérien en vue de simuler le comportement hydrologique des sols vis-à-vis de l'érosion hydrique. Il vise à déterminer les effets de diverses utilisations des terres sur la capacité du sol à infiltrer les eaux de pluies en utilisant la méthode du monocylindre (Roose et al., 1993).

L'infiltration qualifie de transfert de l'eau à travers les couches superficielles du sol, lorsque celui-ci reçoit une averse ou s'il est exposé à une submersion (Musy & Higy, 2004). L'eau pénètre dans le sol par les pores, les fissures, les orifices pratiqués par les vers ou occasionnés par la

pourriture des racines ainsi par les cavités résultants des labours ou de la préparation du sol pour la plantation. Elle remplit en premier lieu les interstices du sol en surface et pénètre par la suite dans le sol sous l'action de la gravité et les forces de succion.

Par ailleurs, la capacité d'infiltration (ou infiltrabilité) du sol représente le flux d'eau maximal que le sol est capable d'absorber à travers sa surface. Elle dépend, par le biais de la conductivité hydraulique, de la texture et de la structure du sol, mais également des conditions aux limites, c'est à dire, la teneur en eau initiale du profil et la teneur en eau imposée en surface (Musy & Higy, 2004).

Certains auteurs ont établi des fonctions de puissance entre le gradient de pente et l'érosion en nappe (Govers, 1991 ; McCool et al., 1993). Il a été démontré, en se basant sur des pluies simulées, que plus la pente est forte plus l'infiltration est faible à cause du changement des propriétés de la surface du sol et la mise en place de la croûte de battance qui se traduisent par l'augmentation de l'érosion (Poesen, 1984).

La quantification de l'infiltration de la pluie par le sol est abordée dans la littérature soit à partir de simulations de pluie (Morgan et al., 1997), soit en reliant les risques d'érosion à des indicateurs accessibles sur des cartes préexistantes (géologie, pédologie) (Veihe, 2002), soit par l'étude, à partir d'une base de données de mesures, des relations statistiques entre des combinaisons d'état de surface

et érosion mesurée (Le Bissonnais, 2005). Différents auteurs se sont attachés à comparer ces différents types de modélisations dans des situations contrastées : bassins versants urbains (Zariello, 1998), bassins versants agricoles (Kannan et al., 2007) ou encore dans le contexte des parcelles expérimentales agricoles (Chahinian et al., 2005). Il en ressort que la mesure de l'infiltration en un point donné du bassin versant est une opération relativement aisée, mais la difficulté réside dans le fait de chercher l'infiltration qui caractérise l'ensemble du bassin, car celui-ci est très hétérogène de point de vue perméabilité. C'est pourquoi il faut faire beaucoup de mesures. De ce fait, l'infiltromètre au monocylindre suggéré par Roose et al., (1993) a été choisi pour faire le nombre de mesures nécessaire. Cet outil n'exige que peu de matériel, peu d'eau, peu de temps et s'adapte parfaitement aux fortes pentes ($> 15\%$). Il a été utilisé pour d'autres régions et plusieurs thématiques par Brouwers (1990), Roose et al. (1993), Roose (1996), Morsli (1997) et Boughalem et al. (2013).

2. Zone d'étude

Le bassin versant (BV) de l'Isser se situe au nord-ouest algérien, entre les longitudes $1^{\circ} 20' 31''$ W et $0^{\circ} 52' 28''$ W et les latitudes $34^{\circ} 41' 22''$ N et $35^{\circ} 9' 37''$ N. Il s'étend sur une superficie de 1122 km^2 pour un périmètre de 207.7 km (Fig. 1).

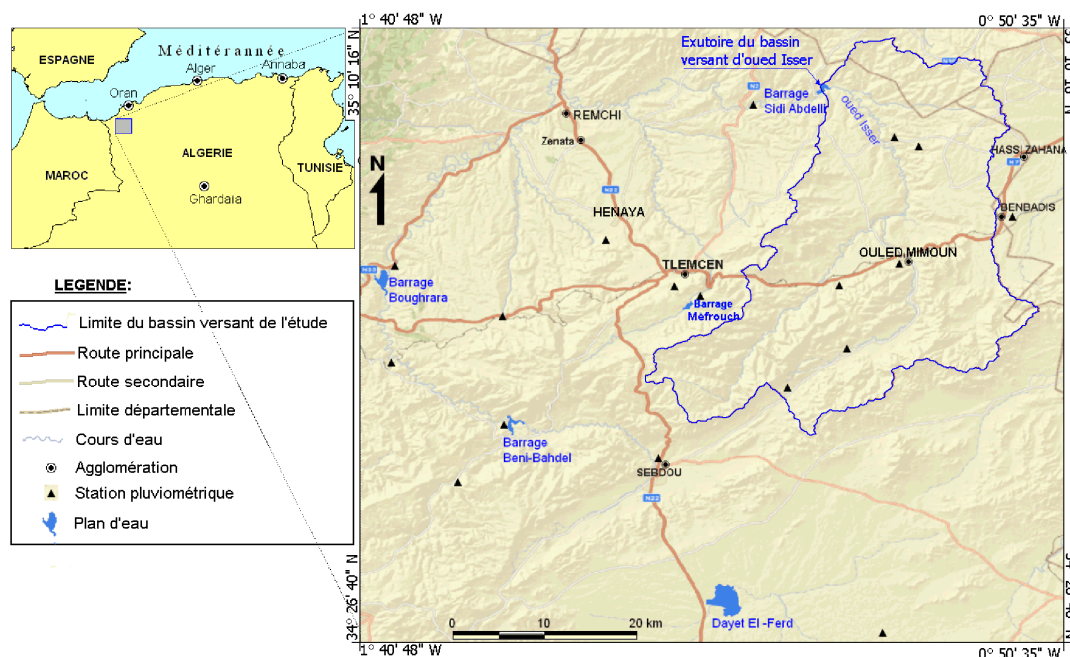


Fig. 1. Carte de situation de la zone d'étude

Affluent rive droite de la Tafna, l'oued Isser est long de 81 km. Il prend sa source à Ain Isser au Sud d'Ouled Mimoun. Il est caractérisé par :

1. Un climat de type méditerranéen semi-aride avec des pluies annuelles qui varient de 280 mm à 500 mm. Ces pluies sont déterminées par une irrégularité spatio-temporelle et par un régime de courte durée et à forte intensité (l'intensité maximale peut atteindre 84 mm/h en 30 min) (Mazour, 2004);
2. Un relief très escarpé et fortement disséqué, ayant souvent de fortes pentes et un réseau de drainage très dense ;
3. Une lithologie définie par des roches en majorité tendres (marnes et grès tendres) ce qui prédispose ces zones aux différents processus d'érosion ;
4. Des formations végétales très dégradées, caractérisées par de faibles densités de recouvrement et de mauvaises conditions de régénération.

La zone nord du bassin, où se trouve le site d'étude est à vocation céréalière (notamment blé et orge). Sur le massif rocheux du Jurassique subsistent encore quelques forêts (Zerdebs et Fougahals). Par ailleurs, la superficie occupée par un couvert forestier dégradé ou mort est de 39% de la surface totale du bassin.

3. Matériel et méthodes

L'étude du comportement hydrodynamique du sol repose sur un dispositif expérimental que nous avons installé au nord du bassin sur 3 campagnes

agricoles (2008-2010) et qui est constitué de 6 parcelles paysannes, rectangulaires de 200 m² chacune, sur des pentes allant de 15 et 20 % (Fig. 2).

Deux de ces parcelles (P1 et P2) ont été semées d'orge, sans labour « semis direct », les quatre autres (P3, P4, P5 et P6) ont été semées de blé tendre après un labour. Les parcelles expérimentales ont été également choisies de façon à avoir 2 états d'exposition (nord et sud). Pour chacun de ces états, nous avons choisi une parcelle en haut de la pente et une autre en bas de la pente pour élargir le spectre des variations. Le choix des parcelles d'essai a été commandé d'abord par les impératifs techniques tels que l'accessibilité et la disponibilité en eau, puis l'uniformité de la surface du sol, le type de sol, la possibilité de gardiennage et surtout l'accord du propriétaire du terrain.

Le Tableau 1 résume les caractéristiques des parcelles expérimentales étudiées.

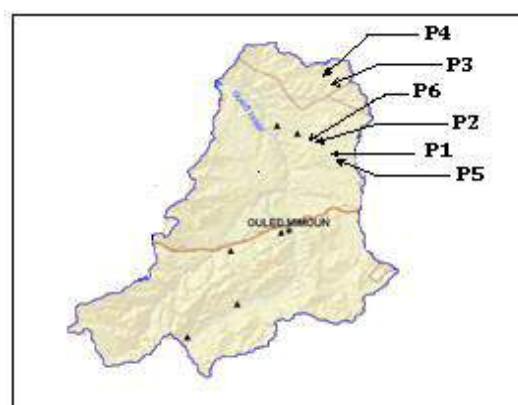


Fig. 2. Localisation des parcelles expérimentales à travers le bassin versant de l'Isser

Tableau 1. Caractéristiques des parcelles expérimentales étudiées

Parcelle	Semis	Exposition	Situation sur le versant	Travail du sol
P1	Orge	Nord	bas de pente	Semi direct
P2	Orge	Nord	haut de pente	Semi direct
P3	blé tendre	Sud	bas de pente	Labour
P4	blé tendre	Sud	haut de pente	Labour
P5	blé tendre	Nord	bas de pente	Labour
P6	blé tendre	Nord	haut de pente	Labour

L'outil choisi pour ce travail est un dispositif à simple anneau à charge décroissante appelée aussi monocylindre (Roose et al., 1996) (Fig. 3). Le

principal avantage de cet infiltromètre est qu'il est portable, car contrairement aux simulateurs de pluie, il ne nécessite, pour fonctionner, qu'un litre d'eau

par test. Sa bonne portabilité le rend ainsi utilisable en terrain montagneux (pente forte, manque d'eau, accès difficile aux sites). Le test consiste à suivre l'infiltration en fonction du temps d'un litre d'eau introduit dans un cylindre métallique de 100 cm² de section et de 10 cm de charge initiale. Il consiste à tracer la courbe de la quantité infiltrée en fonction du temps d'arrosage. Des couples de lecture (hauteur d'eau « h », temps « t ») sont effectués avec une périodicité en fonction de la vitesse d'infiltration. Ce test est poursuivi jusqu'à ce qu'on obtienne une vitesse d'infiltration stable. Cinq mesures ont été effectuées sur chaque parcelle le long d'un transect de façon à estimer la variabilité intra parcellaire. Le travail se fait à la chaîne et mobilise au moins 4 personnes. Les valeurs d'infiltration obtenues ont été corrigées en fonction de la forme de la tâche d'humectation du sol sous le cylindre.



Fig. 3. Test d'infiltration au monocylindre

3.1. Influence de l'état hydrique des sols

Afin d'avoir des résultats comparables, tous les tests de suivi de la vitesse d'infiltrabilité ont été effectués en période d'été pendant le mois d'août, lorsque les sols se trouvaient dans leur état le plus sec (humidité du sol = 5%).

Toutefois l'état hydrique initial des sols varie au cours de l'année, raison pour laquelle des répétitions ont été menées en automne (novembre), en hiver (février) et au printemps (fin avril) sur des sols qui renfermaient respectivement une teneur d'eau mesurée en pour-cent massique de l'ordre de 15%, 45% et 28% dans les dix premiers centimètres du sol. Le choix de ces dates a été fait surtout sur la base de la répartition de la pluie au cours de l'année.

4. Résultats

La variabilité spatio-temporelle de l'infiltration de l'eau dans le sol est décrite par des courbes d'infiltration, représentant la distribution verticale des teneurs en eau dans le sol, à différents instants donnés (Fig. 4). Ces courbes présentent toutes, la même allure de décroissance avec le temps.

4.1. Influence de l'état hydrique initial du sol sur l'infiltration de l'eau

Durant les trois campagnes agricoles, les vitesses d'infiltration enregistrées en été (août) sont 2 à 3 fois supérieures à celles observées pendant la période humide au mois de février. Elles varient de 998 à 344 mm/h pour les sols secs (humidité = 5%), de 620 à 50 mm/h pour les sols humides (humidité = 15 - 28%) et de 398 à 38 mm de pluie par heure pour les sols très humides (humidité = 45%). Ces valeurs montrent que l'infiltrabilité d'un sol dépend surtout de son état hydrique initial.

4.2. Effet des modes de gestion des terres sur l'infiltration de l'eau

4.2.1. Parcelles en semis direct

L'infiltration moyenne est élevée sur les parcelles semées directement (998- 44mm /h), par contre, sur les parcelles labourées elle est moyenne et varie de 871 à 37 mm/h : la présence d'une litière à la surface du sol, fortement transformée par les vers de terre et les termites, explique la disparition des croûtes de battance et l'amélioration de la capacité d'infiltration de l'eau par le semis direct.

Sur les parcelles en semis direct exposées nord (**P1** et **P2**), l'infiltration moyenne est variable et augmente de l'amont vers l'aval des versants. C'est de ce fait qu'elle est modeste sur la parcelle **P2** située en haut du versant (920- 88 mm/ h) alors qu'elle atteint 988 mm/h sur la parcelle **P1** située en bas du versant.

4.2.2. Parcelles labourées (**P3**, **P4**, **P5** et **P6**)

L'infiltration moyenne varie en fonction de l'exposition des versants « nord/sud » et augmente de l'amont vers l'aval des versants. Ainsi, l'infiltration moyenne est plus élevée sur les parcelles **P5** et **P6** exposées nord (871- 38 mm/h) que sur celles exposées sud (**P3** et **P4** : 850-37 mm/h).

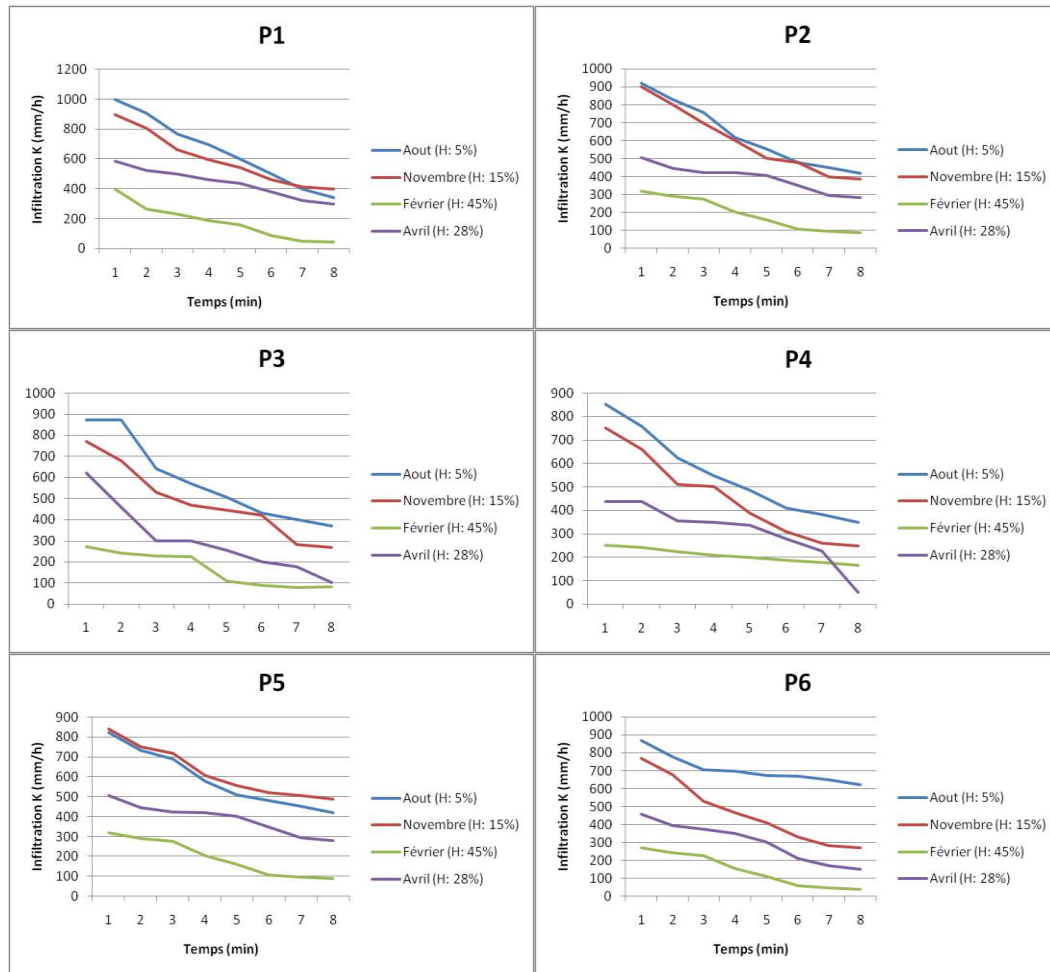


Fig. 4. Courbes d'infiltration des parcelles expérimentales étudiées

4.2.2.1. Parcelles exposées nord (P5 et P6)

Sur la parcelle **P6** exposée nord et située en haut du versant, l'infiltration moyenne est modeste (403 mm/h), alors qu'elle atteint 449 mm/h sur la parcelle **P5** exposée nord et située en bas du versant.

4.2.2.2. Parcelles exposées sud (P3 et P4)

L'infiltration moyenne est modérée (871- 82 mm/h) sur la parcelle **P3** (située en bas de pente). Sur la parcelle **P4** (située en haut de pente), l'infiltration moyenne de l'eau est encore plus faible (852- 50 mm/h). Celle-ci peut atteindre jusqu'à 38 mm/h quand le sol est humide (3^{ème} essai en février).

5. Discussion

Malgré leur bonne stabilité structurale, les sols marneux restent très sensibles à l'érosion du fait de leur comportement hydrodynamique particulier. Ils sont affectés d'alternances d'humectation et de dessiccation (déterminées par les conditions météorologiques) entraînant une microfissuration

des agrégats. Lorsque ces sols sont fissurés, l'infiltration est très élevée et une érosion interne peut être engendrée. Ces infiltrations peuvent même favoriser des mouvements de masse. A l'état plus ou moins saturé, l'infiltration devient très faible, ce qui déclenche facilement le ruissellement.

Les résultats montrent que ce sont les parcelles orientées au nord et situées en bas de pente qui enregistrent les valeurs d'infiltrabilité les plus élevées. Cela s'explique par leur richesse en biomasse qui favorise l'infiltration et s'oppose ainsi au ruissellement.

En effet, les teneurs en matières organique sur les versants nord sont relativement élevées et diffèrent selon les modes d'utilisation des terres. Les versants sud les moins arrosés et les plus érodés sont exposés à des conditions favorables de minéralisation de la matière organique (Mazour, 2004). De cette analyse de l'infiltration, il ressort que : i) si l'infiltration est élevée lorsque le sol est sec, elle peut atteindre des valeurs moyennes à faibles et même très faibles lorsque le sol est humide ; ii) l'infiltration sur les parcelles en semis

direct est plus élevée que sur parcelles labourées ;
iii) l'infiltration est variable dans l'espace : elle est plus élevée sur les versants exposés nord que ceux exposés sud. D'autre part, pour le même type de sol et la même orientation, l'infiltration augmente de l'amont vers l'aval des versants.

Par ailleurs, la valeur d'infiltration la plus faible a été mesurée sur la parcelle **P4**, labourée, orientée sud et située en haut du versant (parcelle pauvre en biomasse, sol tassé et endurci, croûte de battance...). Tandis que la plus forte valeur d'infiltration a été enregistrée sur la parcelle **P1**, en semis direct, orientée nord et située en bas du versant ; à ce niveau, le sol est maintenu couvert en permanence par une biomasse sèche de résidus végétaux, sa vie biologique s'anime, sa fertilité s'enrichit et il est à l'abri des différentes formes de dégradation. En réduisant le ruissellement, le système du semis direct constitue une protection efficace contre l'érosion.

Le travail du sol par labourage entraîne, en revanche, l'élimination des vers de terre qui entretiennent un réseau de galeries permettant la progression des racines et l'infiltration de l'eau. L'oxygénation du sol minéralise la matière organique, la terre s'appauvrit mais la culture en place bénéficie des minéraux libérés, ce qui donne l'impression d'une amélioration de la fertilité. En fait c'est le capital agronomique qui est consommé.

D'après Ehlers (1977 in Raheliarisoa, 1986), l'infiltration de la pluie s'est trouvée meilleure dans le cas d'un sol non labouré que dans le cas d'un sol labouré (blé sur sol loessique), et la différence est surtout nette pour les fortes intensités de pluie ; par conséquent le ruissellement et l'érosion sont réduits. Ce même auteur a démontré que la porosité totale des sols labourés et les pores supérieurs à 30 microns sont élevés dans la couche 0-10 cm, mais très réduits dans la semelle de labour (20-30 cm). Par contre, dans les sols non labourés, la porosité et les tailles des pores sont plus homogènement répartis dans tout l'horizon (0-45 cm).

Certains facteurs favorisent la structure du sol, d'autres la régénèrent. Un travail du sol excessif diminue la stabilité de la structure, de même qu'une hydratation trop brutale des agrégats, suivie d'une dessiccation rapide. Certains éléments interviennent sur la stabilité structurale et ont des interactions positives comme par exemple le calcium, l'humus et

le fer (Oades, 1984; Amézketa, 1999). La destruction de la structure ou la désagrégation se produit par une perte de porosité, de perméabilité, par une prise en masse, un état de dispersion, et par la formation d'une croûte de battance à la surface du sol.

Les résultats obtenus concordent avec ceux trouvés dans la littérature : Ehlers, 1977 ; Govers, 1991 ; Mc Cool *et al.*, 1993 ; Morsli, 1997 ; Mazour, 2004.

6. Conclusions

La connaissance de l'infiltrabilité de la couche superficielle du sol est nécessaire pour l'analyse de la modélisation du fonctionnement hydrologique d'un sol agricole. Le test d'infiltration au monocylindre sous charge décroissante présenté dans ce travail permet de mesurer ce paramètre ainsi que la sorptivité du sol de manière simple, rapide et économique. Sa faible consommation en eau le rend bien adaptée aux milieux arides et semi-arides (Al Ali, 2008). Par ailleurs, la simplicité de sa mise en œuvre nous a permis de multiplier les essais sur parcelles expérimentales, d'en étudier la variabilité spatiale et de définir ainsi les zones contributives au ruissellement et à l'érosion conséquente.

Les sols marneux se caractérisent par une structure stable et une infiltration très variable dans le temps et dans l'espace. Les mesures d'infiltration effectuées sur ces sols ont révélé une liaison étroite entre les dynamiques hydriques et structurales (porale). Lorsque ces sols sont desséchés, la macroporosité fissurale est responsable de l'infiltration très élevée. L'eau de pluie s'engouffre dans les fentes qui constituent les voies préférentielles d'écoulement.

En fin, cette étude nous a permis d'évaluer l'influence des contraintes naturelles (pentes, exposition) sur les propriétés hydrodynamiques des sols sous différents modes de gestion des terres à l'échelle de l'année. Par ailleurs, une meilleure connaissance de l'infiltrabilité des sols et de sa variabilité spatiale permettrait d'améliorer les résultats d'un modèle hydrologique de fonctionnement de l'espace agricole en termes de prédiction et d'examen de scénarios d'aménagement.

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The potential of water erosion in Slănic River basin

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Abstract: This study represents a hydrogeomorphological approach and aims to evaluate the potential of water erosion in the Slănic river basin. The analyzed river basin is highly susceptible to water erosion due to synergic actions of morphometric factors (high slope values, high slope convexity, surface runoff acceleration), hydrologic factors (high convergence of the river network in several areas), land cover (low degree of afforestation) and others. In order to analyze the potential of water erosion, GIS techniques were used for geoprocessing several environmental variables (factors) with an important role in water erosion process occurrence. The proposed index, Land Erosion Potential Index (LEPI), obtained by analyzing eight environmental factors, showed that almost 26% (111.1 km²) of the total study area (427.4 km²) is characterized by high and very high potentials of water erosion. The results can be useful for identifying viable measures for the control of the analyzed process.

Keywords: Slănic River basin, water erosion potential, LEPI, GIS techniques.

1. Introduction

Land erosion is one of the most critical environmental hazards in many parts of the world (Jain & Kothyari, 2000), the soil being one of the most affected environmental components. It is estimated that almost 75 billion tons of soil are being annually eroded, globally speaking. The agricultural lands are the most affected, with an annual rate of soil loss ranging from 13 tones/ha to 40 tones/ha in some cases (Piementel & Kounang, 1998). Generally, pedogenesis is a slow process, and, as a consequence, soil loss due to erosion is 13-14 times faster than the recovery rate (Piementel & Kounang, 1998).

The loss of the productive capacity of ecosystems is one of the most important consequences of land erosion, due to surface runoff, water infiltration decrease, loss of nutrients, organic material and soil biota (Jones et al., 1997; Piementel, 2006). At the same time, due to surface runoff erosion, another important global consequence is related to the high values of carbon emissions (the soil being the third most important global environment of carbon storage, after oceans and forests) (Lal, 1999), which is one the most important contributing gasses to the present global climate change (IPCC, 2007).

Globally, there are some areas strongly affected by land erosion (southern Asia, the sub-Saharan region of Africa, the Central America and the Andean region of Southern America) (Ral, 2001). The region of Southern Asia is one of the most affected, especially because of water erosion (Singh

et al., 1992). In Europe, the most important water erosion issues are mainly related to its southern part, the Mediterranean region (Gobin et al., 2004), where the natural components of the environment are affected, as are the agricultural systems which suffer from a severe decrease of crop yields (Stoate et al., 2001). Land erosion is a major issue in Romania also, and the Subcarpathians' area is one of the most vulnerable because of the aggressive human impact over time (deforestation), the presence of friable rocks on large areas (clays, marls, sands) and the high potential for surface runoff (due to high slope values, high slope convexity etc) (Grecu et al., 2007; Prăvălie & Costache, 2013; Prăvălie & Costache, 2014).

This study aims, through the use of GIS techniques, to identify the areas with water erosion potential in the Slănic river basin, considering several environmental factors with a key role in the occurrence of land erosion process.

2. Study area

The hydrographical basin of Slănic River is located in the central south-eastern part of Romania and it is a major tributary of the Buzău River (Fig. 1). The surface of the basin is almost 427.4 km². The position of the river basin in an area of friable rocks, predominantly represented by clays and marls, and of large deforested areas, makes it vulnerable to geomorphological processes like surface erosion (Grecu et al., 2007).

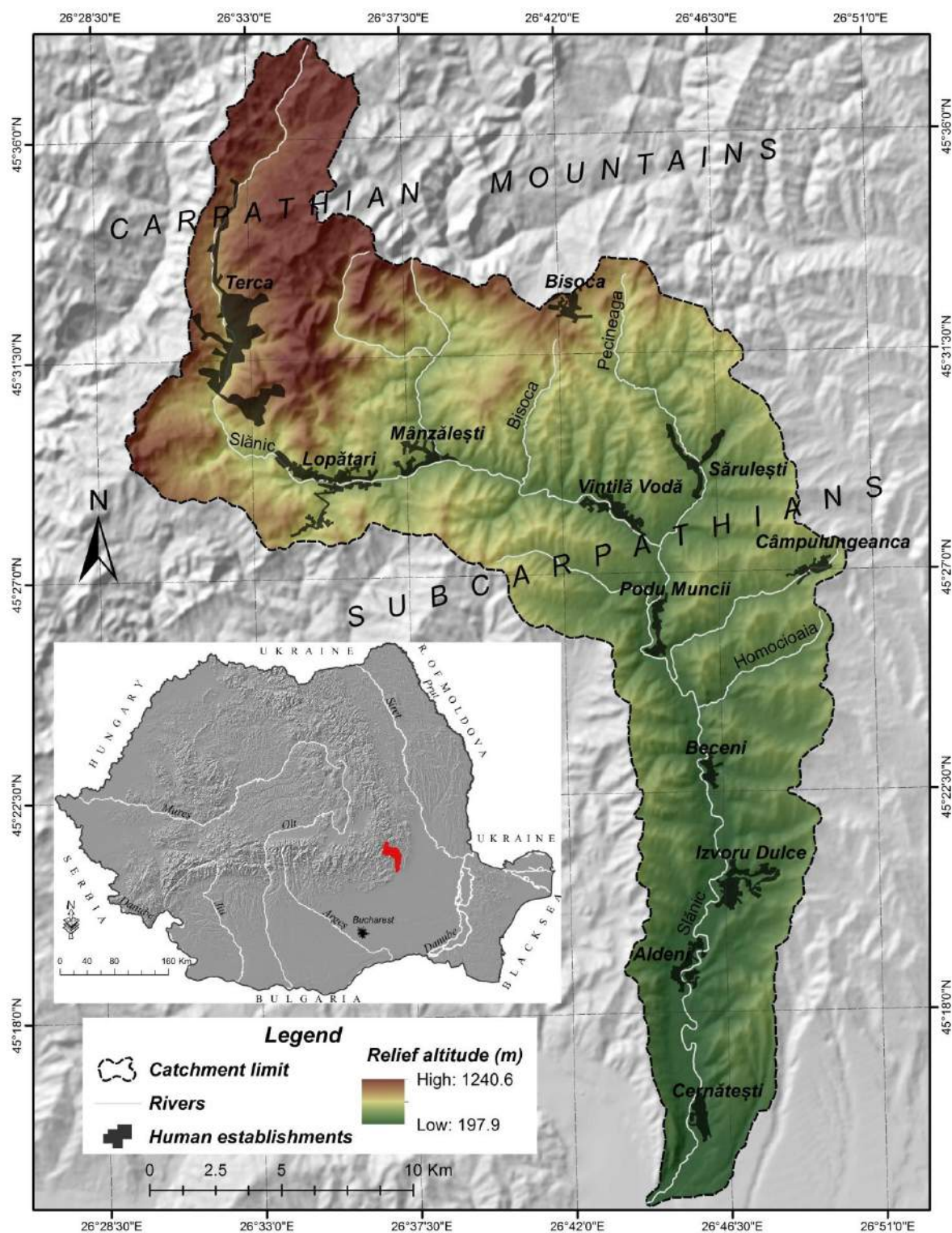


Fig. 1. Location of the Slănic River basin in Romania

The degree of afforestation in the Slănic River basin is of almost 40% and the forest covers almost 170 km² of the study area. The northern part of the river basin has a higher degree of forest coverage, therefore erosion processes are less aggressive. Besides the low forest coverage on many areas of the river basin and the friable substrate, slopes that exceed 15°, found in almost 28% (116 km²) of the

study area, represent another important factor that increases erosion processes. At the same time, the high convexity of the slopes (in vertical and horizontal profile), as well as the hydrographic particularities (like the high density of the hydrographical network and the high convergence of torrential systems), ensure the conditions of surface runoff, with direct consequences on land

erodibility. Also, the absence or the inefficiency of the anti-erosion management in Slănic River basin, can favor the increase of land erosion processes on large surfaces in this catchment river.

3. Data and methods

In order to highlight the areas prone to land erosion in the Slănic River basin, the *Land Erosion Potential Index* (LEPI) was calculated and spatially modeled. The proposed index was obtained by integrating, in GIS environment, eight geographical factors (figures 2 and 3) that influence water erosion. Therefore, the morphometric factors, i.e. slope angle, plan curvature, profile curvature, L-S factor, Stream Power Index and slope aspect, were obtained in raster format, with a 20 m cell size, from the digital elevation model.

The numerical model of altitudes for the Slănic River basin was obtained by interpolating the contours digitized from the Topographic Map of Romania, at a 1: 25.000 scale (DTM, 1981). The other two factors, lithology and the distribution of the average multiannual runoff depth were firstly obtained in vector format, and subsequently converted into raster format at a 20 m cell size.

These factors were selected in the context of their importance in land erodibility. The slope is an important morphodynamic factor that highlights the gravitational development of water flow (Bilaşco et al., 2009; Grecu, 2009; Minea & Zaharia, 2011; Fontanine & Costache, 2013). Thereby, the higher the slope values, the more aggressive is the water erosion.

Another factor, largely used in studies regarding the potential to water erosion, is the L-S factor (Weaver, 1991; Moore et al., 1993; Hickey, 2000; Arghiuş & Arghiuş, 2012; Cherni & Samaali, 2012), which is defined as the ratio between the slope angle and the slope length (Moore et al., 1993). The calculation of L-S factor is based on the formula elaborated by Moore et al. (1993): $LS = ((m+1)*(As/22.13)^m)*(\sin\beta/0.0896)^n$,

where As =contributing area, $m=0.4$ and $n=1.3$.

The plan curvature represents the change in slope values on a parallel direction to the contours (Blaga, 2012). The positive values show a divergent water

flow (with decelerated water flow) and the negative values show a convergent flow (accelerated water flow – high potential to land erosion).

The profile curvature represents the changes in slope values in a vertical plan (Smith et al., 2012) and differentiates the convex surfaces (negative values), with accelerated water flow, from the concave surfaces (positive values), with decelerated water flow.

The slopes aspect is another morphometric factor that influences surface runoff (Costache & Prăvălie, 2013) and, consequently, the process of water land erosion. On sunny slopes, water infiltration is increased by the low degree of water saturation of the soil, whereas on shaded slopes surface runoff is accelerated due to constant humidity.

The Stream Power Index is used to describe the transport capacity of torrential valleys. The index is the multiplication between the contributing area (As) and the slope (p) and is computed by the following formula: $SPI=As*\tan p$ (Constantinescu, 2006). With this index, sectors along torrential valleys, where intense erosion processes occur (high values) or where sediments accumulate (low values), can be identified.

The spatial distribution of the rock types another important factor in assessing the potential to erosion (due to rocks friability), was obtained by digitizing the lithological formations from the Geological Map of Romania, at a scale of 1: 200.000 (IGR, 1968). The classification of lithology, in terms of rocks hardness, was done after Bomboe & Mărunţeanu (1986).

The assessment of the distribution of the average multiannual runoff depth in Slănic river basin (a complex factor which accelerate water erosion in case of high runoff depth) was possible due to the mathematical model SCS-CN (CN = Curve Number), developed by the USDA Natural Resources Conservation Service. This method is based on the formula: $Q = P - I_s - I - E - n$ (Bilaşco, 2008), where: Q – volume, P – precipitation, I_s – capacity of water infiltration, I – interception, E – evapotranspiration, n – other retentions of rainfall.

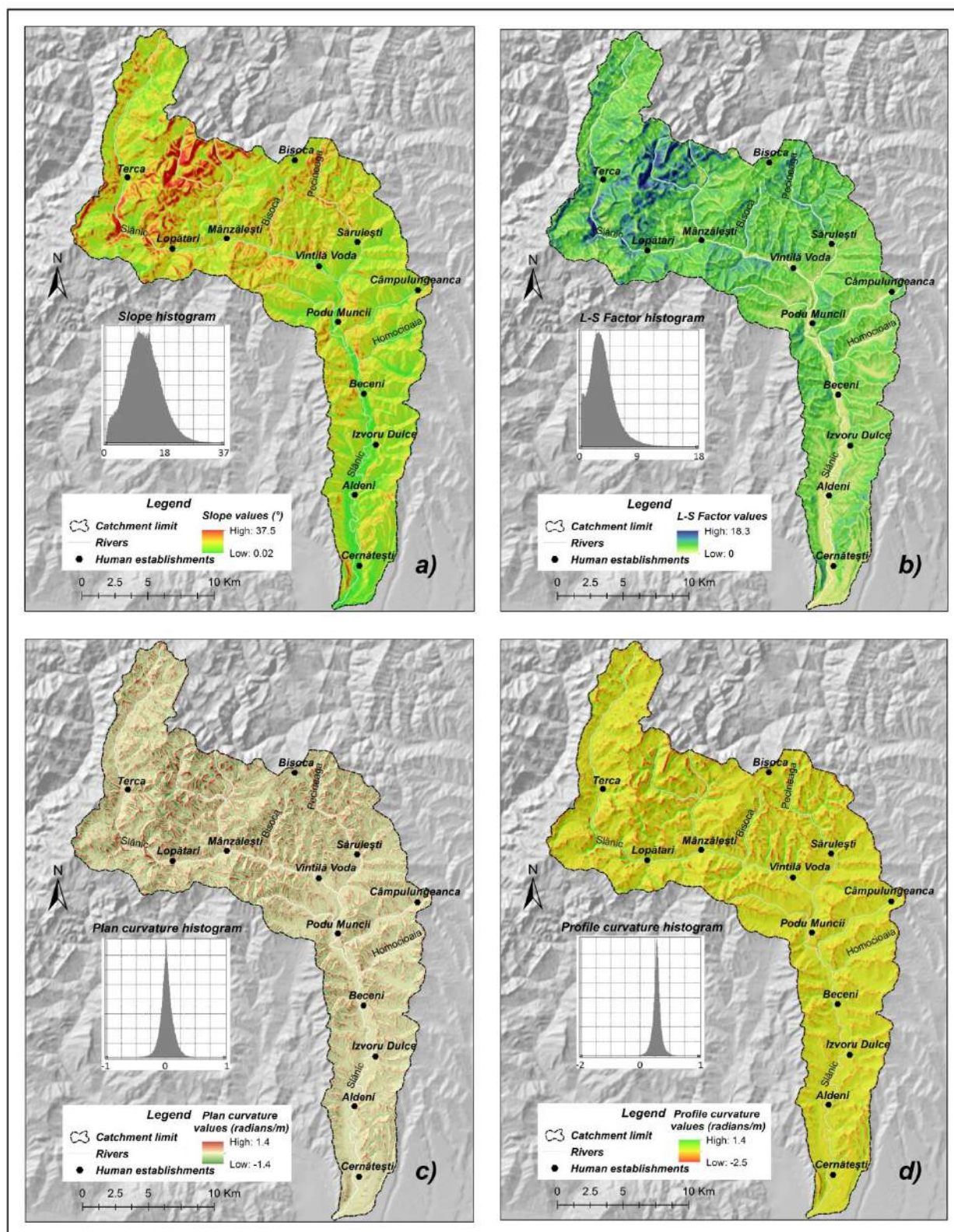


Fig. 2. The spatial distribution of slope angle (a), L-S Factor (b), plan curvature (c) and profile curvature (d) in the Slănic River basin

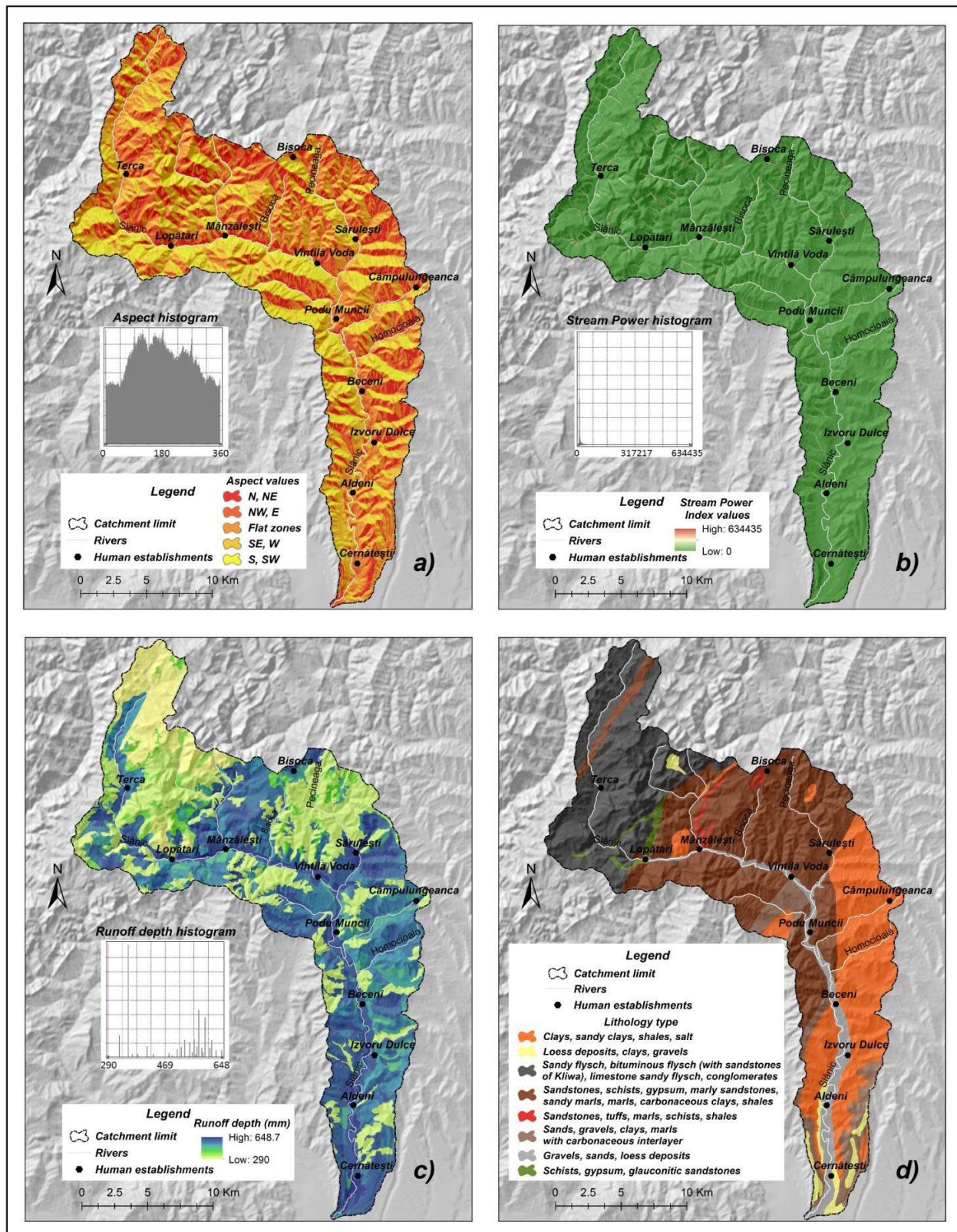


Fig. 3. The spatial distribution of slope aspect (a), the Stream Power Index (b), runoff depth (c) and rock types (d) in the Slănic River basin

The CN method is based on the conventional representation of the maximum potential of water retention during rainfall (Bilaşco, 2008), depending

on the type of land cover and the hydrological group of soil. Mathematically, the estimation of water flow is based on the following equation: $Q = (P - 0.2 \cdot S)^2$

/ $(P + 0.8 \cdot S)$ (Ponce & Hawkins, 1996), where Q – water flow (mm), P – precipitation (mm), S (mm) – potential of water retention (computed in accordance with the curve number of a surface depending on the type of land use and hydrological group of soil: $CN = 1000 / (10 + S)$). In a GIS environment, the computation of the mean multiannual runoff depth was performed with the Curve Number method, by using the ArcCN – Runoff extension (Zhan & Huang, 2004). Thereby, three datasets were inserted in the extension, respectively land use /cover (CLC, 2006), soil types (ICPA, 1976), in terms of the hydrological group (Domnița, 2012) and average value of multiannual precipitation (obtained by interpolation methods) in the river basin (Clima României, 2008).

In order to obtain the *Land Erosion Potential Index*, the classes of the eight factors were given scores, on a scale from 1 to 5. The score 1 corresponds to characteristics that strongly decrease the water erosion potential and the score 5 corresponds to characteristics that strongly increase water erosion potential (Table 1). As the stated factors have different importance regarding their influence on water land erosion process, they were weighted (Table 1) by using the Weight module of Idrisi Selva (Behera et al., 2012).

The values of the resulting index were grouped in five classes. The *Natural Breaks* method was used in ArcGIS 10.1, which is a standard method for grouping a dataset in a homogenous number of classes (North, 2009).

Table 1. Classification and scoring of geographical factors necessary to compute *Land Erosion Potential Index*

Parameters	Type/values				
Slope (°) - 15%	0 - 3	3.1 - 7	7.1 - 15	15.1 - 25	> 25
L-S Factor - 11%	0 - 2	2.1 - 4	4.1 - 6	6.1 - 8	> 8
Plan curvature (radians/m) - 11%	-	-	0.9 - 1.69	0 - 0.9	-1.4 - 0
Profile curvature (radians/m) - 13%	-	-	0.91 - 1.61	0 - 0.9	(-2.9) - 0
Aspect - 5%	S, SE	V, SE	Flat zones	E, N V	N, NE
Stream Power Index - 10%	0 - 5000	5001 - 10000	10001 - 20000	20001 - 50000	> 50000
Runoff depth (mm) -25%	290 - 368	368.1 - 433	433.1 - 529	529.1 - 586	586.1 - 648
Lithology type - 10%	Sandstones, schists	Gypsum, flysch, tuffs, bituminous flysch (with sandstones of Kliwa, glauconitic sandstones	Marls, clays, marly sandstones, conglomerates, shales, salt, sandy flysch, limestone sandy flysch, carbonaceous clays, marls with carbonaceous interlayer	Sandy marls, sandy clays, sands, gravel	Leoss deposits, gravel, sands
Score given Land Erosion Potential Index (class values)	1 Very low 15.8 - 24.3	2 Low 24.31 - 28.6	3 Medium 28.61 - 33.9	4 High 33.91 - 38.5	5 Very high 38.51 - 47.4

4. Results

By applying the described methodology, the *Land Erosion Potential Index* (LEPI) was proposed, calculated and spatially modeled, with values

between 15.8 and 47.4, divided in five classes (Fig. 4).

The resulting first two classes of values correspond to surfaces with very low and low potential for land erosion.

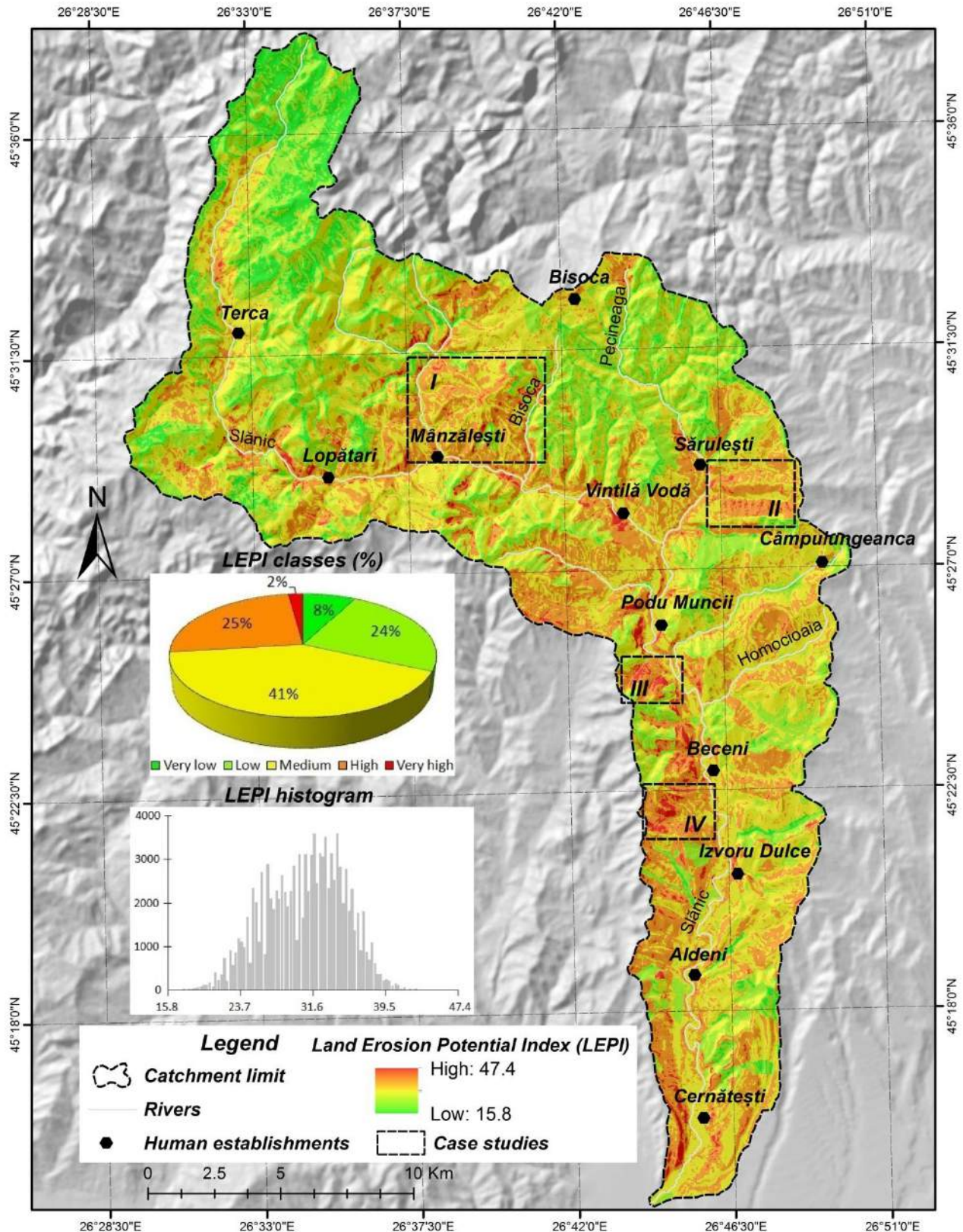


Fig. 4. Spatial distribution of Land Erosion Potential Index in the Slănic River basin

The cells with values between 15.8 and 28.6 overlap the areas with low slope values, generally under 7°, where the potential of water flow is low due to forest vegetation and cohesive rocks with high resistance to the erosive effect of gravitational

water flow. Regionally, these values occur especially in the northern part of the river basin, in the Carpathians' area, but also in the northern half part of Pecineaga sub-basin, near Bisoca locality. On the entire study area, very low and low values of

the LEPI occur on almost 32% of the total area of Slănic river basin.

The medium values of the LEPI range between 28.6 and 33.9 and are found on almost 41% of the study area. These values have a uniform distribution and a tendency of concentration in the southern half of the study area, on the left side of the main river. The appearance of moderate values of the potential for land erosion is favored by the combination of several factors, like slope with values between 7° – 15° , agricultural lands and rocks with medium hardness.

High values, between 33.9 and 38.5 are found on almost 25% of the Slănic River basin. These areas occur generally on the surfaces with north-western and eastern exposure, with slope angles of 15° – 25° , a low density of forest vegetation and friable

lithological formations, such as clays, marls or loess deposits. Also, these areas are characterized by a high convergence of torrential systems.

The synergic context of these factors favors the flow of a higher volume of water, in an accelerated manner, so that low cohesive soil fragments would be intensively eroded. In the Slănic River basin, the high values of the LEPI occur generally to the south of the confluence between the Pecineaga River and the main river in the study area, on its right side.

The values in the 5th class of LEPI indicate the areas with very high potential for land erosion (critical areas). These values are between 38.5 and 47.4. The areas with very high potential for land erosion have a scattered distribution in the study area. Such values, exceeding 38.5, are found on the right side of the Slănic River, near Beceni locality.

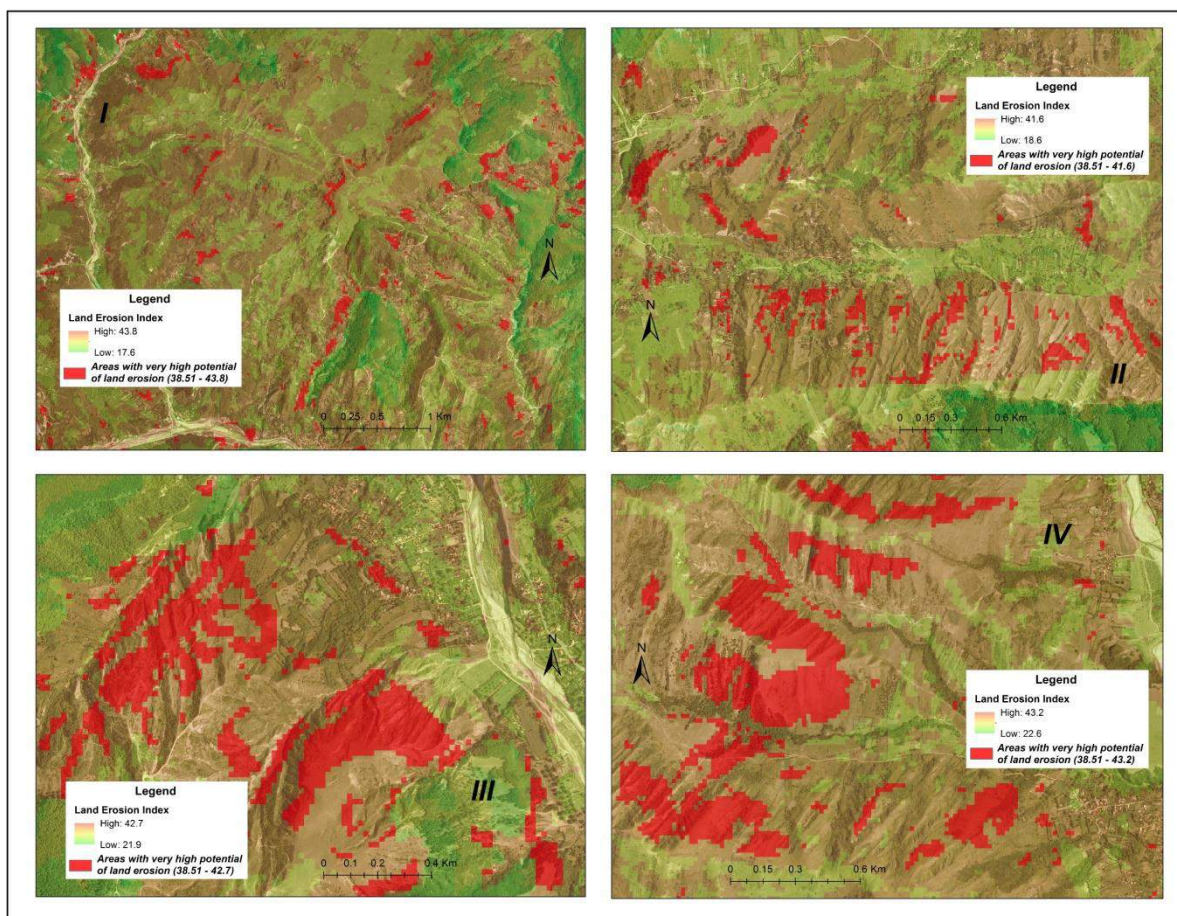


Fig. 5. Spatial relation between critical values of the LEPI (> 38.5) and geographical particularities highlighted by orthophotomaps, 2008 edition (ANCPI, 2008)

Another sector on the right side of the main river with a very high potential for land erosion is a 3 km long strip, between Săpoca and Cernătești localities. In the study area, the surfaces with very high potential for land erosion cover approximately 2% from the total.

In order to validate the results, a spatial relation between the values of the LEPI and the reality on the field was tested (empirical assessment). As the field surveys did not cover all the study area, the analysis of the relationship between the results obtained using GIS techniques and the actual terrain

situation was performed with the aid of orthophotomaps at a scale of 1:5000, 2008 edition (ANCPI, 2008). Four case studies were chosen (Fig. 4), focused especially on the maximum values of the LEPI (class > 38.5). Also, the case studies were selected in such a way that they cover the study area relatively uniformly (Fig. 4).

The results proved that in these case studies there is a correspondence between the maximum values of the LEPI (the 5th class of values) and the geographical particularities of the terrain, typical for intense erosion processes (Fig. 5). According to all the four case studies, the areas with high potential of water erosion occur generally on steep slopes, lacking vegetation, with a high convexity (vertical and horizontal) or torrential convergence, also with predominantly friable substrate (Fig. 5). All these characteristics, to which the lack of anti-erosion management could be added, highly increase the risk of occurrence of other erosion-associated phenomena (flash-floods genesis, landslides).

5. Conclusions

Following the water erosion potential assessment, it was found that the Slănic catchment generally has a high susceptibility to this process, especially in the central-southern area. This is due to a series of geographic factors, of which the most important are the low vegetation cover and steep slopes of certain areas.

The analysis of the proposed index, Land Erosion Potential Index, revealed that critical areas, corresponding to the index class with very high erosion potential (with values exceeding the 38.5 threshold in the 15.8-47.8 interval) cover approximately 2% of the total catchment area (about 8.5 km²).

These areas are the most important, as they can provide the fundamental support for further analysis

on erosion risk, in order to assess vulnerable anthropic elements.

It should be noted that the study does have certain shortcomings. They can be related to input data calibration – e.g. lithology and soil data are available at a less detailed scale (1:200.000) than the other data sets. Another issue can be related to the fact that the study does not address more complex analyses, such as mathematical models (e.g. analyses based on the Universal Soil Loss Equation), which allow a quantitative erosion assessment.

However, the proposed methodology can provide satisfactory results, based on which areas with high potential of water erosion can be identified in the Slănic catchment area.

This analysis can therefore be useful primarily for locally-based policy makers who, should they choose not to enforce the appropriate measures to overcome this hydrogeomorphological risk phenomenon, will experience severe medium and long-term consequences, both ecologically (especially soil degradation / soil loss) and socio-economically (agricultural land productivity decrease).

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Analysis of natural hazards in urban areas: The city of Bou Saada as a case study in Algeria

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Abstract. Dealing with major risks has become one of the most important challenges for sustainable urban development in the light of rapid urbanization, which touched most of Algerian cities and led to a doubling of human, material, economic and environmental losses, which in turn led to the deterioration of the urban fabric. Since the early 1960s the city of Bou Saada underwent a fast, chaotic and unplanned urban evolution over 65% of its surface, most of which is located on slopes - slopes of mountains, of valleys - and near the sand dunes, being thus exposed to the risk of flooding, rockfalls and desertification. A morpho-dynamic analysis shows that this is linked to the physical environment on the one hand and, on the other hand, human activities like rapid population growth in urban areas, the ambiguity of the real estate Algerian slums and the various irresponsible types of configuration carved these dangers and increased their severity in the urban system. In order to reduce their harm, these natural hazards must be understood, their impact on the urban area determined and the urban agglomerations must be protected from their effects.

Keywords: natural hazards, urban environment, flooding, rockfalls, desertification.

1. Introduction

The city is an integrated urban unit closely linked to the environment surrounding it and thus Man had to deal with natural and environmental hazards. Wherever they are in the world, they are the inevitable result of the growing population, but functional and technical studies should be adopted by cities in this expansion trend, taking into the rights of easements from natural hazards on the one hand and, on the other hand, the rational management of the resulting environmental risks. Natural hazards have a great influence on the urban environment, the impact on the physical side and on the city limit being the demolition of buildings and the occurrence of breaks in the urban fabric and the emergence of pockets of gaps inside. "The lives of human beings are threatened continuously as a result to what the world is witnessing: disasters and events are annually causing material and considerable human losses and with the beginning of the sixties multi-natural hazards won the largest share in articles, studies and scientific researches and university conferences at the beginning of the sixties" (Moral, 2006). Natural hazards, including earthquakes, have caused heavy losses of lives and property and infrastructure in many parts of the world. For example, the earthquakes between 1960-

1990 are the most deadly and destructive disasters that have killed about half a million people worldwide and caused losses estimated as totaling \$ 65 billion dollars; estimates indicate the presence of about one million earthquakes in each year (Ahmad, 1998; Houcine, 1984; Essaid, 1981). The phenomenon of drought wiped out nearly half a million people, all from developing countries in the period between 1974 and 1990 and increased total economic losses across the whole world from about 10 billion \$ in the sixties to about 30 billion \$ in the seventies, and to 93 billion \$ in the eighties (Attoui, 2001, 2002; Ahmad, 1998; Farouk, 1994), "For example, the area prone to flooding in France is not less than 1/10 of the total area, where the cost of losses resulting from the flooding is of 230 million Euros per year which adding to the 74% of municipalities exposed to flooding and 3 million inhabitants located in the threat zones" (Chikouche, 2008).

Algeria, like other countries of the world, is subject to many risks, where reports indicate that recent flooding caused the collapse of 400 houses in minutes. In Adrar alone, the number of families affected is 100 in addition to the losses in agriculture. On November 10, 2001, a black day in the history of Bab El Oued in the capital, torrential floods left about 733 casualties and the destruction of many of the facilities and infrastructure. Similar

is the case of the recent floods of Ghardaia, on October 30, 2008. The earthquake of May 21, 2003 in Boumerdes, where 2278 persons were killed, 130,000 remained homeless and losses were estimated at 100 million \$, exposed the fragility of the urban fabric and the lack of planning in the field of disaster management and risk (Attef, 2002; Traves, 1997; Mohamed, 1996).

The diversity of its natural terrain, induced by the nestling of the city between the mountains as well as by the hydrographic network density and the sand dunes besetting them, make the city of Bou Saada an area prone to flooding, desertification and rockfalls, as well as to environmental hazards, the most important of which is pollution caused mainly by waste and sewage. The latter one has become a concern for residents of the city, where the lack of management increased the gravity of the situation especially in conditions of chaotic and unplanned neighbourhoods.

In the light of what has been stated, the major problem is the presence of most of the urban agglomerations in areas prone to natural hazards, and several other problems, including:

- the deterioration of the situation of urban neighbourhoods in the city of Bou Saada and the overall shape of the urban fabric;
- implications of natural hazards occurring in the non-built-up space of the city .

The overall objective of the study is to understand how to deal with natural hazards in the urban area through:

- inventorying natural hazards and determining their impact on the urban domain;
- protecting urban communities from the effects of natural hazards.

The study is based on two hypotheses:

- the hypothesis of urban nature: chaotic neighbourhoods are the most vulnerable to natural hazards;
- the hypothesis of regulations and management: the neglect of natural hazards as a compulsion in the decision making process while initializing urban agglomerations, with the absence of techniques for the management of urban disasters caused by these threats.

The study has adopted a descriptive and analytical methodology to address the problem of management of natural hazards in the city of Bou Saada, describing the phenomena to be studied and determining the causes and effects to validate the hypotheses.

2. Management of natural hazards

2.1. Means of managing of natural hazards

In the early nineties analysis and management tools appeared, in particular Geographic Information Systems (GIS), Remote Sensing, digital elevation models (DEMs). Being the most widely used framework in new risk approaches, serving for data collection and inventory and estimation of hazard patterns based on multiple criteria, the Geographic Information Systems (GIS) are an important tool in the management of emergency situations. Their importance lies in the speed of defining damaged items in areas of risk and of defining multiple places for the event in a very short time. They are also known as IT tools working on the definition of the environment and on the management and exploitation of local data through the integration between machines and networks, operating systems and database information.

The specialists in geographic maps also confirm the role of geographic maps in the management of technological dangers in the centers of urban systems, the maps serving as a pillar in the definition of the central danger. They also propose analytical maps in scale 1/25000 which are related to the type of risk and commend the establishment and use of compositional maps which combine natural hazard and technological risks (Chorowicz, 2007; Grecu, 2002, 2009; Grecu et al, 2012 a, b; Moral, 2006 etc).

2.2. Management of natural hazards according to the Algerian law

The Law 04-20 of the 25th December 2004 on risk prevention and disaster management in the context of sustainable development, consisting of 75 legal items, aims at enacting rules of prevention of major risks and managing disasters in the context of sustainable development. Article 9 states that the law is a comprehensive system initiated and supervised by the state, implemented by public institutions and regional groups, in consultation with the tradesmen, economists and social scientists and the involvement of citizens. This system aims at (M. H., 1990, 2003, 2004, 2006):

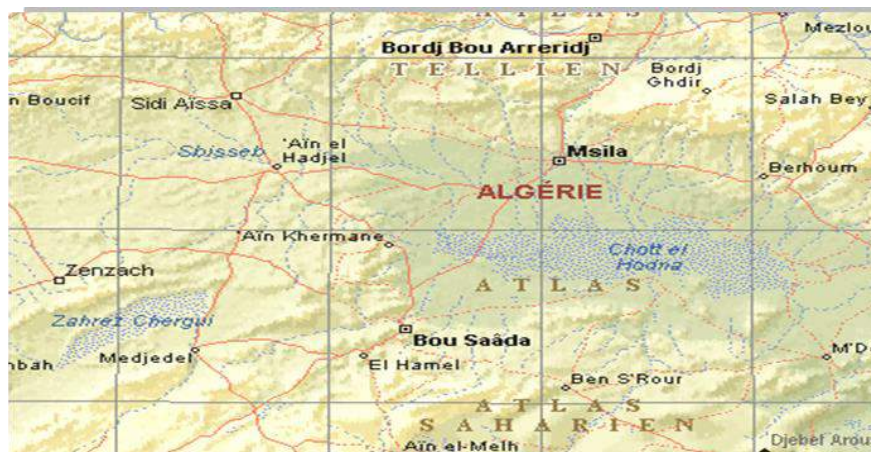
- improving the knowledge of the threats and promoting their control as well as the media development of preventive measures against these threats;
- taking into account the threats in land use and construction and reducing the exposure of persons and property;

- designing harmonious and integrated and adapted management works to every disaster.

3. Study area

The municipality of Bou-saada is administratively situated in the southern part of M'sila. It is bounded to the north by Ouled Sidi brahim, to northeast by Maarif, to the east by the Houamed municipality, to the west by the municipality of Tamsa, to south-east

and south-west by the municipalities of Oultem and El-Hamel. It covers an area of 255 km² with a population 143 236 inhabitants and a population density estimated at 483 inh/ km² according to figures of 2008. It is characterized by the strategic location in terms of its presence on the axis of the National Road 08 Algiers – Bou Saada and National Road 46 Biskra - Djelfa , i.e. between the north and the south of Algeria (Salamani, 2009; Faid, 2009; Nouibat, 2009) (Fig. 1).



a. (source: URBA, 2005)



b.

Fig. 1. The administrative (a) and geographic (b) location of the Bou Saada city

4. Applied research study

Bou Saada city occupies the slopes of north-eastern Ouled Nail mountains in the Saharian Atlas between blocks of mountain in the north and north-west as

well as in the south and low-lying areas in the south-east and east. It is located in the southwest of the Shot El Hodna basin, on the East longitude of 4.11° and North latitude of 35.13° (Fig. 1).

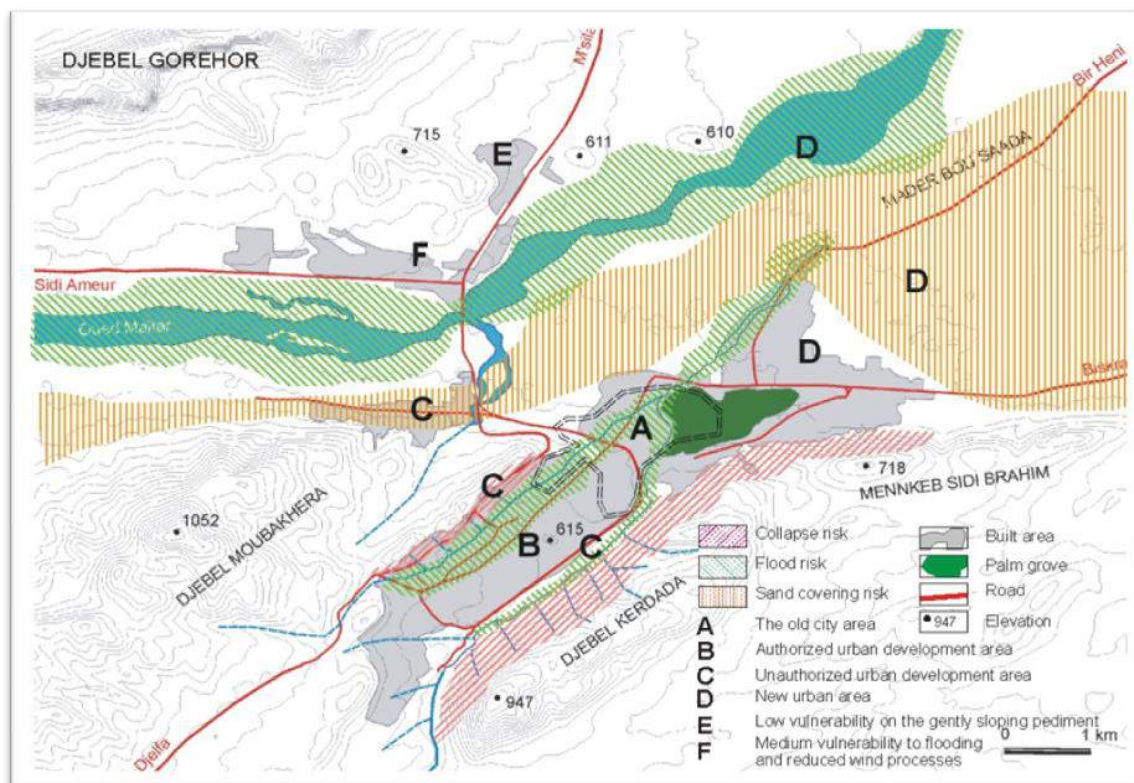


Fig. 2a. The vulnerability map of the Bou Saada city (after Grecu et al., 2012)



Fig. 2b. Slope-related hazards

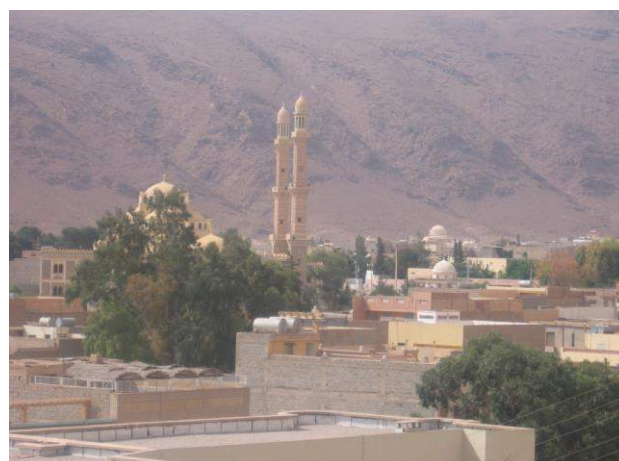


Fig. 2c. Old city of Bou Saada

Table 1. Elements at risk by natural hazards in the urban agglomeration of Bou Saada

Neighborhood	Urban data					risk %	AR (ha)	BR (ha)	NBR (ha)	PR	DR
	TDA (ha)	DBA (ha)	NBD (ha)	NP	ND						
Sidi slimane	104	30	84.2	22771	3946	RI	41.6	25.6	30.5	5921	846
						RE	12	3.46	8.54	2626	1138
Louainet	71.2	23	48.2	8731	1247	RI	38.1	12	26.1	4555	651
						RE	8	2.6	5.4	987	141
Maitar	30.2	15	15.2	1400	200	RI	16.2	8.1	8.1	756	108
						RE	12.2	6.1	6.1	559	81
Koucha and Kaissa	55.2	29	26.2	19694	2188	RI	27.49	14.4	13.03	9779	1086
						RE	8.2	4.3	3.9	5433	601
Dachra and Rasfa	41.9	16.4	25.4	8362	1063	RI	8.8	3.4	5.4	1733	220
						RE	15	6	9	3059	389
Djnan Btoun	119	3.8	115.2	1741	229	RI	15.36	0.5	14.86	229	30
						RE	/	/	/	/	/
Mouamine	38.2	11	27.20	6609	944	RI	12.20	3.50	8.70	2102	316
						RE	/	/	/	/	/
20 Aout	80.5	25	55.8	12720	1817	RI	20.9	6.5	14.4	3307	472
						RE	/	/	/	/	/
Staih and CADAT	130	38	92	17132	2447	RI	20.6	13.33	7.27	2646	378
						RE	/	/	/	/	/
Mohmed Chabani	90.7	25	65	1054	1506	RI	21.3	5.8	15.5	1446	349
						RE	13.2	3.63	9.57	1530	219
Ksar	27.1	16	11.1	5739	1187	RI	9.3	5.6	3.7	2009	415
						RE	/	/	/	/	/
Plateau	61.5	25	36.5	4963	109	RI	20.6	13.33	7.27	2646	378
						RE	/	/	/	/	/

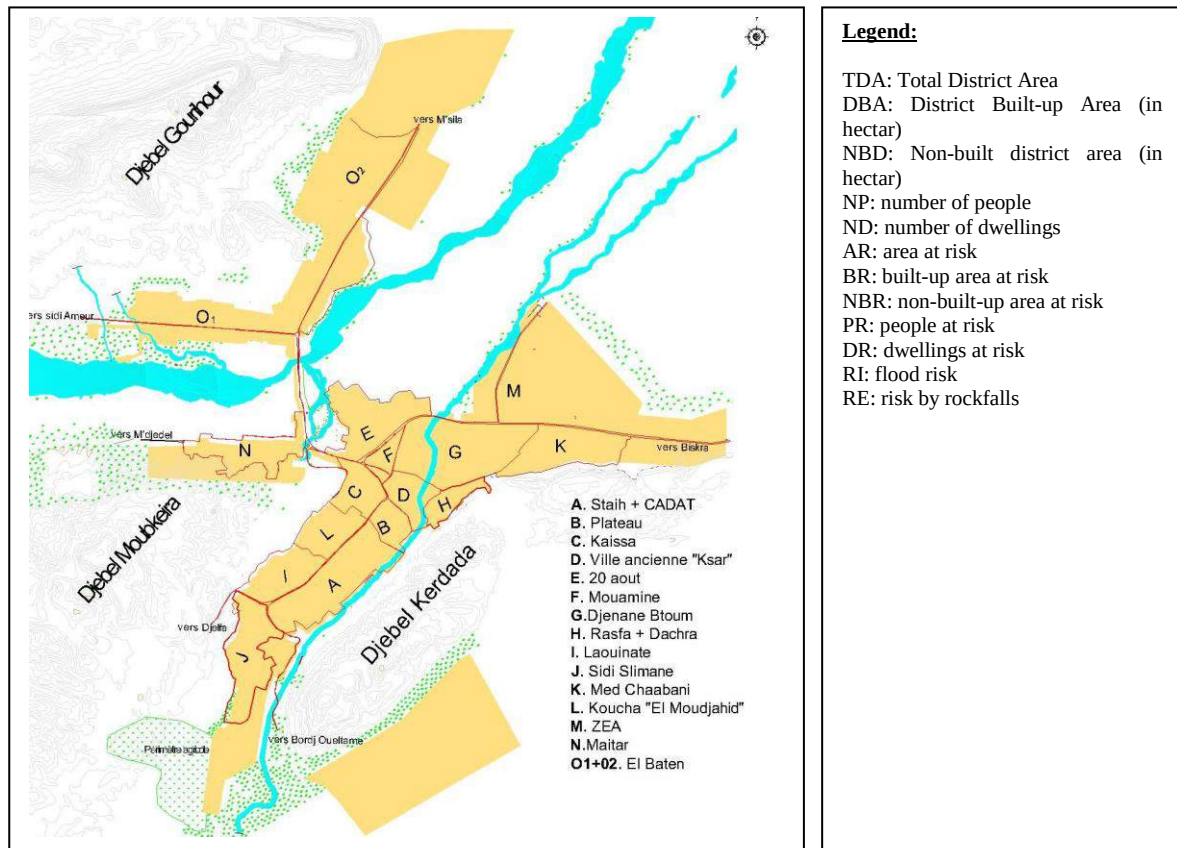


Fig. 3. Location of the Bou Saada neighborhoods

In this part, the most important natural hazards, that urban agglomerations in Bou Saada are exposed to, have been identified. In order to verify the hypotheses put forward, the hazard ratio for each district was computed, the current status of urban agglomerations and the extent of exposure to natural hazards have been identified, focusing on floods, rockfalls and desertification (Figs. 2, 3, 6-10).

Through the analytical study of natural hazards and environmental factors that affect the urban space in the neighbourhoods of Bou Saada, threat zones, that increase the disaster-caused loss of material and human resources, have been identified. This zoning relies on important terrain maps of the city: the 1956 military map, the 1972 and 2009 aerial photographs and the Director Plans and the Bou Saada city Urban Plan. From the historical

evolution of neighbourhoods of Bou Saada it became obvious that the expansion of these neighbourhoods was not adopted in the master plan that identifies the reconstruction rules. As a consequence, unplanned (chaotic) neighbourhoods appeared which do not respect the barriers between urban space and natural areas, therefore allowing the infiltration of natural threat zones into the urban system. The study results prove that the proportions of natural threats are significantly higher in the unplanned neighbourhoods than in the planned ones, due to their location between the mountain foothills, valleys and dunes, where a larger share of the area at risk is included (flood risk, risk to rockfalls in the presence of the steep slopes and desertification risk).

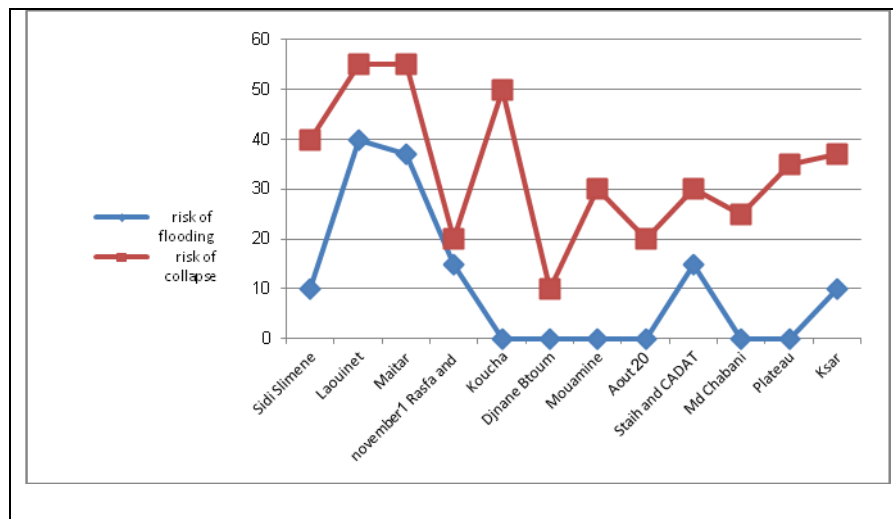


Fig. 4. Percentage of the flood risk and rockfall risk at the level of city districts

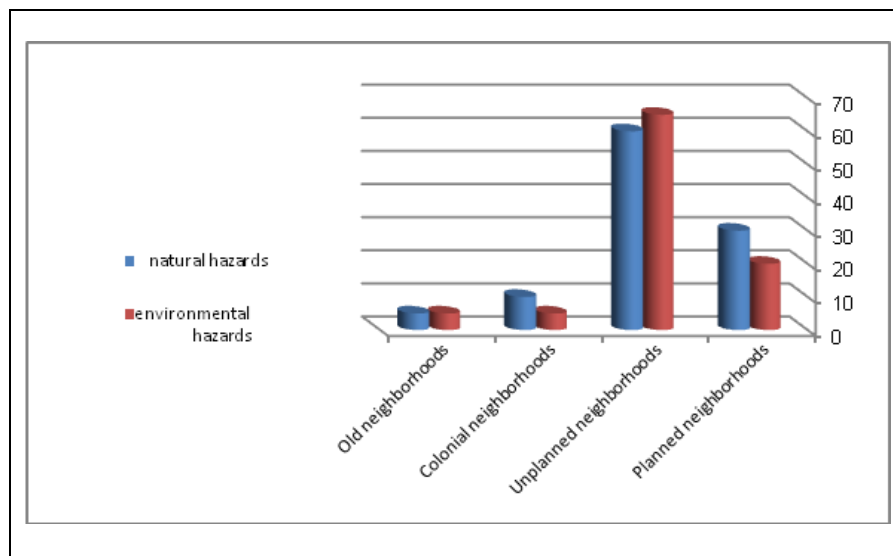


Fig. 5. Natural and environmental hazards for different neighbourhood of the Bou Saada city

Figures 4 and 5 illustrate the ratios of natural hazards in the neighbourhoods of Bou Saada, demonstrating that the proportion of natural and environmental hazards are higher in the unplanned (chaotic) neighbourhoods. This validates the hypothesis that the marks of anarchism are the most vulnerable to natural hazards. The exposure to natural hazards in planned neighbourhoods also validates the second hypothesis of the neglect of natural hazards during the completion of the the initialization and reconstruction schemes of Bou Saada (Figs. 4 and 5).

5. Conclusions

Based on the results of the analytical study of the Bou Saada neighbourhoods in terms of natural hazards, the identification of areas prone to the severity of the risks and according to the law easements within the disaster prevention law 04-20, we advance a set of suggestions and recommendations that will limit the risks (human and material losses) resulting from the hazards affecting the urban agglomerations of the city (Table 1, Fig. 3):

A - Areas located in slopes:

- In sands areas, areas located in on valleys' banks and hazardous slopes, where the severity of the risk is stronger, communities must be protected from sand burying as well as through the foundation of bilateral channels for sewage and storm water drainage. These recommendations should be applied to some neighbourhoods like the

Maitar and Sidi Slimane districts, where the sand and debris materials have their origin on the mountains slopes.

- The conversion of the steep slopes to nature reserves (afforestation) would provide benefits through the allocation of internal recreational spaces to the residents of a particular neighbourhood and to the city's population in general.
- The establishment of a supporting wall along the edges of the Maitar valley.

B - Areas at risk to rockfalls should be protected by a completion belt along the mountain in addition to the establishment of a strip of landscaping.

C - Areas prone to the risk of skidding vehicles:

- Works for the completion of an external belt with a length of 4.41 kilometers from the junction leading to Algiers to the road leading to Djelfa behind the Azzedine Mount. This would reduce the sliding trucks on the road and turn the way to a utilitarian motorway. This is the case according to the director and urban plans of the Bou Saada city for the year 2008.

Taking into consideration the establishment of green and forested areas and green belts on the outskirts of the city in the north-eastern side (20 Aout district, Mohamed Chaabani district, 1-ZEA 01 activity and storage area, "North West" Maitar district, 2 -ZEA 02 activity and storage area.



Fig. 6a. The Maitar Oued

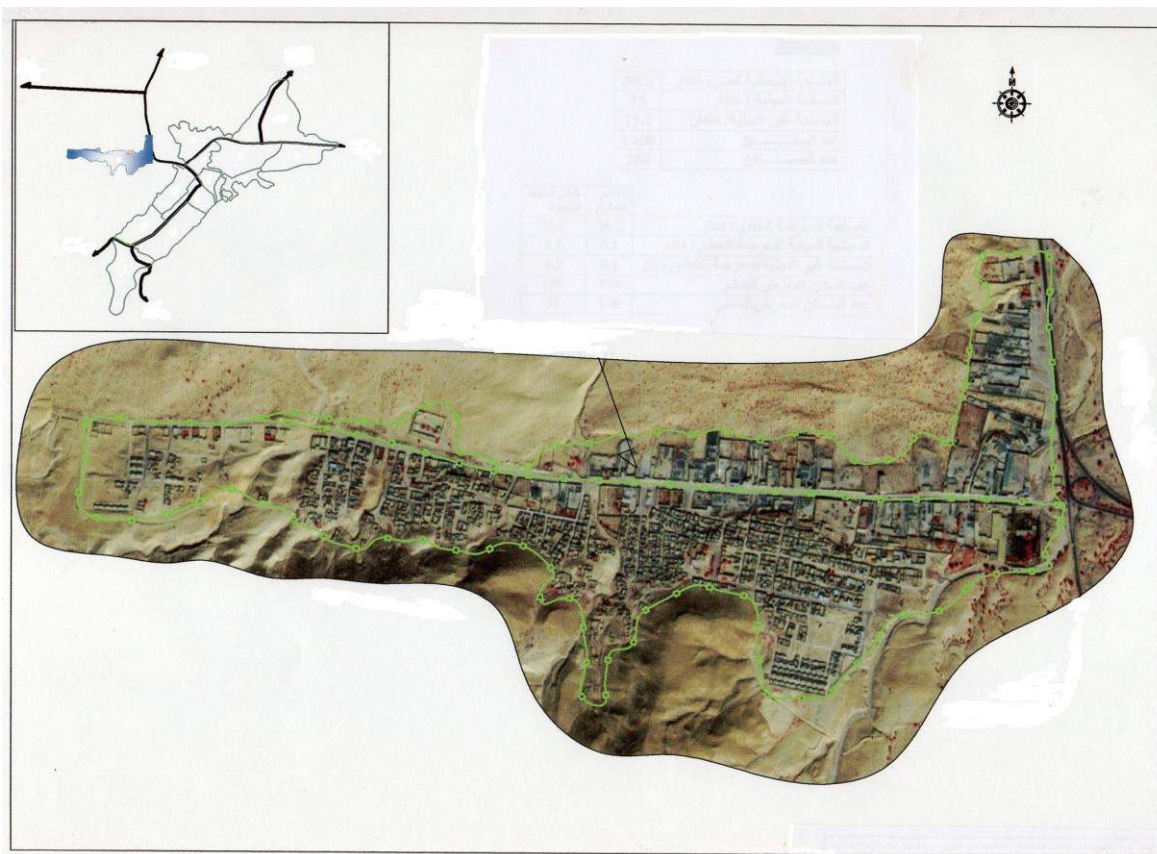


Fig. 6b. Aerial view of the Maitar district

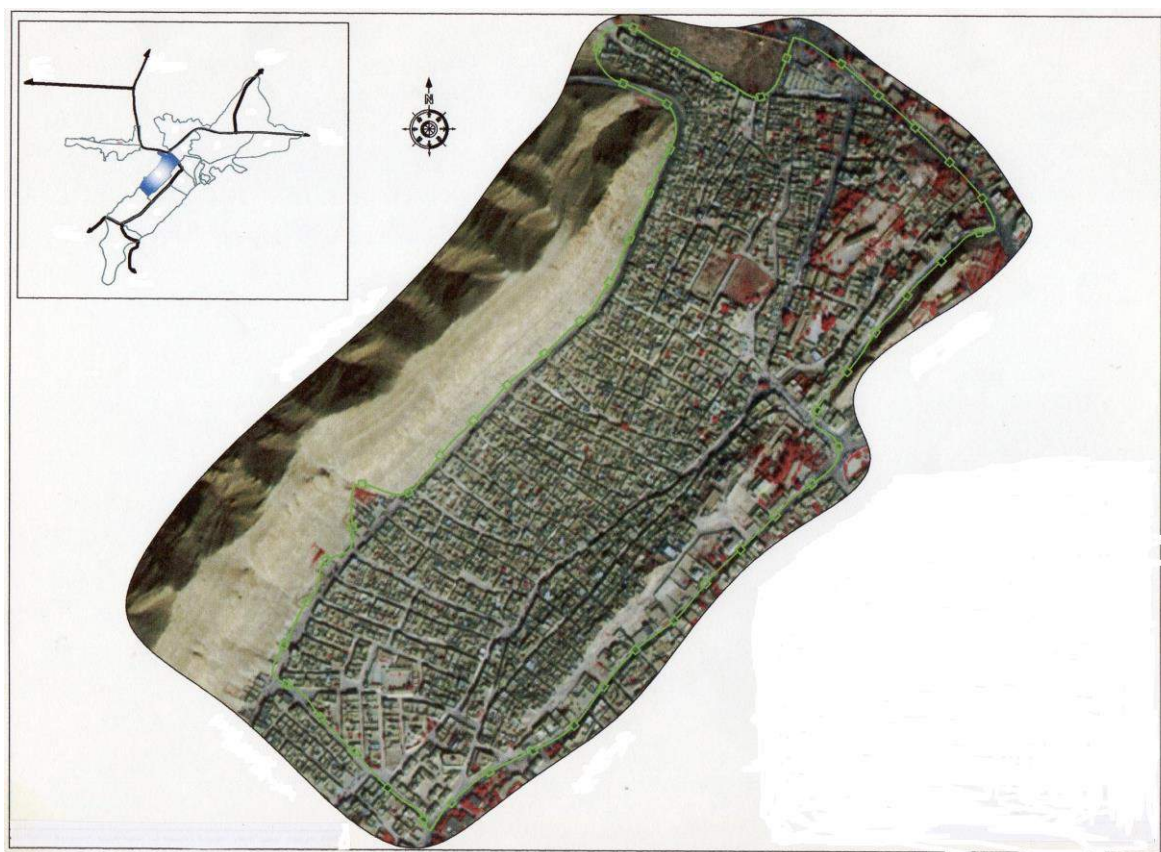


Fig. 7. Aerial view of the Koucha and Kaissa districts

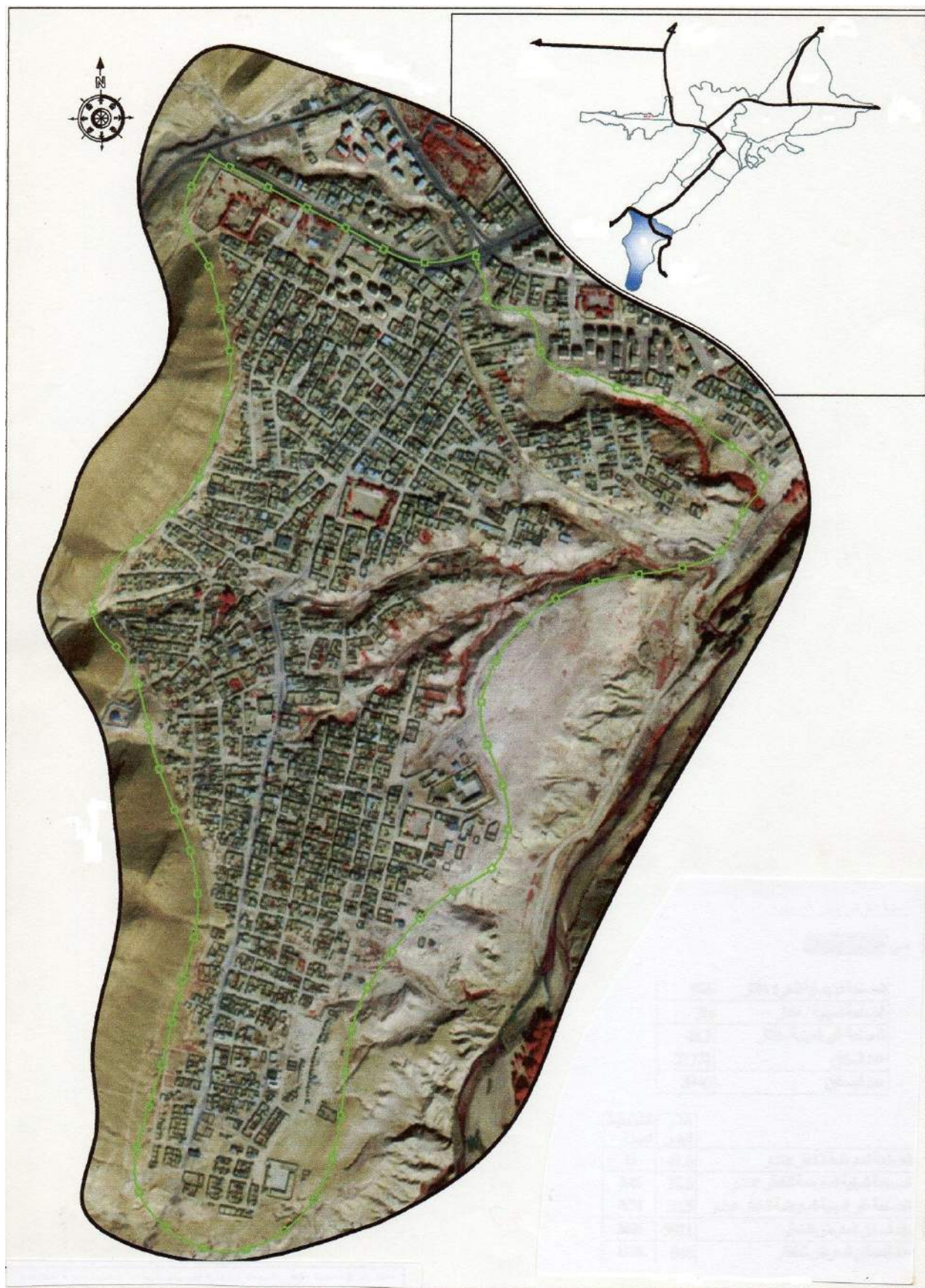


Fig. 8. Aerial view of the Sidi Slimane district



Fig. 9. River pollution



Fig.10. Degradation of oasis vegetation

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Geomorphosites in the Ialomița Subcarpathians

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Abstract. The authors of this scientific papers have pursued a double goal: a scientific one, namely to identify, classify, characterize and map the geomorphosites in the Subcarpathians of Ialomița; and a practical one, specifically to evaluate the tourist potential of each geomorphosite in turn, in order to integrate them into the tourist circuit. In order to select, characterize and evaluate the geomorphosites in the above-mentioned Subcarpathian area, we have used the methodology that has been recently agreed upon concerning the study of this category of applied geomorphology themes. So, in the Subcarpathians of Ialomița, we have identified and assessed a number of eight geomorphosites. Two of them (Cheile Dâmboviței and Malu de Răsună) could become part of a tourist circuit during a proximal stage, while the sandstones from the area of Bela – Miculești (north of Pucioasa) and the cuestas from the zone in which Cricovul Dulce springs (Râpa Șoimilor) meet the conditions required to be declared *natural monuments*.

Keywords: geomorphosites, identification, evaluation, classification, hierarchy, Ialomița Subcarpathians

1. Introduction

Geomorphosites are a type of relief or geomorphological process which, in time, acquired esthetical, scientific, cultural, historical or economic value, due to human perception (Panizza, 2001; Piacente, 1993, cited in Pralong, 2005).

As part of the current geomorphological heritage, „geomorphosites are important in studying the history of the Earth, the evolution of the climate, the evolution of life on the planet, and they are also important from an ecological, economic and cultural point of view” (Grandgirard, 1997, cited in Reynard et.al., 2007, p. 148).

In the scientific literature, a series of terms were used to name the components of the geomorphological heritage: geomorphological values; geomorphological goods; geomorphological sites; geomorphological geotypes; sites of geomorphological interest; geomorphosites.

In his paper „L’évaluation des géotopes” (*The Assessment of Geotypes*), Grandgirard (1999) considers that the evaluation of the geomorphosites is performed according to three important criteria: rarity, representativeness and integrity. There are also certain optional criteria which can be added according to the context, such as the ecological value, the educational value and the paleogeographic importance.

In Romania, geomorphosites were not very much studied until now. The most important contributions to the study and knowledge of geomorphosites after 2000 belong to Ilieș and Josan (2009), Comănescu

et al. (2009), the latter authors referring to the geomorphosites in the Bucegi and Ceahlău mountains.

Another approach to the Romanian geomorphic heritage belongs to Szepesi (2007), who analyses the geomorphologic geotypes in the Iezer Mountains, naming them *geomorphologic objectives*. The evaluation of these was performed on the basis of two types of criteria: factors (integrity, specificity, exemplary quality – representativeness, rarity, paleogeographical value, sites of special interest) and indicators (dimension, geometrical configuration of the types of relief, composition, age, geodiversity, number of relief types, their aggregation and distribution, the context, the environment, the morphogenetic activity, their functionality etc.).

By approaching this subject, the authors have pursued a double goal: a scientific one, namely to identify, classify, create a hierarchy and map the geomorphosites in the Ialomița Subcarpathians (with a projection towards a possible selection of natural monuments) and a practical one, specifically to evaluate the touristic potential of each geomorphosite, in order to integrate them as beneficially as possible in the economic circuit.

The selection, the characterization and the evaluation of the geomorphosites in this Subcarpathian sector has respected a methodology that has come to light increasingly clearly in the applied geomorphological studies, not only abroad but also in our country. The results obtained can constitute a support for the specialized agencies

from Dâmbovița and Prahova County, concerned with the touristic development through the promotion of new interesting touristic destinations for the young generation and the general public.

In the Ialomița Subcarpathians, we have identified and evaluated a number of eight geomorphosites. Two of them could become part of a tourist circuit in a future stage (Cheile Dâmboviței and Malu de Răsună), while the sandstones from the area of Miculești – Bela and Râpa Șoimilor could be declared *natural monuments*.

2. Methods

In order to identify and evaluate the geomorphosites in the Ialomița Subcarpathians from a qualitative and a quantitative point of view, we have considered a series of features and criteria, namely those agreed upon by the specific studies in this domain.

Pralong (2005) and Reynard (2006) from the University of Lausanne, in their evaluation of the geomorphological sites, use four sets of criteria and features, quantified by scores from 0 to 1: the *scenic criterion* (number of observation points, average distance to the observation points, area covered, height, chromatic contrast with the neighborhoods), the *scientific criterion* (paleogeographic interest, representativeness, rarity, integrity, ecological importance), the *cultural criterion* (cultural traditions, iconographic representations, historical and archeological importance, religious importance, cultural and artistic events), and the *economic criterion* (accessibility, natural risks, annual number of visitors from the region in which the site is situated, attractiveness, official level of protection).

Ielenicz (2010) synthesized, in a few synoptic tables, the features, the criteria and the scores used for assessing the geomorphosites, the criteria for the selection of the geomorphosites and the features and criteria highlighting the tourist value of a geomorphosite. The above-mentioned author has valorized the data of the foreign and Romanian specialized literature in connection to this theme as well as his own viewpoints on this topic. So, in order to choose the geomorphosites in a geographic unit, the following features were retained: physiognomy, frequency, relation to other types of geosites, accessibility, endowments, types of tourist activities, importance for the regional development.

The identification work, through observations in the field and through the analysis of large-scale topographic maps, has allowed us to classify and map, describe and evaluate a number of eight geomorphosites in the Ialomița Subcarpathians.

3. Results

3.1. Identification, classification and mapping of the geomorphosites in the Ialomița Subcarpathians

In the Ialomița Subcarpathians, there are certain forms of relief that can be included in the category of geomorphosites. These are forms that, through their specificity and representativeness, rarity or even uniqueness, or their spectacular aspect, appear as sites of a special scientific interest for the specialists, as sites that have gradually become - to the population and the collective perception - true landmarks on topographic maps, in localities' monographs, in specialized scientific papers, and in tourist guides. All these features signal a certain touristic potential for the respective geomorphological sites.

The landforms that we are referring to are conditioned by the petrographic and structural peculiarities, brought to light by specific modeling agents (fluvial erosion, torrential erosion) or by certain gravitational processes (landfalls, landslides etc.). Such is the case of the petrographic and structural scarps, of the precipices resulted following erosion or landslide processes (often strongly affected by ravines), of the prominent erosion witnesses (hills, mounds, cliffs/rocky ridges), of the sandstones visible in the relief (Loghin, 2000).

Their scientific importance is given by the fact that, being representative for the morphology of this geographic unit, they can constitute landmarks for morphogenetical and morphodynamic theories.

The practical value derives from those dimension- and shape-related features that make them impressive, spectacular or scenic, turning them into tourist destinations. They are places increasingly frequented, often by pupils (during hiking and trips), by students (during their field-trips, for instance by the bachelor and master students of the Geography Department of the Valahia University of Târgoviște), and also by the general public (during different leisure activities).

Through their intrinsic features, through their reflex in the landscape, some geomorphosites from the Ialomița Subcarpathians are or can be proposed as natural monuments or as protected areas. For example, the Dâmbovița Gorges (Cheile Dâmboviței) from Cetățeni are included among the sites NATURA 2000, while the sandstones from the area of Miculești – Bela (in the north of Pucioasa Town) and the Râpa Șoimilor gully (in the area of Cricovul Dulce springs) meet the necessary requirements to be declared "natural monuments".

The diversity of the selected geomorphosites has obliged us to use the classification operation first and then to proceed to their typological mapping. In their classification, we have applied the genetic criterion for the relief forms. The following have been identified:

- *Gorges*: Cheile Dâmboviței at Cetățeni;
- *Structural and petrographic escarpments* in form of cuesta scarps cut in brittle sandstones with a monocline or quasi-horizontal stratification: Râpa Șoimilor, in the source area of the Cricovul Dulce, along Costișata Valley; Malu de Răsună, in the upper Bizdidel catchment, upstream of Bezdead locality; Râpa Obrocea, Cuesta in the in the source area of the Râu Alb River;
- *Fluvial erosion scarps*, with the appearance of terrace structures at the surface, bringing to light the succession of gravels, loesses and fossil quaternary soils: the escarpment carved by the Prahova River in the front of Câmpina terrace, downstream of the confluence with the Doftana River, north of the Cocorăștii Caplii locality;
- *Salt massifs*: the salt massif from Ocnîța, modeled by dissolution (clints), erosion and rockfalls;
- *Petrographic outliers*: the cliff Colțul Bratei, situated in the upper side of the left slope of

Ialomița Valley, within the perimeter of Buciumeni commune, the peak Cetățuia, on the interfluvial Bărbulețu – Valea Largă, the escarpment Piatra Corbului, on the interfluvial Râu Alb – Ialomicioara;

- *Sandstones* which have come to light in the relief (interfluvial, slope and riverbed sandstones): on the interfluvial Ialomița – Bizdidel (in the area of Bela village, which is part of Pucioasa town), on the right slope of Bizdidel valley and in the riverbed of Bizdidel river, upstream from Miculești (Pucioasa) (Loghin et al, 2005).

A particular category of geomorphological points having a touristic value is that of the highest points in a relief unit, which are important not by themselves, but by the fact that their dominant position and their uniqueness provides them the quality of revealing observation points, with a large panorama over the relief and the geographic setting as a whole. They are points from which the geographers and the geologists carry out general scientific observations, they are belvedere points for tourists and for all those who love to see new, spectacular, charming and relaxing sights. These points are generally situated along the line of the highest peaks, representing the watersheds or the upper area of the hills.

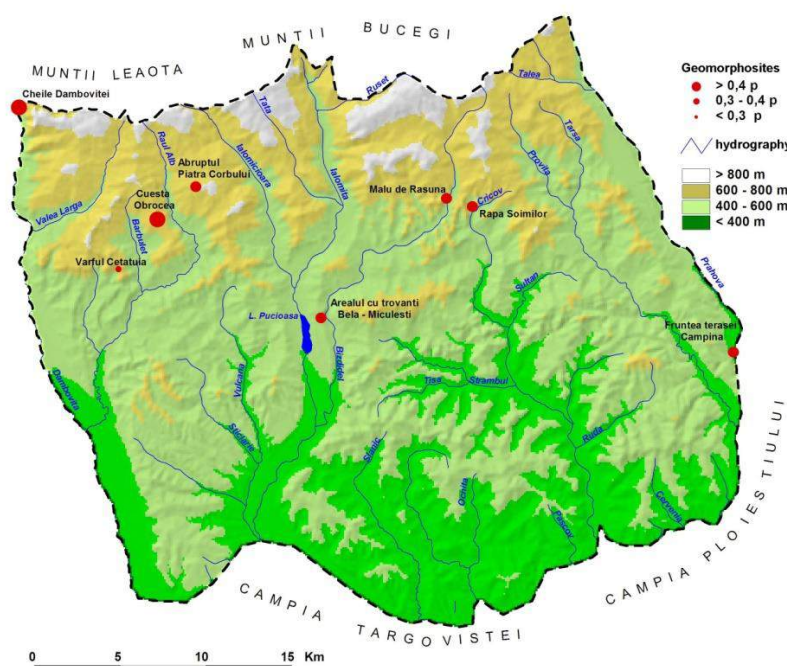


Fig. 1. The geomorphosites in the Ialomița Subcarpathians according to their global value

3.2. Evaluation and hierarchy of the geomorphosites in the Ialomița Subcarpathians

The evaluations carried out for the geomorphosites of the Ialomița Subcarpathians have relied on the

criteria and scores proposed by Pralong (2005). We are referring to the scenic, scientific, cultural and economic criteria and their scores range from 0 to 1. We would like to mention that these evaluations have provided almost identical scores to those

The eight geomorphosites selected following our field research were characterized based on standard sheets. These standard sheets helped us select scores for each sequence and they represented the criterion based on which we were able to calculate the sites' global value. The analytical and the synthetic values, as well as the structural diagrams have allowed us to put down the following ideas:

- the highest scores have been obtained, in order, by the criteria: *scientific value* (4.571), *economic value* (4.25) and *scenic value* (4.15) (Fig. 2). The

- the highest *scenic value* was obtained for Cheile Dâmboviței (0.70), the maximum *scientific value* also for Cheile Dâmboviței (0.750), while the highest *economic value* corresponds to Malu de Răsună (0.65); the second place is occupied by: Cuesta Obrocea and Râpa Șoimilor (0.60) in terms of *scenic value*, the sandstones from the area of Bela – Miculești (0.666) in terms of *scientific value*; Cuesta Obrocea in terms of *economic value* (0.60) (Tables 1, 2, 3 and 4);

- after summing up the scores obtained according to the evaluation criteria, it was possible to calculate the global value and the hierarchy of the geomorphosites from the Ialomița Subcarpathians (Table 5, Figs. 1 and 3). On the first three places are situated: Cheile Dâmboviței with a general score of 0.5125, Cuesta Obrocea (0.50625), Malu de Răsună (0.42275). So, the maximum global score is held by Cheile Dâmboviței (0.5125), while the minimum global score pertains to the Cetățuia peak (0.30625), with a significant difference.

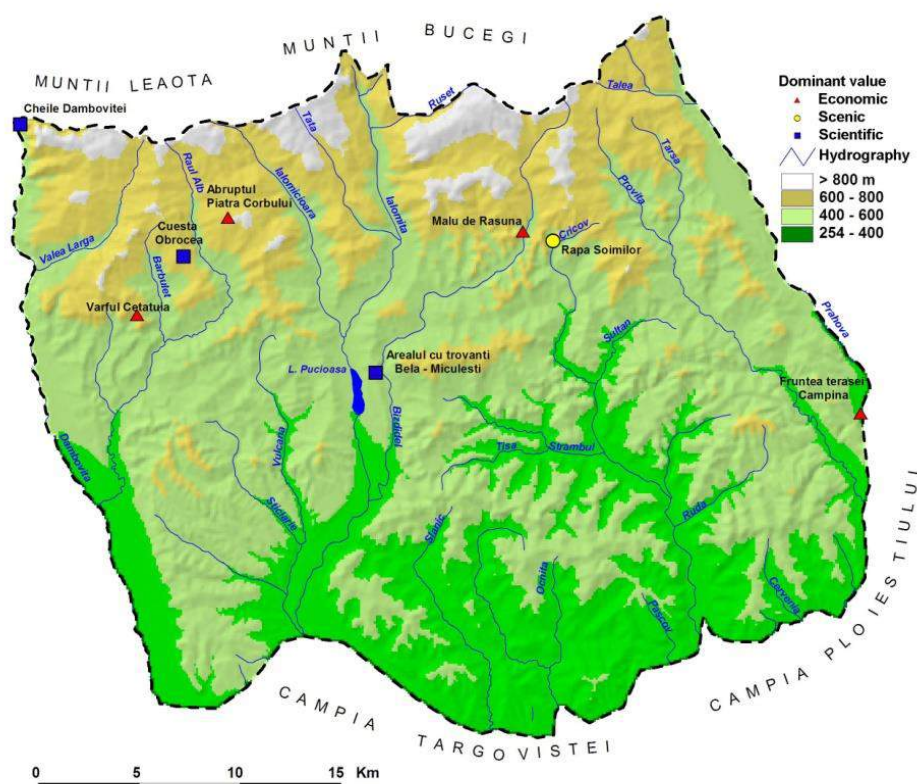


Fig. 2. The geomorphosites in the Ialomita Subcarpathians according to the dominant value in their score

Table 1. Scenic value of the geomorphosites

No.	Name of the geomorphosite	Scenic value					
		Sc ₁	Sc ₂	Sc ₃	Sc ₄	Sc ₅	Total
1.	The gorge Cheile Dâmboviței	0.25	1	1	1	0.25	0.70
2.	The hill Cuesta Obrocea	0.75	0.75	0.25	0.25	1	0.60
3.	The peak Vârful Cetățuia	0.5	0.5	0.25	0.5	0	0.35
4.	The escarpment Piatra Corbului	0.5	0.5	0.5	0.25	0.5	0.45
5.	Malu de Răsună (The Sounding Slope)	0.5	0.75	0.25	0.5	0.5	0.50
6.	The ravine Râpa Șoimilor	0.5	0.75	0.5	0.75	0.5	0.60
7.	The sandstones in the area of Miculești – Bela	0.5	0.25	0.75	0.25	0.5	0.45
8.	The front of Câmpina terrace, downstream from the Prahova – Doftana confluence	0.25	0.25	0.5	0.5	1	0.50

Table 2. Scientific value of the geomorphosites

No.	Name of the geomorphosite	Scientific value						
		Șt ₁	Șt ₂	Șt ₃	Șt ₄	Șt ₅	Șt ₆	Total
1.	The gorge Cheile Dâmboviței	1	1	1	1	0.5	0	0.750
2.	The hill Cuesta Obrocea	0.25	0.75	0.25	1	1	0.5	0.625
3.	The peak Vârful Cetățuia	0.25	0.25	0.25	0.25	1	0.25	0.375
4.	The escarpment Piatra Corbului	0.25	0.5	0.5	0.5	1	0.5	0.541
5.	Malu de Răsună (The Sounding Slope)	0	1	0.5	0.5	1	0.25	0.541
6.	T he ravine Râpa Șoimilor	0	1	0.5	0.5	1	0.5	0.583
7.	The sandstones in the area of Miculești – Bela	0	1	1	1	0.75	0.25	0.666
8.	The front of Câmpina terrace, downstream from the Prahova – Doftana confluence	0.75	0.75	0.5	0.5	0.5	0	0.500

Table 3. Cultural value of the geomorphosites

No.	Name of the geomorphosite	Cultural value					
		C ₁	C ₂	C ₃	C ₄	C ₅	Total
1.	The gorge Cheile Dâmboviței	0	0.25	0	0	0	0.05
2.	The hill Cuesta Obrocea	0	0	0	0	1	0.20
3.	The peak Vârful Cetățuia	0	0	0	0	0	0.00
4.	The escarpment Piatra Corbului	0	0	0	0	0	0.00
5.	Malu de Răsună (The Sounding Slope)	0	0	0	0	0	0.00
6.	The ravine Râpa Șoimilor	0	0	0	0	0	0.00
7.	The sandstones in the area of Miculești – Bela	0	0	0	0	0	0.00
8.	The front of Câmpina terrace, downstream from the Prahova – Doftana confluence	0	0	0	0	0	0.00

Table 4. Economic value of the geomorphosites

No.	Name of the geomorphosite	Economic value					
		E ₁	E ₂	E ₃	E ₄	E ₅	Total
1.	The gorge Cheile Dâmboviței	0.5	1	0	0.75	0.5	0.55
2.	The hill Cuesta Obrocea	0.75	0.75	0	1	0.5	0.60
3.	The peak Vârful Cetățuia	0.5	0.75	0	1	0.25	0.50
4.	The escarpment Piatra Corbului	0.25	1	0	1	0.25	0.50
5.	Malu de Răsună (The Sounding Slope)	0.75	1	0	1	0.5	0.65
6.	The ravine Râpa Șoimilor	0.25	0.25	0	1	0.25	0.35
7.	The sandstones in the area of Miculești – Bela	0.75	0.25	0	1	0.5	0.50
8.	The front of Câmpina terrace, downstream from the Prahova – Doftana confluence	1	0.5	0	1	0.5	0.60

Table 5. Global value of the geomorphosites

No.	Name of the geomorphosite	Scenic value	Scientific value	Cultural value	Economic value	Global value
1.	The gorge Cheile Dâmboviței	0.70	0.75	0.05	0.55	0.51250
2.	The hill Cuesta Obrocea	0.6	0.625	0.2	0.6	0.50625
3.	The peak Vârful Cetățuia	0.35	0.375	0	0.5	0.30625
4.	The escarpment Piatra Corbului	0.45	0.541	0	0.5	0.37275
5.	Malu de Râsună (The Sounding Slope)	0.5	0.541	0	0.65	0.42275
6.	The ravine Râpa Șoimilor	0.6	0.583	0	0.35	0.38325
7.	The sandstones in the area of Miculești – Bela	0.45	0.666	0	0.5	0.40400
8.	The front of Câmpina terrace, downstream from the Prahova – Doftana confluence	0.5	0.5	0	0.6	0.40000

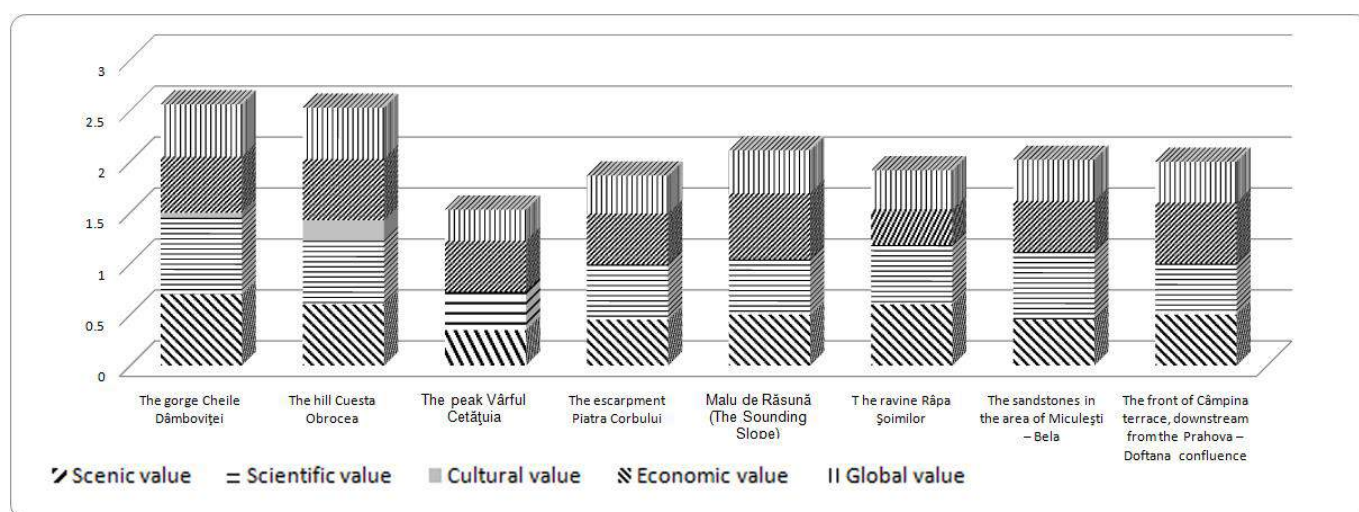


Fig. 3. Diagram representing the value-related structure of the geomorphosites in the Ialomița Subcarpathians

4. Conclusions

We consider that this evaluation and hierarchy reflects the objective reality, so that it could offer to decision makers a base to prioritize in integrating, managing and touristically exploiting these destinations. This is an action that we envision as one that should be undertaken along with the protection of the geomorphosites having a final goal the inclusion of some of them into the category of natural monuments or protected areas. In this sense,

we consider that the geomorphological sites of Cheile Dâmboviței (Cetățeni) and Malu de Râsună (translated: *The Sounding Slope*) (Bezdead) meet the most adequate conditions for their integration, as soon as possible, in the touristic management and exploitation circuit. At the same time, we propose that the geomorphosites represented by the sandstones from the Miculești – Bela area (Pucioasa) and the Râpa Șoimilor gully (source area of the Cricovul Dulce river) should receive the status of *natural monuments*.

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Miscellanea

Le XXX^e Colloque National de Géomorphologie

Relevance de la géomorphologie pour la société: réalisations et perspectives

Orșova, le 29-31 Mai 2014

La trentième édition du colloque national de géomorphologie a été organisée par l'Association des Géomorphologues Roumains en collaboration avec la Faculté de Géographie, l'Université de Bucarest, de 29 à 31 mai 2014. Le colloque a eu lieu à la station de recherches géographiques qui appartient à l'université bucarestoise, sur le bord du Danube, à Orșova.

Sur les auspices de ces 150 ans de l'Université de Bucarest et de 50 ans de la station de recherches d'Orșova, le rencontre scientifique a groupé 60 géomorphologues, géographes, hydrologues, cartographes. Le sujet du colloque a correspondu parfaitement aux intérêts les plus pertinents développés dans l'Europe Occidentale concernant les nouvelles directions géomorphologiques de recherches. Il s'agit de la *Relevance de la géomorphologie pour la société: réalisations et perspectives*.

Les 75 communications orales et posters ont été groupés en trois sections : *La géomorphologie des versants et sa relevance pour la société*, *La géomorphologie fluviale et sa relevance pour la société* et *La géomorphologie appliquée*. Le colloque a eu également une session pour les communications poster où, sur les murs des chambres de conférences, les chercheurs ont posté 16 posters qui ont touchés les trois sections thématiques mentionnées. Tous les résumés des communications orales et posters ont été recueillis en volume coordonné par prof. univ. dr. Florina Grecu.

La première journée du colloque (le 29 mai) a été consacrée seulement pour la registration des participants. Pendant la deuxième journée du colloque (le 30 mai) tous les participants ont exposé leurs recherches. Dans la dernière partie de la journée, une excursion sur terrain a été organisée. Les chercheurs ont eu la possibilité de voir la plus spectaculaire section de la vallée danubienne (de toute son cours, de Forêt Noir au delta): les Grands et les Petits Cazans. Ces structures

géomorphologiques dominant les eaux du Danube, forment la vallée danubienne des Portes de Fer et représentent la plus importante attraction touristique de cette région. Les gorges sont sculptées dans des roches calcaires jurassiques et crétacées. Les murs-versants s'élèvent à 100-150 m de la surface de l'eau, où se trouve un plateau calcaire avec plein de microformes karstiques (dolines, lapiazs, uvaes). A ce point-là, les participants ont eu la chance de choisir entre deux petites excursions : une moitié des participants ont monté sur le plateau de Ciucaru Mare où ils ont admiré les belles gorges du Danube ainsi que les microformes karstiques. L'autre moitié a visité la grotte de Poncova. Cette grotte est la plus grande et la plus importante de tout le secteur des gorges du Danube (avec deux galeries, une active et une fossile et avec des formes spécifiques pour les grottes).

L'application sur terrain au long du Danube a compris toujours d'autres arrêts, assez intéressants. Le monastère de Mraconia et la statue de Décébale ont représenté un arrêt très éducatif. Le monastère de Mraconia montre assez bien comment la construction du barrage des Portes de Fer a affecté les activités humaines (notamment sur les versants entourant le lac). Le monastère que nous avons visité est là depuis les années soixante-dix, immédiatement après la construction du barrage et l'inondation de l'ancien monastère de Mraconia (situé sur le bord de la rivière homonyme, aujourd'hui un beau golf). La statue de Décébale est sculptée toujours sur un versant de golf de Mraconia, dans un gros bloc calcaire. La réalisation a été financée par l'homme d'affaire roumain Iosif Constantin Drăgan qui a voulu édifier un monument-symbole pour cette région chargée avec beaucoup d'histoire.

On a aussi visité les anciennes forteresses de Triukle et de Drencova. Les deux forteresses ont été bâties dans le quinzième siècle pour des raisons militaires : l'arrêt de l'expansion ottomane. Situées sur le bord du Danube et construites en pierres

dures, les deux forteresses médiévales ont résistées jusqu'aux nos jours, malgré l'apparition du lac et leur inondation partielle. Heureusement, pendant la conférence, le niveau des eaux du lac a été très bas (environ trois ou quatre mètres dessous du niveau habituel), ainsi que nous avons eu la chance de mieux observer les deux constructions (nous avons pu descendre jusqu'à la base des tours de Trikuale).

Deux autres attractions touristiques (mais aussi scientifiques) qui doivent être mentionnées dans cette application sur terrain sont le dôme volcanique de Trescovăț et la cascade de Bigăr. Le premier géosite est très bien identifiable dans le paysage de la vallée danubienne. Avec une altitude de 755 m, le dôme volcanique de Trescovăț prouve la grande géodiversité qui s'y trouve ainsi que l'ancienne activité volcanique existante ici pendant le permien.

On quitte la vallée danubienne et on arrive à la cascade de Bigăr, sur la rivière de Miniș. Les gorges du Miniș et la cascade de Bigăr sont les plus importants géosites des montagnes d'Anina. De plus, ils sont situés exactement sur la parallèle de 45 degrés nord.

Voilà donc quelques points de la trentième édition du colloque national de géomorphologie. Un colloque commencé, officiellement, dans la grande salle de la mairie de la ville d'Orșova et fini sur le terrain, comme on est habitué. C'était le deuxième colloque national de géomorphologie organisé par la station de recherches d'Orșova (après celui de 1988), qui souligne, encore une fois, le rôle important de cette station géographique dans la vie scientifique roumaine.



Les membres de l'Association des Géomorphologues Roumains entre les tours de la forteresse de Trikuale (dans un moment historique, quand les eaux lac ont été très bas, environ trois ou quatre mètres dessous du niveau habituel. Photo A. Beldiman



Les membres de l'Association des Géomorphologues Roumains sur le rive du Danube, en face de la Statue de Décébale

Daniel IOSIF

17th Joint Geomorphological Meeting
The geomorphology of natural hazards: mapping, analysis and prevention
Liege, June 30 – July 3, 2014

During the summer of 2014 the 17th Joint Geomorphological Meeting took place, dealing with topics grouped under the title *The geomorphology of natural hazards: mapping, analysis and prevention*. It was organized by the Belgian Association of Geomorphologists, Department of Geography, Faculty of Science, University of Liege, and was held in Liege, Belgium, from June 30 to July 3, 2014.

Proceedings of the Symposium presented interesting approaches with high scientific value, grouped in two sections: oral and poster presentations. The 13 oral presentations highlighted various extreme geomorphologic phenomena occurring in Belgium, Italy, Greece, Romania, France, Central Africa, Venezuela, Siberia, Poland. Participants came from over 10 countries. Besides the countries' committees directly involved in organizing these periodical meetings, the official national geomorphological associations of Romania, Italy, France, Greece, and Belgium (AGR – Asociatia Geomorfologilor din Romania; AIGeo – Associazione Italiana di Geografia fisica e Geomorfologia, GFG – Groupe Français de Géomorphologie; HCGE – Hellenic Committee for Geomorphology and Environment; BAG – Belgian Association of Geomorphologists) also geomorphologists from Poland, Russia, Africa attended the meeting.

The representatives of the Romanian Association of Geomorphologists were Acad. Dan Balteanu and PhD. Marta Jurchescu, holding plenary presentations on the following topics:

Geomorphic Hazards in the Romanian Carpathians and Modelling gully erosion susceptibility in an area of southern Romania. Also, there were 12 posters which presented a variety of topics related to extreme events affecting various areas from Carpathians, Danube basin, some river basins, etc.

The first day field trip aimed to present the landscape features resulting from various types of natural hazards, in different geomorphological contexts in the areas around Liege: active karstic features at La Roche aux Faucons, south of Liege and in the Vallons des Chantoirs; a dry valley on the northern border of the Ardennes massif; a coal mining spoil heap at Retinne, in the NW part of the former Liege mining area; the ancient landslides in the Pays de Herve, east of Liege. The second day field trip was held in order to visit or observe the fluvial geomorphology and flood hazard, in the middle Warche River of NE Ardennes; the Stavelot abbey; the geomorphic traces left by periglacial debris flows and flash floods at the confluence of the Chefna; the Amblève basin; the Meuse floodplain from Liege.

This is a meeting that takes place every two years in each of the countries of the committee. The previous edition took place in 2012 in Rome, and the next will be in France in 2016. The meeting was a great success, with high level scientific presentations, highlighting a multitude of aspects related to the geomorphology of natural hazards, a real opportunity for reunion, discussion, knowledge enrichment.





Anca MUNTEANU

2nd International Conference "Water resources and wetlands",
Tulcea, Romania, September 11-13, 2014
2^e Conférence Internationale « Ressources en eau et zones humides »,
Tulcea, Roumanie, 11-13 Septembre 2014

L'Association roumaine de limnographie organise une conférence internationale tous les deux ans, à Tulcea, en Roumanie, sous le thème de « Ressources en eau et zones humides ». La réunion envisage de créer le cadre d'échange scientifique sur la problématique de l'eau en tant qu'enjeux mondial pour le développement durable.

Pour la deuxième édition, du 11 au 13 septembre 2014, l'Association roumaine de limnographie a eu comme partenaires la Société polonaise de limnologie, la Société tchèque de limnologie et l'Administration de la réserve de la biosphère du Delta du Danube. L'organisation de la conférence a été possible grâce à l'équipe enthousiaste de prof. Petre Gâstescu et dr. Petre Brețcan.

La conférence a réuni 126 participants de vingt-sept pays sur quatre continents et de domaines variés comme l'aménagement, la biologie, la chimie, la géographie et l'ingénierie ; les géomorphologues travaillant sur les milieux humides ont été les bienvenus.

Du point de vue scientifique, la conférence a regroupé :

- environ soixante communications orales et soixante-dix posters (sessions parallèles : Écologie des écosystèmes de rivière et de lac, Changements climatiques et ressources en eau, Milieu littoral, Deltas et zones humides, Politiques publiques dans le domaine de l'eau) ;

- une table ronde sur le thème de « L'eau minérale en bouteille – perspectives dans le contexte

socio-économique roumain », en collaboration avec la Société nationale des eaux minérales ;

- une excursion dans le delta du Danube en bateau, de la ville de Tulcea sur le bras rectifié de Sulina jusqu'à la commune de Crișan, puis le long du vieux Danube jusqu'à la commune de Mila 23, puis le long du canal Gârla Șontea jusqu'au retour à Tulcea ; l'excursion a eu comme thématique l'observation ornithologique et du paysage.

Du point de vue socio-culturel, les organisateurs ont proposé aux participants une soirée de gala au bord du Danube, à la découverte des danses folkloriques roumaines et de la cuisine locale à base de poisson.

Pour conclure, les points forts de la conférence ont été la complémentarité des recherches des participants, le caractère international des cadres géographiques de réflexion scientifique (des îles philippines au nord canadien) et l'ambiance amicale. Grâce à la conférence, chaque participant a sûrement mieux compris le rôle de ses travaux dans le monde interdisciplinaire des recherches sur l'eau et a pris de nouveaux contacts. Nous tenons à remercier les organisateurs pour ce moment de découverte, à la fois scientifique et culturelle, des zones humides.

Rendez-vous à la 3^e édition ! Restez à jour sur le site de l'Association roumaine de limnographie www.limnology.ro.



Gabriela IOANA-TOROIMAC

International Symposium on SEASONAL SNOW AND ICE

Lahti, Finland, 28 May–1 June 2012

The International Symposium on Seasonal Snow and Ice was organized by the International Glaciological Society, in collaboration with the Department of Physics, University of Helsinki and the Micro-Dynamics of Ice (Micro-DICE) network of the European Science Foundation. The symposium was held in Lahti, Finland, during 28 May–1 June 2012. The Scientific Committee was formed by Leppäranta Matti Lauri Arvola, Nikolai Filatov, Peter Jansson, Yuji Kodama, Zhijun Li, Lasse Makkonen, Martin Schneebeli.

There were 148 participants from 21 countries present at the event. The various topics dedicated to snow and ice included: observations of temporal changes of seasonal snow and ice cover, snow and ice phenomenology, in situ observations and mathematical modelling techniques; physical, chemical and biological processes of seasonal snow and ice, snow metamorphosis, snow structure models and the effect of snow quality on the biosphere; micro-dynamics of ice, analysis, modelling and interpretation of ice and snow microstructures and linking microstructures to geophysical signals; seasonal sea-ice dynamics and the impact of seasonal sea ice on the ocean, scaling of ice dynamics, mathematical models, ice ridges, and the oceanic boundary layer under sea ice; frozen ground and permafrost, focussing on observations, theoretical advances and modelling; lake and river ice - ecology of frozen lakes, river ice models, estuaries; ecological impact of snow cover and snow quality; remote sensing techniques applied to seasonal snow and ice, sea and lake ice and snow-mapping technology; theoretical and numerical

advances in modelling seasonal snow and ice, coupling of cryosphere models with regional climate models and intercomparison of models; projections and forecasts of seasonal snow and ice in a changing climate, downscaling methods and evaluations.

The presentations and posters exposed covered various mountainous, subpolar or polar areas from the Alps, Storglaciären (Northern Sweden), Western Himalaya (India), the Khibiny Mountains (Russia), the Japanese central mountains, the Tibetan Plateau, the Hardangervidda Mountain Plateau, the Carpathians Mountains, Svalbard, Weddell Sea, the Lena River basin (Siberia), Tarim River Basin, the Laptev Sea, the Baltic Sea, the Kara Sea, the Barents Seas, the Greenland Sea, Western Arctic Ocean, the Lake Ladoga, the Lake Pääjärvi, the Lake Baikal, Norway, Finnish Lapland, northern Sweden, Fairbanks (Alaska), Eastern Fennoscandia, Eastern Antarctica, Türkiye, Xinjiang (China), the Siberian Arctic, the Canadian coastal waters, the Eurasian boreal forests and tundra, etc.

The program was varied and rich in activities, including field trips to the vast spaces shaped by glaciers near Lahti, on Vesijärvi glacial lakes, Lake Päijänne at Lehmonkärki, where specific Finnish cultural, sport and traditional activities were held.

The high-level scientific manifestation was a good opportunity of better understanding the world-wide and Polish cryokarst, it offered an exchange of experiences to those present and an opportunity to facilitate the connections between different generations of researchers. Special thanks to Magnus Már Magnússon, Michael Lehning.



Anca MUNTEANU

RECENZII/REVIEWS

Virgil GÂRBACEA – *Relieful de glimee*, Presa Universitară Clujeană, 2013, 260 pages, 56 figures, English abstract, 400 bibliographic titles

Deep-seated landslides of „glimee” type represents one of the specific sorts of relief encountered on the Romanian territory which attracted the attention of international scientists as a consequence of the presentation made by Morariu and Gârbacea at the New Delhi International Congress in 1968. As for the genesis of this type of relief, although frequently approached in the scientific literature, especially the glimee deep-seated landslides in the Transilvanyan Depression, there haven't been formulated unanimously accepted causal explanations yet. That is why one should state as a great achievement the publishing of a study on the analysis, hypothesis and researches on glimee deep-seated landslides in Romania which also defines the activity of a specialised scientist in the study of glimee deep-seated landslides – the Professor Virgil Gârbacea.

The structure of the study follows the characteristics of this type of relief renown both in the national and the international scientific literature. The author supports his opinion through his direct researches made in different areas (Saschiz, Transilvanyan Plain) etc.. Consequently there is a logic in the succession of the 13 chapters of his book as follows: definition, toponyms, classifications, history of researches (chapter 1 and 2); the position on the slope, the absolute altitude, the connection with the relief evolution in general (chapter 3); the morphographic and morphometric characteristics through which the main defining elements for glimee deep-seated landslides are reflected such as: the detachment cornice, the

landslide glacis, relief microformes, the relative altitude etc. (chapter 4); the genetic factors and conditions (chapter 5); the morphodynamic of glimee deep-seated landslides with examples different authors' opinions (chapter 6); the link with the geological structure – insecvential or asecvential glimee (chapter 7); associated geomorphological processes, of past and actual modelling of glimee through erosion, suffosion etc. (chapter 8); the age of landslides of glimee type (chapter 9); the causes of their formation (chapter 10); the synthesis of glimee research in Romania (chapters 11 and 12); the valuing of fields with glimee and conclusions (chapter 13).

The abstract extended on 14 pages makes the work accessible for specialists that don't know Romanian as well. We think that the work doesn't need more presentations or interpretations and we rather invite those interested in the topic to discover the unique character of this book.

It is a very valuable work through the richness of its interpreting and through Prof. Virgil Gârbacea clear, explicite, original style. We think that we don't make any mistake by affirming that he is the only geographer/geomorphologist who studied perseverently and thoroughly for a long time the glimee deep-seated landslides, gathering exhaustively in one study the literature for this type of relief (the bibliographic references comprise 400 titles). One should state that this study will be a topic of research for other generations as *glimee* type of relief also fascinated us and stired us up to research.

Florina GRECU

Authors' instructions

Title page information

- Title. Concise and informative. Use Sentence case, Times New Roman, Font 14, bold.
- Author names. Please indicate the first name with a Sentence case and the last name(s) with an Uppercase. Use Times New Roman, font 12. Please insert a superscript Arabic number for linking the affiliation provided at the end of the article. Example:
Petronela DARIE (CHELARU)¹, Ion IONITA¹

Abstract

A concise abstract of 150-250 words is required. The abstract should state the purpose of the research, the main results and conclusions. References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

Use Times New Roman, font 10, followed by a dot and by the abstract text, without indentation. Example:

Abstract. From a morphological point of view, the Ialomița Upper Valley represents a typical mountain valley. This feature frequently determines the appearance of torrential geomorphological processes (runoff, gulling, and torrent). The goal of this article is to highlight the occurrence of soil erosion using a bivariate analysis in the Ilwis 3.4 software.

Statistical approaches are indirect methods for assessing susceptibility, involving statistical determinations by combining variables that determined the known processes. The weights of evidence modeling for torrential erosion is based on overlapping the erosion map with parameter maps (slope, aspect, geology, land use, soil, etc.), which aims at obtaining the susceptibility map and the final prediction map (success rate map).

Keywords

Immediately after the abstract, provide a maximum of 6 keywords, avoiding multiple concepts (avoid, for example, 'and', 'of'). Only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

Example:

Keywords: erosion, susceptibility, maps, statistical analysis, Ialomița Upper Valley.

Text information

Manuscripts should be submitted in Word. Please save files in the .docx format for Word2007 or higher or .doc format for older versions of Word. Use a normal font of 11 point Times New Roman.

Use italics for emphasis.

Article structure

Subdivision - numbered sections

Divide your article into clearly defined and numbered sections. If subsections exist, these should be numbered (1.1., then 1.1.1, 1.1.2, ...; then 1.2 etc). The abstract is not included in the section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line, distanced by one line from the text above and below.

Examples for sections that should not miss:

1. Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

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The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a **Discussion** or **Results and Discussion** section.

For first subsections' headings use Bold italic. Example:

3.1. Relief

For second subsections' headings use italic only. Example:

2.1.1. Un secteur dominé par des jebels aux versants raides avec une lithologie favorable au ruissellement

First paragraph of each section/subsection should have no indentation.

Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references. List here people, grants, funds, etc.

Abbreviations

Abbreviations must be defined at their first mention. Ensure consistency of abbreviations throughout the article.

Math formulae

Use the equation editor for equations.

Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data).

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If there is text in the figures, please keep it consistently sized throughout all the figures in the article.

Do not include titles or captions within your illustrations.

All the figures are to be numbered using Arabic numbers.

Each figure should have a concise caption describing its content (Bold, Font 9), not in the figure itself, but beneath the figure. The captions should be preceded by the term "Fig." (italic font 9) and the figure number and dot (italic font 9).

Example:

Fig 1. Landslides

Photo 1. The Ialomița Valley

Figures should be cited in the text respecting their order of appearance. Figure parts have to be signaled by lower-case letters (a, b, c etc.).

Examples:

Figure 2

Figure 11b

(Fig. 3)

(Figs. 3 and 4)

Previously published figure material should be cited by giving the original source in the form of a citation at the end of the figure caption. Additionally, if the figures have been published before elsewhere, you are obliged to obtain permission from the copyright owners for both the print and the online format. If these rights are not granted for free, you need to use other material from other sources.

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All tables should be numbered using Arabic numbers. Each table should have a table caption above (centered) explaining its content.

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Example:

Table 1. Index classification on categories of fluvial vulnerability

All tables should be cited in the text in the order of their appearance.

Example:

Table 2

(Table 5)

References

Citations inside the text

Cite references in the text by name and year in parentheses. Consider the following examples:

- This results in the displacement of soil and/or rock particles by rainsplash and runoff as dispersed and concentrated flow (Moțoc, 1963).
- Changes in land cover can lead to significant changes in leaf area index, evapotranspiration (Mao & Cherkauer, 2009)
- As to gully development in the Bârlad Plateau, the long term findings obtained by Ionita (1998, 2000, 2007) and Ionita et al. (2006) are as follows
- The analysis proves the fact that this frequency is strongly influenced by the resistance degree of the rock types from the hydrographical basins (Zăvoianu et al., 2004).
- ...further into the sea sediments can be redistributed under the influence of waves, with a subsequent phase of mouth asymmetry, with the bar anchored on one of the shores (Bhattacharya, 2003; Giosan, 2005).

Reference list

References section (3 lines distanced from the text, 1 line between the title **REFERENCES** and the actual list). The title **REFERENCES** should be centered.

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Example:

COSTA, M.H., BOTTA, A., CARDILLE, J.A., (2003), "Effects of large-scale changes in land cover on the discharge of the Tocantins River, Southeastern Amazonia", *Journal of Hydrology*, **283**, 206–217.

- Book

Example :

VELCEA-MICALEVICH, V., (1961), *Masivul Bucegi: Studiu geomorfologic*, Edit. Academiei R. P. R., 152 p.

- Book chapter

Example:

CHURCH, M. A., (1992), "Channel Morphology and Typology", in: CALLOW, P., PETTS, G.E. (Eds.), *The Rivers Handbook*, Oxford, Blackwell, 126-143.

- Online document

Example:

RĂDOANE, M., CRISTEA, I, RĂDOANE, N., (2011), *Cartografierea geomorfologică. Evoluție și tendințe, I*, <http://geo-spatial.org>. Accessed 26 June 2012

- Dissertation

Examples:

KARRAY, M.R., (1977), *L'extrémité nord-est de la Dorsale tunisienne : recherches géomorphologiques*, Thèse de doctorat, Université de Tunis, 166 p.

IOANA-TOROIMAC, G., (2009), *La dynamique hydrogeomorphologique de la rivière Prahova (Roumanie): fonctionnement actuel, evolution recente et consequences geographiques*, PhD thesis, Université Lille 1, 341 p.

In case of journals, only standard abbreviations should be used. If this is not certain, please provide full name of the journal.

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Use Times New Roman, 11, Bold for the Institution name and address, Bold italic for the Department, right alignment.

Example:

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