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The Romanian School of Geomorphology

Mihai IELENICZ

Abstract: The Romanian school of geomorphology developed within geography by the end of the 19th century with the first studies influenced by the west European schools. There are stages of theoretical and practical directions of research and world renowned scientists (and their followers):

- *The first stage* (until 1925) - with a combination of papers made both by geographers (the first geomorphologic PhD theses) and Romanian and foreign geologists; the studies were based on the evolutionary interpretations of west European and American concepts; relevant figures were Simion Mehedinți and Emmanuel de Martonne.

- *The shaping stage of the geomorphologic school* (1925-1960) had the following characteristics - deepening and widening of doctrines, imposing university centers (Bucharest, Iasi, Cluj, Chernovtsy) as centers of research and promotion of ideas regarding landforms, numerous PhD theses, dominant geomorphologic leaders of exceptional geographical culture, sizable regional research of different Romanian and foreign geomorphologists (G.Vâlsan, C. Brătescu, M. David, V. Mihăilescu, V. Tufescu).

- *The completion stage of geomorphologic school* (1960 - end of the 20th century) – development of geomorphologic university education, outstanding research contributions in all branches of the geomorphologic system, training within doctoral programs, volumes of papers and participations in numerous national and international conferences (leaders: T.Morariu, Gr.Posea, C.Martiniuc).

- *The current stage* (after 1990) is characterized by: the significant increase in number of geomorphologists involved in various national or international research institutions and programs, doctrinal diversification, differentiation of leaders and followers on domains and sub-domains (periglacial, glacial, karst, landslides, coastal morphology, river morphodynamics, etc.).

Keywords: geomorphology, geomorphologic school, geomorphologic leaders, doctrine.

1. Introduction

The scientific school is a system resulted gradually in a certain area where there is a certain community of practitioners of the laws, principles and methods of a specific domain, that leads to the overall development of theory and research, training and experience of a growing number of followers and informative database.

Within a certain school, there were high spiritual and talented leaders that traced theoretical and practical persuasion directions to provide scientific development, research and volume (treasure) information, which define their evolutionary state (level) at some point, in the previous steps, including perspective, preparing their disciples and collaborating with similar schools. Secondly, they seek competent followers and many forms of expressing, transmitting and assimilating doctrinal and methodological elements.

2. The Romanian school of geomorphology developed within Geography

The Academician Simon Mehedinți started and built a modern geographical school in Romania, a process completed and amplified according to the socio-historical settings by a pleiad of geographers - his disciples. Over the years, on various special occasions, or in synthesis volumes (geographical monographs, Geography of Romania), the most significant moments in the evolution of geography school and the roles of different personalities in its assertion were highlighted.

Development was not unitary within the entire system of geographic components. Consequently, there were some directions of a greater extension of thought, research and collaboration with schools abroad, but also between individual scientific cores, especially between the academic centers in Romania. The result was reflected in the tendency to shape personalized groups as school types on certain fields

(components), although in some cases not entered in essence. Naturally, the appellative Romanian geographical science may be applied only for a few areas (Geomorphology, Anthropogeography, Geopolitics, etc.), and only partially in the other directions.

There are different development stages and moments, but with common characteristics as: *a hesitant start* by outlining the main directions influenced by foreign ideas, concepts or other scientific fields (geology, meteorology, sociology, etc.); *a system shaped gradually*; *the current evolution of the system* based on high technique, global view and local trends.

There are relevant situations for the Romanian school of geomorphology.

2.1. The first (debut) stage coincides with the end of the 19th century and the first two decades of the 20th century. There were several disparate studies with a regional character (dominant in some Carpathian units, Dobruja and the Romanian Plain) or methodology belonging to foreign or Romanian geographers and geologists. The concepts were based on the German, French and American ideas on the genesis and evolution of landforms.

There were some relevant studies as Emm. de Martonne's early works on the Meridional Carpathians and southern Romania (glacial landforms, landforms as support of landscapes), then the major contributions of the Romanian geologists: Gr. Cobălcescu (first differences and geographical names of the morphostructural units, the use of terms 'terrace', 'floodplain', etc.); Gh. Munteanu-Murgoci and L. Mrazec (leaders of the Romanian Society of Geography) studied the tectonics and development of the Meridional Carpathians, Subcarpathians, Dobruja and developed genetic ideas on the controversial areas in the Carpathians, Romanian Plain, etc. There were three PhD theses made by S. Mehedinți ('Über die Kartographische Induction' – presented in Germany, Leipzig, 1899 – example of geographic analysis based also on map study), Emm. de Martonne ('La Valachie', Paris, 1902) and V. Meruțiu V. ('The Rodna Mountains', a geographical study based geology). These are examples of complex geographic analyses with special regard on landforms.

Those were two decades of landform studies and regional syntheses, based on field analyses and evolutionary interpretations according to the concepts in vogue in west Europe and the U.S.A.

- There were some significant moments **between 1905 and 1925**, with consequences in

landform knowledge: first, geography became a distinct field in higher education institutions (Bucharest, Iași); then the Society of Geography directed its main activities toward Romanian landform research, applying the doctrinal ideas of the American, French and German schools; the middle school teachers were thought to understand the realities of local and regional horizon from simple to complex; the first atlases and maps representing landforms were published.

Professor Simion Mehedinți had a distinct role in the organization, thematic presentations, especially in guiding students to research topics and PhD theses mainly on landforms, anthropogeography and ethnography. The immediate consequences were some articles published in the Bulletin of the Society of Geography, conferences and scholarships in France, Germany, scientific relations with renowned personalities (W.M. Davis, Emm. de Martonne, A. Penck, F. Richthofen, etc.).

The results of these first decades of research were *the first PhD theses of genetic-evolutional geomorphology on distinct geographical units in Romania* ('Untere Die Donau und Braila zwischen Turnu Severin', Berlin, 1910, by Al. Dumitrescu Aldem; 'The Romanian Plain', Bucharest, 1915, by G. Vâlsan; 'Geological Research in the Moldavian Plateau', Iași, 1919 by M. David; 'The Danube Delta' – genesis and morphological evolution, Bucharest, 1922 by C. Brătescu). Add the second PhD thesis of Emm. de Martonne – 'The Transylvanian Alps' (1907, Paris), and 'The Danube Delta' (1914) by the naturalist Gr. Antipa, and numerous geomorphology papers, rich in ideas, written especially by geographers.

All these must be considered as factors that have led to the creation of specific guidelines for the modern geomorphology in our country, based on deep research and innovative ideas related to the doctrine of great personalities in Germany (A. Penck, F. von Richtohfen), the USA (W.M. Davis), France (Emm. de Martonne) that the Romanian geographers have met at international scientific meetings or during certain stages of training (scholarships).

2.2. The achievement of Geomorphology School was a process that lasted over four decades resulting in:

- *deepening the doctrines* previously used with ideas from the Russian geographical (naturalistic) school, and the *correlations with the results from complex analyses of all environmental factors in diverse regional areas* (landforms are considered

the support and essential component in the genesis and evolution of natural and human systems); the overall realistic combination of these two directions would provide the theoretical background of the Romanian School of Geomorphology resulting in research and publications in various scientific forums;

- *individualizing four landform core research and idea promotion centers* within the universities of Bucharest, Iași, Cluj, Chernovtsy. They were created and promoted by some distinct geographic personalities (S. Mehedinți, G. Vâlsan, M. David, C.Brătescu). The Institute of Geography (founded in 1945) was founded by a group of geographers headed by V. Mihăilescu and belongs to the Romanian Academy. These were the first generation of undisputed geomorphologic Romanian leaders, who made distinct studies, and also research directions (regional geomorphology, geomorphologic components or geographical systems, etc.);

- *significant results of some geomorphologic PhD theses* (V. Mihăilescu – 1924, L. Someșan – 1934, T. Morariu – 1935, V. Tufescu – 1936, N. Al. Rădulescu – 1937, N.M. Popp – 1939, P. Cotet – 1957, etc.), numerous studies published in academic journals including regional Geographic Institutes (Cluj), Romanian Royal Geographic Society Bulletin, volumes of the International Congresses of Geography, etc.;

- *a new generation of leaders with perfect geographical culture and outstanding contributions in the development of geomorphology* through distinct achievements in several directions – university courses (theory, practice – regional) of morphology, very important in teaching geography students; PhD theses and regional syntheses; the activities organized and run by the Romanian Royal Society of Geography resulted in pre-university teachers' better knowledge of landforms; participation in international scientific meetings, documented mainly through scholarships abroad. There were two categories – *leaders strictly related to geomorphologic issues* (N. Popp, P. Cotet) and *leaders with interests in regional geography issues that emphasized the systemic landform analysis* and made correlations especially between morphographical, morphogenesis, current dynamics of slope processes and all environmental components that lead to different consequences in landscape evolution (V. Mihăilescu, V. Tufescu, N. Al. Rădulescu);

- *numerous geomorphologic studies*: the analysis of erosion surfaces in mountainous, hilly and plateau regions (starting from Davis's ideas and

paleogeographic interpretations of geological data), valley formation and evolution (based on morphologic elements – terraces, orohydrographic structure, paleogeographic interpretations to state the genesis of canyons by capture or antecedence, etc.), the Danube Delta (measurements, analysis of orographic maps, correlations with the ideas of foreign researchers on seaside morphology), correlating landforms with human settlements' development (landforms as support and development factor), a theoretical approach of slope morphodynamics (especially landslides, rock falls, mud flows, etc.), piedmonts, terraces, and the study of petrographic and structural landforms in plateau regions (especially in Moldavia), etc.;

- *geomorphologic research of some foreign geographers* (Emm. de Martonne, R. Fischeux, A. Nordon, H. Slaner, M. Pfannenstiel etc.); they published regional studies of geomorphology (emphasizing the evolution of a geographic unit) and collaborated actively with the Romanian geographers (especially Emm. de Martonne, who coordinated PhD theses with Romanian topics) etc.;

- *distinct presences of some Romanian geomorphologists in international meetings* (G. Vâlsan held positions in some boards) or scholars at various universities in France, Germany (D. Burileanu, V. Tufescu, N. Orghidan etc.);

- *diversification of geomorphologic illustration* (by photographs, maps, panoramic sketches, profiles) that is required by a high content of elements supporting analyzes, clarity and accuracy.

*All of these contributed to the development of a **Geomorphologic School within the geographic system**, characterized by a genetic and evolutionary approach of large regional units and in accordance with the theoretical and methodological influences of west Europe (France, Germany).* There were also some regional nuances as the analysis of structural landforms (Moldavia) and the differential influence of landforms on human activities and landscapes (with different shares, depending on the university center) etc.

There were two significant periods *between 1940 and 1960*, when the social and historical conditions produced some changes in the evolution of scientific schools (not only in our country). The World War II, in which Romania participated directly, resulted in a decrease (even stagnation) of the directions developed before. Then, after 1950, structural changes occurred in education and research (dissolution and creation of new scientific forums, changes in publication content), all under the active influence of Soviet geographic school, and also pressures and banishments of some

valuable geographers. Some actions supported and developed Geography, and especially Geomorphology after 1960. This process must be linked to the quite difficult organizational and scientific contribution of the interwar leaders and a significant number of students keen to study environmental conditions. Many of them have become researchers and subsequently formed a new generation of leaders. The Institute of Geography (set up in 1944), the Society of Geography and Natural Sciences (set up in 1948) and the departments of geography within the faculties of sciences supported geomorphology, geomorphologic research and publications, publishing theoretical and regional geomorphologic papers in geographic magazines, making large geographical monographs (1957-1960) with Romanian-Soviet coordination, geomorphologic PhD theses, teaching physical geography in several Soviet universities.

2.3. The completion stage of geomorphologic school, developing directions of landform approach and interpretation. This is a new stage of the second part of the 20th century (especially after 1960), with the following characteristics:

- *developing geomorphologic university education* in Bucharest, Cluj, Iași with geomorphology groups (specializations) during certain periods; making collectives of geomorphologists and geographers and sections specialized in landform research at the Institute of Geography of the Romanian Academy (Bucharest, Iași and Cluj affiliates) and the Society of Geography. These would result in achieving several significant features of the Romanian school of geomorphology – *the conceptual unit* (inherited genetically and reconstructed through immediate and future applicability); *studies based on research* (detailed mapping, punctual analyses correlated with the regional situations, realistic interpretation of statistical data or results from the surveys on current dynamic processes and their consequences, etc.); *mapping using a system of symbols and methods widely and worldwide accepted*; *outstanding contributions to the geomorphologic information fund through regional syntheses or theoretical studies*;

- *a new generation of geomorphology leaders emerged* by scientific results, organisation skills, training abilities for a large number of students, PhD students, researchers etc., including the university professors: T. Morariu in Cluj (who coordinated over 50 PhD theses in geography, mostly geomorphology, ran the geographical movement in Romania for several decades,

organised numerous national and international conferences out of which two of geomorphology, created a pleiad of renowned geomorphologists, was member of leading international forums of UIG, etc.), Gr. Posea in Bucharest (a special contribution through geographical works mostly covering all theoretical and practical geomorphology, was the chairman of the Society of Geography in which he organized a section of geomorphology and numerous conferences, brought together many geomorphologists in the department of geomorphology he led at the university, directed over 40 doctors in geomorphology, was the first president of the Association of Geomorphologists in Romania - affiliated to the international one, etc.), C. Martiniuc in Iași (developed geomorphology through studies based on detailed research, organised the geomorphology scientific activity of geographers in that faculty and some institutes of Moldavia, contributed to doctrinal unity and practical training in the field). In addition, there was a large group of geomorphologists at the Institute of Geography, with branches in Bucharest, Iași, Cluj Napoca, and groups made in the last three decades within the faculties of geography from other universities (Oradea, Timișoara, Suceava, Craiova, etc.) led by geomorphologists trained in the secular universities.

- *the geomorphologists were involved in research programs in schools, training camps, research stations, debate societies, scientific sessions organised by different institutions*: the Society of Geography with its section of geomorphology, etc. There have been 21 conferences of geomorphology in Romania by now, and most results were published in special volumes, among which the Journal of the Association or the Journal of Geomorphology (after 1990) at the University of Bucharest;

- *doctoral training programs* (over 1100 doctor degrees, out of which over 400 doctor degrees in geomorphology) and the possibility to publish the research results in geographic or geomorphologic journals or independent publications; they have regional character (all geographic regions were studied) and diverse topics;

- *the research issues aimed all sides of the geomorphologic system*, but some works were appreciated even internationally – the genetic and evolutionary geomorphology (the study of morphogenetic steps correlated with morphochronologic systems), the structural geomorphology, the seaside, glacial, periglacial, karst, slope and river bed geomorphology, geomorphologic mapping at different scales

(especially in Bucharest and Iași centers), the inter-connection between landforms and human society studied dynamically, through its consequences (from hazard to risk), and complex programs meant to ensure a better organisation and valuation of environment, taking into account the favourable or restrictive elements of landforms;

- *the results were published in many scientific publications*, as Romanian and foreign geographic and geomorphologic journals (27), national or international conferences of geomorphology (14), many PhD theses of geomorphology (most of them published), syntheses (papers, books). These works approached representative issues (glaciation, landslides, piedmonts, erosion surfaces, terraces, etc.) of national or regional level ('The Romanian Landforms', 'The Carpathians', 'The Subcarpathians', 'Dobruja', 'The Moldavian Plateau', 'The Romanian Plains', 'The Cross Valleys in Romania', etc.), theoretical approaches with suggestive exemplifications ('The Natural and Accelerated Erosion', 'The Karst Landforms', 'The Quaternary', university courses of geomorphology, landslides, etc.), and diverse and expressive landform mapping (especially atlases published at the Romanian Academy) etc.;

- *participations in numerous national and international conferences* of geography and geomorphology, yearly organisation of some national or international conference on actual topics, membership of many Romanian geomorphologists in different structure of scientific organisation at U.I.G., A.I.G., E.G.E.E.A., Carpat-Balkanica, Society of Geography, as well as reviewers for journals of the field.

The following institutions have important roles in the organization and coordination of geographical and geomorphological activities in Romania: the National Geographic Committee, the Institute of Geography, the departments of geography of some faculties, the Association of Geomorphologists in Romania (founded in 1990, having annual sessions and its own journals), the Society of Geography (1875, annual conferences). All of these are responsible for organizing scientific regional and interstate scientific meetings (significant for geomorphology – the Italiano-Romanian-Belgian-French-Grece, Romanian-Turkish, Carpatho-Balkan colloquia, etc.).

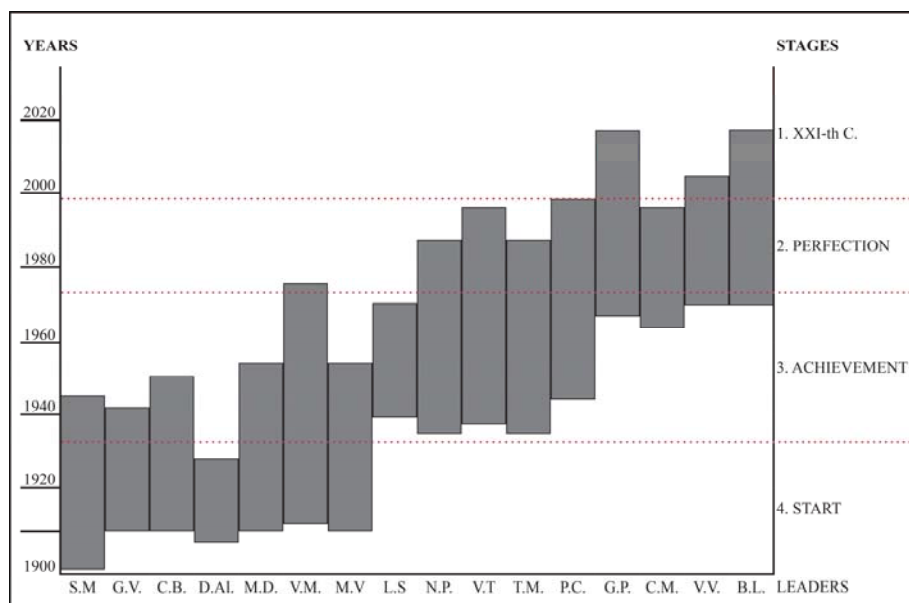
2.4. The current stage represents the latest two decades with looming significant changes, among which:

- *an increased growth in numbers of geomorphology geographers*, involved - in various research institutions – in solving complex problems in variable-sized regional areas where extremely active morphodynamic processes (especially overflows, floods, landslides, torrents) had caused disasters and significant changes not only in the landscape, but also in the local economical organization which required quick solutions based on mappings and top technology recordings;

- *including geomorphologists in major national and European programs* concerning environmental conditions, evolution and protection, ensuring sustainable development, rational exploitation of all resources, which sought continuous perfection through university masters, doctorates, scholarships etc., based on knowledge and application of techniques and methodologies added to the classic ways that are always updated but not negligible;

- *there is no consistent doctrine* whereas to concepts transmitted and passed by Romanian thinking for over a century (that came from the west schools, and in recent years from the soviet school) were added rapidly through multiple contracts (through scholarships, scientific meetings of different rankings, at national and international levels) with centers and scientific personalities from EU, U.S. and Canada, etc., many theoretical and practical ideas based on a methodology that facilitates in-depth analyses, rapid and expressive calculations, graphic and cartographic representations, and finally, ease in evolutionary forecasting; more terrain areas and experimental stations are organized, also analysis laboratories. Inevitably, more stringent needs of organization, preservation and protection of the environment will lead to a *twining of these concepts into an unitary doctrine that combines genetic-evolutional knowledge with practical needs* (immediate and in the future), and *mathematical analysis background*;

- *it is the stage when geomorphology leaders and adepts from various areas of expertise* (glaciology, periglaciology, karst science, landslides, coastal morphology, riverbed morphodynamics) *begin to differentiate, and less throughout all the branches of science, or large morpho-climatic or morpho-structural regions*. There is an informational background so complex and varied so that its synthesis today cannot be done except for lower levels, following that in future decades geomorphology will be able to point out higher-level generalizations, highlighting laws, and maybe universal conceptual systems.



Reports to the table:

I. Founders and leaders:

- SM (Simion Mehedinți, 1869-1962), GV (George Vâlsan, 1885-1935), CB (Constantin Brătescu, 1882-1945), DAL (Demetrescu Alden, 1880-1917), MD (Mihai David, 1886-1954), VM (Vintilă Mihăilescu, 1880-1978), MV (Martiniuc Vasile, 1881-1943), LS (Laurian Someșan, 1901-1986), NP (Nicolae Popp, 1908-1989), VT (Victor Tufescu, 1908-2000), TM (Tiberiu Morariu, 1905-1982), PC (Petre Coteș, 1914-1988), GP (Grigore Posea, 1928), CM (Constantin Martiniuc, 1915-1990), VV (Valeria Velcea, 1929 - 2008), BL (Badea Lucian, 1929).

II. Romanian geographers from different universities (B – Bucharest, C – Cluj Napoca, Is – Iași) who had different contributions at different stages in the development of geomorphology (1, 2, 3, 4 in the table):

- V. Băcăuanu (Is,3); N. Basarabeanu (B,3); I. Berindei (C,3); I. Bojoi (Is,3); D. Burilanu (B,2); T. Constantinescu (B,3); H. Grumăzescu (B,3); M. Iancu (B,3); Silvia Iancu (B,3); I. Ilie (B,3); I. Ichim (Is, 3); Gh. Lupașcu (Is,3); Lupu Silvia (B,3); Șt. Manciu (C,2); T. Naum (B,3); Gh. Niculescu (B,3); N. Orghidan (B,2); Dida Popescu (B,3); N. Popescu (B,3); Gh. Pop (C,3); N. Al. Rădulescu (B,2-3); I. Rădulescu (B,3); Al. Roșu (B, 3); Th. Rusu (C,3); Al. Săndulache (C,3); I. Sărcu (Is,3); Al. Savu (Cj,3); V. Sencu (B,3); V. Sficlea (Is,3); V. Trușăș (B,3); P. Tudoran (C,3); M. Vârlan (Is,3); I. Vintilescu (B,3).

III. Romanian geologists who have contributed to the development of Romanian geomorphology

- Gr.Cobălcescu (1); G. Munteanu Murgoci (1,2); L. Mrazec (1,2); I. Simionescu (1,2); S. Atanasiu (1); I. Atanasiu (2); V. Mutihac (3); B. Ionesi (3); M. Săndulescu (4); I. Liteanu (3); C. Ghenea (3); N. Mihăilă (3); V. Bandrabur (3); M. Bleahu (3); D. Paraschiv (3).

IV. Foreign geographers who surveyed geomorphological studies on geographic units in Romania:

- Emm. de Martonne (1,2); R. Ficheux (2,3); A.Nordon (2); L. Sawicki (1); J. Cvijic (1) etc.

V. Romanian geographers with special results in geomorphology, some with status of leaders in the making:

– Bucharest:

- University of Bucharest – M. Grigore, N. Popescu, M. Ielenicz, I. Marin, E. Vespremeanu, Florina Grecu, Gh. Vișan, O. Mândruț, Iuliana Armaș, I. Povară, C. Goran, A. Nedelea, Laura Comănescu, M. Ene, B. Mihai, Laura Tîrlă, A. Vespremeanu Stroe, Smaranda Simoni (Toma), Anca Munteanu etc.
- Institute of Geography – D. Bălțeanu, Gh. Niculescu, V. Sencu, Maria Sandu, E. Nedelcu, A. Cioacă, Mihaela Dinu, A. Cioacă.

- **Cluj Napoca:**
 - *University and Institute – V. Gârbacea, I. Mac, I. Tovissi, I. O. Berindei, A. Savu, P. Tudoran P. Cocean, V. Surdeanu, V. Schreiber, D. Petrea, I. Irimuş, W. Schreiber, , V. Buz, N. Hodor*
- **Iaşi:**
 - *University – I. Donisă, Irina Ungureanu, I. Hârjoabă, N. Barbu, I. Ioniţă, C. Rusu, E. Rusu, I. Stănescu, Lesenciuc, M. Mândrescu.*
- **Other centers – Timişoara:** *P. Urdea;*
Oradea: *N. Josan, Gh. Măhăra, F. Bente;*
Craiova: *S. Boengiu, E. Marinescu, C. Savin;*
Suceava: *C. Brânduş, Maria Rădoane, V. Chiriţă, N. Rădoane etc.*

3. Conclusions

- during a century of intense scientific and practical concerns, and multiple forms of international collaboration, a full and valuable school of geomorphology was established in Romania, with results connected with the entire system of landform analysis.

- the Romanian School of Geomorphology – like many other institutions in west or central Europe – was created through a continuous process within Geography, but preserving and strengthening its relationship with Geology and other sciences from which it took its ideas, methods, techniques, etc. required in analysis and research support, data processing and forecasts.

- it consists mostly of geographers with a valuable interdisciplinary training, based on contemporary realistic concepts, applied in research taking into account the specific landforms of our country. This was always considered a dynamic, complex system, connected with all environmental factors.

- geomorphologic school's onset is followed by two stages in which its definition was enriched with development and deepening, while some great geomorphologists became renowned leaders nationally and internationally for their merits taken in organization and development of this scientific quorum (from small geomorphologic cores to an unified national assembly with a large number of doctors in geomorphology; a considerable volume of materials published in prestigious journals; transition from local geomorphic debate circles to an active Geomorphology Section in the GSS and, since 1990 the National Geomorphology Association became an active member of the International Association of Geomorphology; maintaining contact of Romanian geomorphologists with those in Europe, USA etc.; national and international scientific meetings).

- a new stage have begun after 2000, characterized by doctrinal wholeness (entwining genetic-evolutional concepts and practices with a background of mathematical analysis and use of high-technologies and experiment in research), affirming leaders towards distinct geomorphologic directions, widening international contacts with specialists from EU and U.S. (scholarships, experience exchanges, various scientific meetings, etc.).

Tafoni formation at Theologos (Fthiotida, Greece)

Z. MODIANAKI^a, N. EVELPIDOU^{a*}, L. STAMATOPOULOS^b, M. STAMATAKIS^a

Abstract. The aim of this paper is to provide further information of the tafoni development. At Theologos area, Fthiotis Prefecture, north Euboean Gulf, a carbonate formation hosts a variety of well developed tafoni. 165 tafoni were, randomly, selected by means of a detailed geomorphological investigation. The presence or absence of lichen cover, rock flaking, and cavern floor debris, amalgamation, salt flakes, different kind of structures, biological communities, were noted, while measurements regarding their dimension took place. Surface hardness values, obtained using a Schmidt hammer.

Although, there is no evidence of the key factor that drives the growth of tafoni, salt weathering and low strength seems determinant of their formation. Moreover, much of the evidences suggest that joints are actively influencing the origin and the morphology of tafoni. It is possible that tafoni formation is initiated at weak zones. The studied tafoni are actively developing and are not relict features inherited from a past environment. It seems that their evolutionary stage is II towards to III. The results of chemical and mineralogical analysis indicate that during the cavernous weathering, silica, sulphates, alumina and iron oxides have replaced carbonate grains. Also, at the non-weathered part of the rock, the main mineralogical phases are calcite and dolomite.

Keywords: Tafoni, flanking, cavernous weathering, carbonate weathering

Introduction

Tafoni are ellipsoidal, semi-cycle, natural rock openings both present in much different kind of rocks such as igneous and sedimentary rocks. Tafoni typically are developed by natural processes and they are divided into small openings, medium and larger cavern size. Tafoni are frequently characterized from complex cells like nests (Blackwelder, 1929; Smith, 1982; Pestrong, 1988; Hejl, 2005; Boxerman, 2006).

These cavernous weathering formations with various sizes and geometries are developed by different physical, chemical, biological and lithological conditions (Martini, 1978).

Tafoni are worldwide spread and common to coastal areas (Mellor et al., 1997), to moist areas (Goudie, 2003), to hot desert areas (Smith, 1978) and to cold desert areas (Calkin & Cailleux, 1962; Wellman & Wilson, 1965; Prebble, 1967; Matsouka, 1995; French & Guglielmin, 2000; Andre & Hall, 2004). Tafoni are rapidly developed in coastal environments, while in desert areas the procedure is slower. Tafoni are the 10% of coastal

retreat reasons (Gill et al., 1981). Tafoni cause lots of damages to monuments, ports, coastal environments or damages to port protective constructions.

The study area, Theologos coastal zone, is located at the eastern part of Lokrida province, at the wider southeast part of Fthiotida Prefecture. Northeast side bordering North Euboean Gulf and South Atalanti Gulf is located (Fig. 1). The study area is far from human activities and some tafoni particularly those on the upper slopes of the study area, were inaccessible owing to slope steepness.

Theologos climate is classified into the mild areas of Greece with cool summers and mild winters. The mean annual temperature is 16.6°C and the mean annual rainfall height is 47.6 mm. Northwest wind is the dominant one affecting vitally the coast morphology during winter's months and east wind during summer (National Meteorological Service – Lamia Meteorological station). The main lithological formation of the studied area is comprised of Jurassic limestones (Maratos, 1965; Almpantakis, 1978).

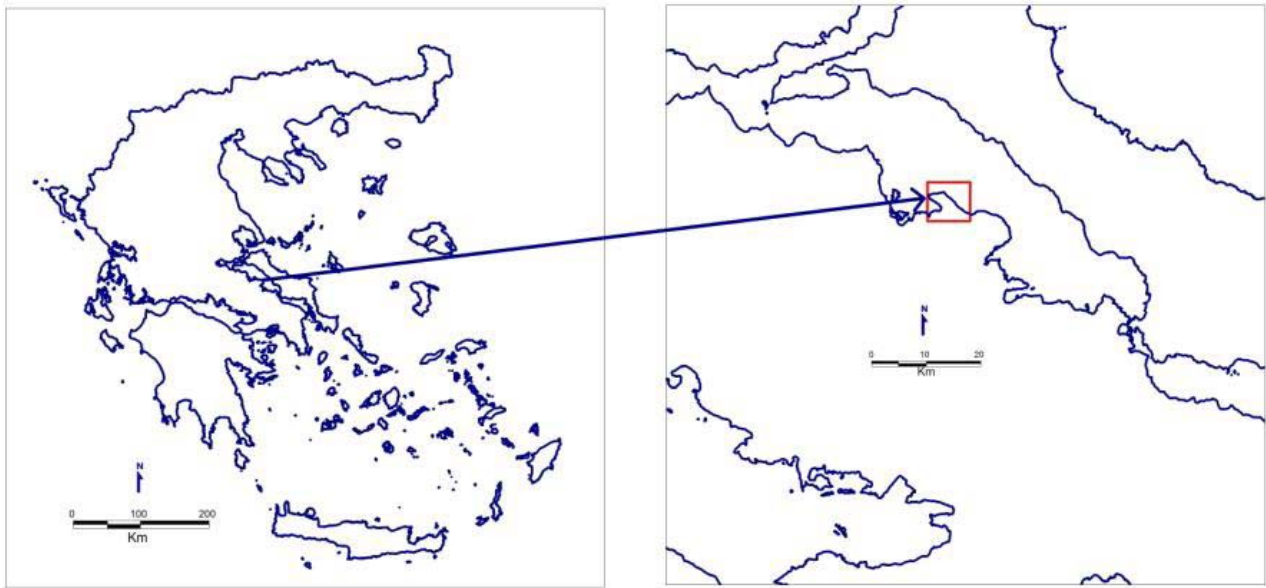


Figure 1. Location map of the studied area

Material and Methods

Fieldwork carried out during August and October 2011, included measurements in 165 tafoni (Table 1). Primary and secondly tafoni, were selected randomly. In order to gain some insight into local geological, topographic and hydrological controls on their formation, the area surrounding each measured tafoni was examined in terms of lithology, jointing, amalgamation and porosity (Table 2).

Each of the 165 tafoni was examined to provide details of its morphological characteristics. The morphological characteristics determined were (A)

Width, of the opening parallel to the base, (B) Depth, which is the distance from the opening to the backwards of tafoni and (C) Height of the cavern floor and the direction of their opening (Fig. 2, Table 1).

For each measured tafone the exact location was recorded by GPS, as well as the occurrences of discontinuities cross or parallel to tafoni opening, visible salt efflorescence or concretions along the fractures internal or external tafoni, the existence of debris or epilithis lichens. Additionally, any visual disaggregation marks like flakes were recorded (Table 3).

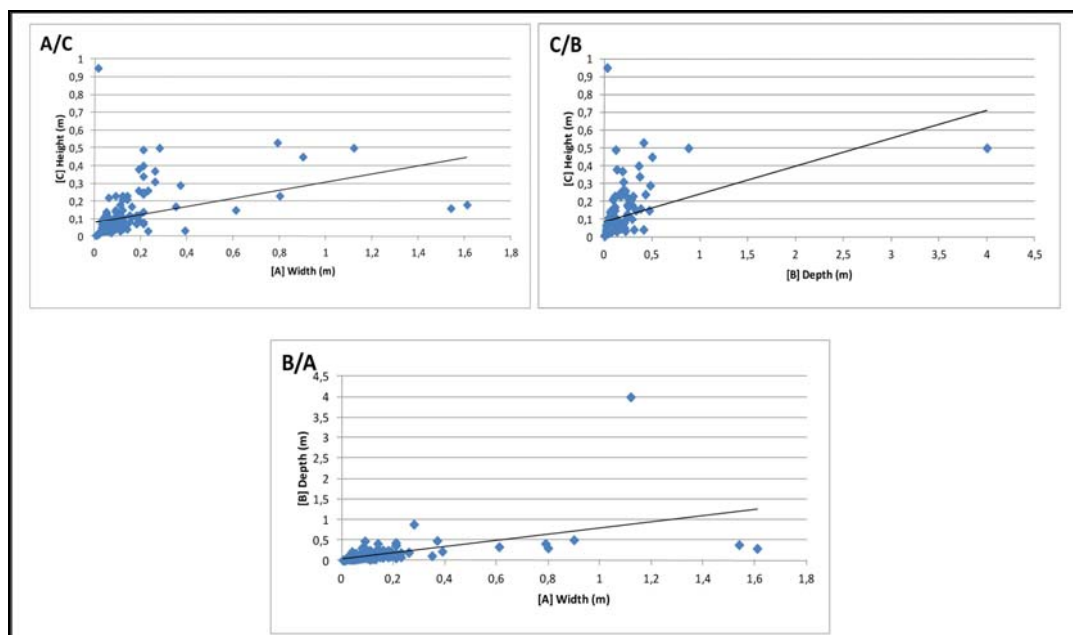


Figure 2. Cross plots of tafoni measurements: (a) width versus height, (b) depth versus height, (c) width versus depth

The surface hardness of each tafone was determined by a Schmidt hammer (low energy), a technique used in previous studies of cavernous weathering (Campbell, 1991). The measurements are taken from the smoothest surfaces of cavern visor, back wall, floor, ceiling, and outer roof, and also to non-weathered rock around the tafone (Table 4). In some cases, no values are taken due to technical problems. Firstly, the small size of the majority of studied tafoni is the main reason of the omitted values, as it prevented from the percussion. Moreover, some tafoni were standing without back or floor. Slick tools were used when it was needed to normalize some rock surfaces.

The majority of the measurements are coming from back wall and floor of tafoni and almost in every case there are measurements of the non-weathered rock. Two rebound values (R-values) were obtained from the same point at each site in order to ensure the accuracy of the measurements.

Four samples were collected from three tafoni (T2, T9, T110). Tafone 2 sample was picked from the back wall, while tafone 9 from the floor. From tafone 110 two samples were taken, one from the roof and one from the floor. Five thin sections were prepared and analyzed by the scanning electron microscope (SEM-ADS) JEOL JSM-5600 LINK ISIS combined with microanalyzer energy dispersive system OXFORD LINK ISIS 300, with software ZAF correction quantitative analysis at laboratories of the same university. The system was operating at 20 KV, 0.5 nA and 50 sec time of analysis. Both fresh and weathered surfaces were examined.

Results

Table 1 presents the morphological characteristics of the studied tafoni, the GPS location for each of them and also the samples origin. The dimensions of majority of the studied tafoni are smaller than 0.1 m. In fact, out of the 165 tafoni only 7 (T2: 0.9 m, T3: 0.8 m, T4: 1.54 m, T5: 1.61 m, T9: 1.12 m, T19: 0.79 m and T26: 0.61 m) have width ranging from 0.6 m up to 1.61 m (Fig. 3). The width of the 68.48% of the studied tafoni is smaller than 10 cm, while the dimensions of the smallest tafoni (T75) is 0.005 m. The depth of the 66.66% of the studied tafoni is smaller than 10 cm, while only two of them present extreme values i.e. T9 with depth of 4 m and T20 with a depth of 0.88 m (Fig. 4). Two tafoni presents high values in height; T19 with 0.53 m and T21 with 0.95 m, while 72.72% from the measured tafoni have height less than 10 cm (Fig. 5). The shape of most of the tafoni is characterized by the

width being larger than depth (51.51% of the measurements), while in 56.36% of the measurements width is larger than height (Table 1). Also, the strongest correlation among the indicators is width versus depth.

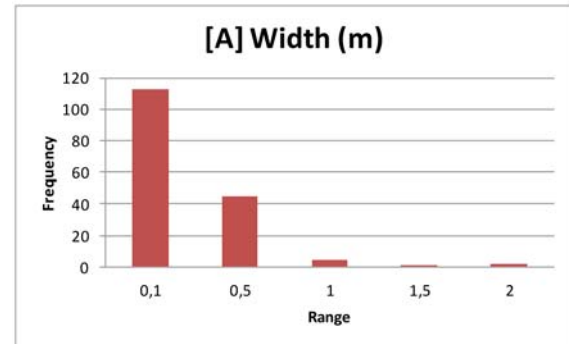


Figure 3. Histogram of width [A] dimension of the studied tafoni

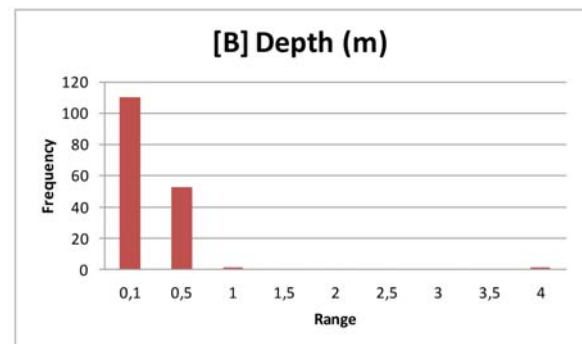


Figure 4. Histogram of depth [B] dimension of the studied tafoni

The mean height of the measured caverns is 0.1 m (Table 1), while the mean width and the mean depth are 0.13 m wide and 0.14 m deep. The largest cavern is 0.5 m high, 1.12 m wide, 4 m deep (T9) and the smallest with an accurate correlation among the indicators precisely at 0.005 m (T75).

Secondary caverns are recorded inside primaries separated by compartments and remnants of walls (Fig. 6). The 3.63% of the investigated tafoni present cavern visor with flaking playing the most important role in active rock weathering since it is occurring in 45.45% of the studied tafoni. Finally, the 22.42% of the studied tafoni presents debris inside the cavern (Fig. 7).

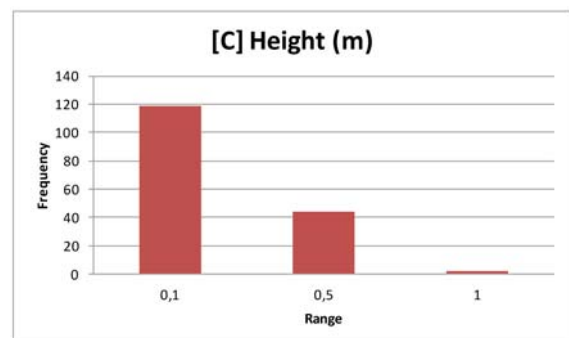


Figure 5. Histogram of height [C] dimension of the studied tafoni



Figure 6. Two separated tafoni are joined in the backwall because of vertical wall destruction



Figure 7. Cavern floor debris

Table 4 presents the results from the tafoni percussions to the interior or the exterior as well as to the non-weathered tafoni surface. Based on these measurements, the difference between non-weathered rock surface and tafoni surface is less than 5 MPa. Measurements from non-weathered carbonates are ranging 10-20%, while only the 23.02% of measurements are lower than 20%. Rock hardness measurements indicate that R – values on the cavern visor and backwall are higher than those taken from the floor. In fact, 25% of measurements taken from the cavern visor are lower than 20%, while from the floor this percentage is getting lower (13.33%). The 75% of the measurements taken from the ceiling and the outer surface of the tafoni are ranging from 10 to 20%.

Lichens cover the outer surface only of 4 tafoni (T21, T128, T149, T159).

The 5 thin sections examined by the SEM-EDS system, showed that the majority of fresh rock surfaces are composed by calcite and dolomite. The weathered surfaces often contain silica, sulphates, alumina and iron-oxides and phosphates in minor

amounts low rates (Fig. 8-10). The origin of these impurities is much likely originated from the erosion of the surrounding rocks and also the sea water [sulphates]. As it is revealed by the SEM images and analysis of each component, these phases have replaced calcite and dolomite crystals, grain by grain [pseudomorphosis].



Figure 8. SEM microphotograph of tafoni's 2 thin section [fresh side] (50% CaO, 0.45% MgO, 0.08% FeO)

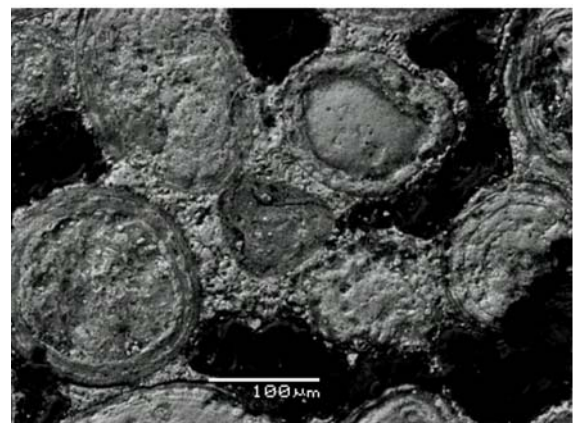


Figure 9. SEM microphotograph of tafoni's 2 thin section [weathered side] (39.45% CaO, 1.67% MgO, 3.18% SiO₂, 0.68% Al₂O₃, 0.66% SO₄)

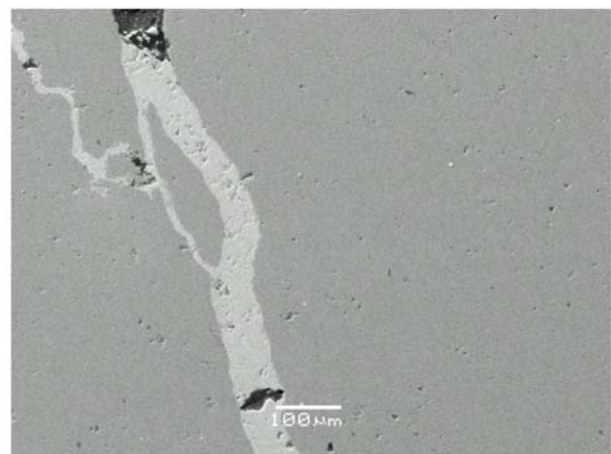


Figure 10. SEM microphotograph of tafoni's 2 thin section [fresh side] (29.12% CaO, 19.57% MgO)

Discussion-Conclusions

Theologos tafoni are both primary and embedded, developed because of joints. Salt weathering has played a significant role; silica, sulphates and alumina have replaced calcite and dolomite. The floor of many studied caverns was covered by debris indicating the active evolutionary stage. The fresh rock is almost exclusively composed of dolomite and calcite.

The morphology of tafoni evidences that the evolutionary stage according to Boxerman (2006) is II because most of the tafoni grow more in depth direction than parallel to the opening. In some locations, though, we believe that the evolutionary stage is II to III especially to the west side of the coast, because of the collapse of intermediate walls and further cavern enlargement.

Schmidt hammer measurements present a harder cavern visor and backwall instead of floor, ceiling or outer surface. Cavern visor results are

consistent to coastal tafoni generally, but backwall results come in conflict to previous studies (Mottershead and Pye, 1994).

Substantially, tafoni development and enlargement is not only a salt weathering phenomenon but it is also relating with weak surfaces, joints and fractures.

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REFERENCES

- ALMPANTAKIS, I.G.M.S. 1970. Geological map of Greece, sheet Larymna 1:50.000.
- ANDRE, M.-F., HALL, K., 2004. Honeycomb development on Alexander Island, glacial history of George VI Sound and palaeoclimatic implications (Two Step Cliffs/Mars Oasis, W. Antarctica): *Geomorphology*, v. 65, p. 117-138. BC: *Geomorphology*, v. 64, p. 87-95.
- BLACKWELDER, E., 1929. Cavernous Rock Surfaces of the Desert: *American Journal of Science*, v. 17, p. 393-99.
- BOXERMAN J., 2006. The Evolution of Tafoni on Coastal Sandstones in Northern California, Unpublished Master's Thesis, Department of Geoscience, San Francisco State University, May, 2006.
- CALKIN, P., CAILLEUX, A., 1962. A Quantitative Study of Cavernous Weathering (Taffonis) and its Application to Glacial Chronology in Victoria Valley, Antarctica: *Zeitschrift fuer Geomorphologie*, v. 6, p. 317-324.
- CAMPBELL, I.A., 1991. Classification of rock weathering at Writing-On-Stone Provincial Park Alberta, Canada: a study in applied geomorphology, *Earth Surface Processes and Landforms*, 16: 70-711.
- FRENCH, H.M., GUGLIELMIN, M., 2000. Cryogenic weathering of granite, Northern Victoria Land, Antarctica: *Permafrost and Periglacial Processes*, v. 11, p. 305-314.
- GILL, E.D., SEGNET, E.R., MCNEILL, N.H., 1981. Rate of Formation of Honeycomb Weathering Features (Small Scale Tafoni) on the Otway Coast, S.E. Australia: *Proceedings of the Royal Society of Victoria*, v. 92, p. 149-154.
- GOUDIE A., 2003. *Encyclopedia of geomorphology*, London, Routledge, p. 1200.
- HEJL, E., 2005. A Pictorial Study of Tafoni Development from the 2nd Millennium.
- I.G.M.S. 1965, 1970. Geological maps 1:50.000 maps: Atalanti, Larimna.
- MARATOS I.G.M.S., 1965. Atalantis geological map 1:50.000.
- MARTINI, I.P., 1978. Tafoni Weathering, with Examples from Tuscany, Italy: *Zeitschrift fuer Geomorphologie*, v. 22, p. 44-67.
- MATSOUKA, N., 1995. Rock weathering processes and landform development in the Sor Rondane Mountains, Antarctica: *Geomorphology*, v. 12, p. 323-329.
- MELLOR, A., SHORT, J., KIRKBY, S.J., 1997. Tafoni in the El Chorro Area, Andalucia, Southern Spain: *Earth Surfaces Processes and Landforms*, v. 22, p. 817-833.
- MOTTERSHEAD, D.N., PYE, K., 1994. Tafoni on coastal slopes, South Devon, U.K.: *Earth surfaces processes and Landforms*, v. 19, p. 543-563.
- National Meteorological Service – Lamia Meteorological station.
- PESTRONG, R., 1988. Tafoni Weathering of Old Structures Along the Northern California Coast, USA: *Proceedings of an International Symposium Organized by the Greek National Group of IAEG*, p. 1049-105.
- PREBBLE, M.M., 1967. Cavernous Weathering in the Taylor Dry Valley, Victoria Land, Antarctica: *Nature*, v. 216, p. 1194-1195.
- SMITH, P.J., 1982. Why Honeycomb Weathering: *Nature*, v. 298, p. 121-122.
- SMITH, P.J., 1978. The origin and geomorphic implications of Cliff foot recesses and tafoni on limestone Hamadas in the Northwest Sahara: *Zeitschrift fuer Geomorphologie*, v. 22, p. 21-43.
- WELLMAN, H.W., WILSON, A.T., 1965. Salt Weathering, a Neglected Geological Erosive Agent in Coastal and Arid Environments: *Nature*, v. 205, p. 1097-1098.

Table 1. Main morphological characteristics of the studied tafoni

Tafoni	y coords	x coords	A] Width. (m)	B] Depth. (m)	C] Height. (m)	[A]-[B]	[A]-[C]	[A]/[B]	[C]/[B]
T1	38° 40.440N	23° 10.206E	0.26	0.2	0.31	0.06	-0.05	1.3	1.55
T2	38° 40.445N	23° 10.202E	0.9	0.5	0.45	0.4	0.45	1.8	0.9
T3	38° 40.443N	23° 10.203E	0.8	0.3	0.23	0.5	0.57	2.66	0.76
T4	38° 40.447N	23° 10.194E	1.54	0.39	0.14	1.15	1.4	4.05	0.42
T5	38° 40.441N	23° 10.196E	1.61	0.33	0.26	1.28	1.35	5.55	0.62
T6	38° 40.444N	23° 10.196E	0.37	0.48	0.29	-0.11	0.08	0.77	0.6
T7	38° 40.448N	23° 10.196E	0.35	0.2	0.17	0.15	0.18	3.18	1.54
T8	38° 40.446N	23° 10.191E	0.21	0.36	0.4	-0.15	-0.19	0.58	1.11
T9	38° 40.445N	23° 10.190E	1.12	4	0.5	-2.88	0.62	0.28	0.12
T10	38° 40.447N	23° 10.189E	0.12	0.09	0.21	0.03	-0.09	1.33	2.33
T11	38° 40.447N	23° 10.187E	0.19	0.21	0.09	-0.02	0.1	0.9	0.42
T12	38° 40.428N	23° 10.183E	0.08	0.21	0.09	-0.13	-0.01	0.38	0.42
T13	38° 40.446N	23° 10.180E	0.21	0.43	0.24	-0.22	-0.03	0.48	0.55
T14	38° 40.439N	23° 10.178E	0.22	0.37	0.34	-0.15	-0.12	0.56	0.91
T15	38° 40.440N	23° 10.177E	0.14	0.23	0.23	-0.09	-0.09	0.6	1
T16	38° 40.439N	23° 10.173E	0.04	0.05	0.05	-0.01	-0.01	0.8	1
T17	38° 40.436N	23° 10.163E	0.06	0.11	0.05	-0.05	0.01	0.54	0.45
T18	38° 40.435N	23° 10.161E	0.1	0.1	0.09	0	0.01	1	0.9
T19	38° 40.436N	23° 10.159E	0.79	0.41	0.53	0.38	0.26	1.92	1.29
T20	38° 40.436N	23° 10.157E	0.28	0.88	0.5	-0.6	-0.22	0.31	0.56
T21	38° 40.436N	23° 10.155E	0.015	0.03	0.95	-0.015	-0.935	0.5	31.67
T22	38° 40.434N	23° 10.154E	0.19	0.13	0.38	0.06	-0.19	1.46	2.92
T23	38° 40.435N	23° 10.153E	0.08	0.17	0.08	-0.09	0	0.47	0.47
T24	38° 40.434N	23° 10.148E	0.09	0.07	0.08	0.02	0.01	1.28	1.14
T25	38° 40.434N	23° 10.147E	0.05	0.06	0.05	-0.01	0	0.83	0.83
T26	38° 40.430N	23° 10.135E	0.61	0.33	0.15	0.28	0.46	1.84	0.45
T27	38° 40.430N	23° 10.132E	0.015	0.005	0.01	0.01	0.005	3	2
T28	38° 40.432N	23° 10.130E	0.15	0.09	0.12	0.06	0.03	1.66	1.33
T29	38° 40.431N	23° 10.136E	0.025	0.03	0.03	-0.005	-0.005	0.83	1
T30	38° 40.433N	23° 10.139E	0.04	0.07	0.03	-0.03	0.01	0.57	0.42
T31	38° 40.433N	23° 10.139E	0.07	0.04	0.02	0.03	0.05	1.75	0.5
T32	38° 40.434N	23° 10.143E	0.08	0.07	0.05	0.01	0.03	1.14	0.71
T33(9A)	38° 40.445N	23° 10.190E	0.21	0.12	0.49	0.09	-0.28	1.75	4.08
T34(9B)	38° 40.445N	23° 10.190E	0.16	0.25	0.17	-0.09	-0.01	0.64	0.68
T35(9Γ)	38° 40.445N	23° 10.190E	0.16	0.07	0.11	0.09	0.05	2.28	1.57
T36(9Δ)	38° 40.445N	23° 10.190E	0.05	0.07	0.14	-0.02	-0.09	0.71	2
T37	38° 40.449N	23° 10.193E	0.26	0.19	0.37	0.07	-0.11	1.36	1.94
T38	38° 40.449N	23° 10.192E	0.06	0.1	0.22	-0.04	-0.16	0.6	2.2
T39	38° 40.449N	23° 10.192E	0.06	0.06	0.07	0	-0.01	1	1.16
T40	38° 40.449N	23° 10.192E	0.04	0.06	0.11	-0.02	-0.07	0.66	1.83
T41(7A)	38° 40.448N	23° 10.196E	0.14	0.28	0.21	-0.14	-0.07	0.5	0.75
T42(7B)	38° 40.448N	23° 10.196E	0.09	0.1	0.08	-0.01	0.01	0.9	0.8
T43(7Γ)	38° 40.448N	23° 10.196E	0.04	0.07	0.05	-0.03	-0.01	0.57	0.71

T44(7A)	38° 40.448N	23° 10.196E	0.03	0.03	0.04	0	-0.01	1	1.33
T45	38° 40.448N	23° 10.196E	0.05	0.07	0.04	-0.02	0.01	0.71	0.57
T46	38° 40.448N	23° 10.196E	0.06	0.12	0.09	-0.06	-0.03	0.5	0.75
T47	38° 40.447N	23° 10.195E	0.08	0.05	0.09	0.03	-0.01	1.6	1.8
T48	38° 40.448N	23° 10.195E	0.15	0.08	0.08	0.07	0.07	1.875	1
T49(48A)	38° 40.448N	23° 10.195E	0.04	0.16	0.06	-0.12	-0.02	0.25	0.37
T50	38° 40.448N	23° 10.195E	0.14	0.41	0.04	-0.27	0.1	0.34	0.09
T51	38° 40.447N	23° 10.203E	0.1	0.12	0.06	-0.02	0.04	0.83	0.5
T52	38° 40.447N	23° 10.203E	0.04	0.07	0.04	-0.03	0	0.57	0.57
T53	38° 40.447N	23° 10.201E	0.09	0.29	0.1	-0.2	-0.01	0.31	0.34
T54	38° 40.441N	23° 10.195E	0.1	0.14	0.06	-0.04	0.04	0.71	0.42
T55	38° 40.447N	23° 10.199E	0.23	0.19	0.26	0.04	-0.03	1.21	1.36
T56(2A)	38° 40.445N	23° 10.202E	0.18	0.11	0.07	0.07	0.11	1.63	0.63
T57	38° 40.446N	23° 10.202E	0.05	0.02	0.06	0.03	-0.01	2.5	3
T58	38° 40.446N	23° 10.202E	0.09	0.07	0.08	0.02	0.01	1.28	1.14
T59	38° 40.446N	23° 10.202E	0.05	0.06	0.08	-0.01	-0.03	0.83	1.33
T60	38° 40.446N	23° 10.202E	0.03	0.05	0.09	-0.02	-0.06	0.6	1.8
T61(5A)	38° 40.441N	23° 10.196E	0.08	0.29	0.1	-0.21	-0.02	0.27	0.34
T62(5B)	38° 40.441N	23° 10.196E	0.11	0.24	0.18	-0.13	-0.07	0.45	0.75
T63	38° 40.444N	23° 10.205E	0.06	0.1	0.04	-0.04	0.02	0.6	0.4
T64(63A)	38° 40.445N	23° 10.203E	0.055	0.06	0.03	-0.005	0.025	0.91	0.5
T65	38° 40.445N	23° 10.201E	0.21	0.06	0.08	0.15	0.13	3.5	1.33
T66(65A)	38° 40.445N	23° 10.201E	0.07	0.11	0.06	-0.04	0.01	0.63	0.54
T67(65B)	38° 40.445N	23° 10.201E	0.04	0.03	0.04	0.01	0	1.33	1.33
T68	38° 40.448N	23° 10.207E	0.1	0.24	0.13	-0.14	-0.03	0.41	0.54
T69	38° 40.448N	23° 10.207E	0.03	0.04	0.03	-0.01	0	0.75	0.75
T70	38° 40.448N	23° 10.207E	0.035	0.06	0.04	-0.025	-0.005	0.58	0.66
T71	38° 40.440N	23° 10.204E	0.09	0.07	0.04	0.02	0.05	1.28	0.57
T72	38° 40.440N	23° 10.204E	0.06	0.07	0.05	-0.01	0.01	0.85	0.71
T73	38° 40.445N	23° 10.206E	0.1	0.09	0.08	0.01	0.02	1.11	0.88
T74	38° 40.444N	23° 10.205E	0.19	0.22	0.26	-0.03	-0.07	0.86	1.18
T75	38° 40.444N	23° 10.205E	0.005	0.005	0.005	0	0	1	1
T76	38° 40.445N	23° 10.205E	0.05	0.05	0.07	0	-0.02	1	1.4
T77	38° 40.445N	23° 10.205E	0.03	0.13	0.03	-0.1	0	0.23	0.23
T78	38° 40.443N	23° 10.206E	0.23	0.08	0.03	0.15	0.2	2.87	0.37
T79	38° 40.444N	23° 10.206E	0.04	0.08	0.07	-0.04	-0.03	0.5	0.87
T80	38° 40.449N	23° 10.302E	0.12	0.04	0.04	0.08	0.08	3	1
T81(80A)	38° 40.449N	23° 10.302E	0.03	0.05	0.03	-0.02	0	0.6	0.6
T82(80B)	38° 40.449N	23° 10.302E	0.03	0.03	0.03	0	0	1	1
T83(80Γ)	38° 40.449N	23° 10.302E	0.01	0.005	0.01	0.005	0	2	2
T84	38° 40.444N	23° 10.206E	0.06	0.08	0.11	-0.02	-0.05	0.75	1.375
T85	38° 40.444N	23° 10.206E	0.07	0.05	0.06	0.02	0.01	1.4	1.2
T86	38° 40.448N	23° 10.203E	0.04	0.04	0.04	0	0	1	1
T87	38° 40.448N	23° 10.203E	0.03	0.05	0.05	-0.02	-0.02	0.6	1
T88	38° 40.431N	23° 10.213E	0.21	0.15	0.07	0.06	0.14	1.4	0.46

T89	38° 40.431N	23° 10.213E	0.08	0.06	0.06	0.02	0.02	1.33	1
T90	38° 40.429N	23° 10.215E	0.19	0.1	0.12	0.09	0.07	1.9	1.2
T91(90A)	38° 40.429N	23° 10.215E	0.12	0.06	0.09	0.06	0.03	2	1.5
T92(90B)	38° 40.429N	23° 10.215E	0.11	0.1	0.08	0.01	0.03	1.1	0.8
T93	38° 40.446N	23° 10.208E	0.05	0.16	0.06	-0.11	-0.01	0.31	0.37
T94	38° 40.448N	23° 10.207E	0.21	0.17	0.25	0.04	-0.04	1.23	1.47
T95(94A)	38° 40.448N	23° 10.206E	0.05	0.04	0.045	0.01	0.005	1.25	1.12
T96	38° 40.451N	23° 10.206E	0.05	0.045	0.09	0.005	-0.04	1.11	2
T97	38° 40.450N	23° 10.206E	0.03	0.05	0.07	-0.02	-0.04	0.6	1.4
T98	38° 40.450N	23° 10.206E	0.045	0.04	0.03	0.005	0.015	1.12	0.75
T99(98A)	38° 40.450N	23° 10.206E	0.02	0.04	0.025	-0.02	-0.005	0.5	0.62
T100(98B)	38° 40.450N	23° 10.206E	0.035	0.035	0.03	0	0.005	1	0.85
T101	38° 40.446N	23° 10.207E	0.08	0.08	0.045	0	0.035	1	0.56
T102	38° 40.452N	23° 10.206E	0.11	0.06	0.03	0.05	0.08	1.83	0.5
T103(102A)	38° 40.452N	23° 10.206E	0.06	0.05	0.035	0.01	0.025	1.2	0.7
T104(102B)	38° 40.452N	23° 10.206E	0.055	0.17	0.045	-0.115	0.01	0.32	0.26
T105	38° 40.446N	23° 10.206E	0.045	0.05	0.05	-0.005	-0.005	0.9	1
T106	38° 40.446N	23° 10.206E	0.04	0.08	0.065	-0.04	-0.025	0.5	0.8125
T107	38° 40.437N	23° 10.207E	0.09	0.11	0.15	-0.02	-0.06	0.81	1.36
T108	38° 40.451N	23° 10.203E	0.09	0.09	0.1	0	-0.01	1	1.11
T109(108A)	38° 40.451N	23° 10.203E	0.04	0.1	0.07	-0.06	-0.03	0.4	0.7
T110	38° 40.448N	23° 10.205E	0.39	0.22	0.032	0.17	0.358	1.77	0.14
T111	38° 40.451N	23° 10.200E	0.05	0.08	0.13	-0.03	-0.08	0.62	1.62
T112	38° 40.452N	23° 10.201E	0.04	0.08	0.05	-0.04	-0.01	0.5	0.62
T113	38° 40.446N	23° 10.187E	0.18	0.08	0.11	0.1	0.07	2.25	1.37
T114	38° 40.446N	23° 10.186E	0.05	0.04	0.05	0.01	0	1.25	1.25
T115	38° 40.447N	23° 10.186E	0.06	0.03	0.05	0.03	0.01	2	1.66
T116	38° 40.444N	23° 10.181E	0.07	0.06	0.09	0.01	-0.02	1.16	1.5
T117	38° 40.447N	23° 10.183E	0.045	0.045	0.11	0	-0.065	1	2.44
T118	38° 40.447N	23° 10.183E	0.06	0.11	0.075	-0.05	-0.015	0.54	0.68
T119	38° 40.447N	23° 10.183E	0.035	0.05	0.04	-0.015	-0.005	0.7	0.8
T120	38° 40.446N	23° 10.183E	0.045	0.055	0.03	-0.01	0.015	0.81	0.54
T121	38° 40.448N	23° 10.183E	0.12	0.045	0.07	0.075	0.05	2.66	1.55
T122	38° 40.446N	23° 10.183E	0.045	0.05	0.04	-0.005	0.005	0.9	0.8
T123	38° 40.447N	23° 10.184E	0.04	0.1	0.05	-0.06	-0.01	0.4	0.5
T124	38° 40.446N	23° 10.184E	0.04	0.025	0.07	0.015	-0.03	1.6	2.8
T125	38° 40.440N	23° 10.177E	0.045	0.04	0.035	0.005	0.01	1.125	0.87
T126	38° 40.441N	23° 10.176E	0.12	0.11	0.23	0.01	-0.11	1.09	2.09
T127	38° 40.440N	23° 10.177E	0.12	0.07	0.15	0.05	-0.03	1.71	2.14
T128	38° 40.440N	23° 10.177E	0.04	0.1	0.04	-0.06	0	0.4	0.4
T129	38° 40.438N	23° 10.169E	0.05	0.11	0.08	-0.06	-0.03	0.45	0.72
T130	38° 40.438N	23° 10.168E	0.035	0.035	0.04	0	-0.005	1	1.14
T131	38° 40.434N	23° 10.163E	0.065	0.06	0.05	0.005	0.015	1.08	0.83
T132	38° 40.436N	23° 10.162E	0.05	0.06	0.04	-0.01	0.01	0.83	0.66
T133	38° 40.436N	23° 10.162E	0.09	0.17	0.23	-0.08	-0.14	0.52	1.35

T134(19A)	38° 40.436N	23° 10.159E	0.21	0.09	0.14	0.12	0.07	2.33	1.55
T135(19B)	38° 40.436N	23° 10.159E	0.1	0.05	0.1	0.05	0	2	2
T136(19Γ)	38° 40.436N	23° 10.159E	0.07	0.05	0.04	0.02	0.03	1.4	0.8
T137(19Δ)	38° 40.436N	23° 10.159E	0.13	0.03	0.07	0.1	0.06	4.33	2.33
T138	38° 40.436N	23° 10.159E	0.09	0.06	0.14	0.03	-0.05	1.5	2.33
T139(138A)	38° 40.436N	23° 10.159E	0.08	0.31	0.04	-0.23	0.04	0.25	0.12
T140(138B)	38° 40.436N	23° 10.159E	0.04	0.21	0.05	-0.17	-0.01	0.19	0.23
T141	38° 40.438N	23° 10.160E	0.13	0.08	0.08	0.05	0.05	1.62	1
T142(141A)	38° 40.438N	23° 10.160E	0.04	0.04	0.06	0	-0.02	1	1.5
T143	38° 40.438N	23° 10.159E	0.05	0.08	0.05	-0.03	0	0.62	0.62
T144	38° 40.442N	23° 10.161E	0.035	0.02	0.03	0.015	0.005	1.75	1.5
T145	38° 40.437N	23° 10.161E	0.045	0.03	0.045	0.015	0	1.5	1.5
T146	38° 40.437N	23° 10.161E	0.08	0.1	0.09	-0.02	-0.01	0.8	0.9
T147	38° 40.437N	23° 10.161E	0.09	0.47	0.15	-0.38	-0.06	0.19	0.31
T148	38° 40.439N	23° 10.160E	0.08	0.11	0.08	-0.03	0	0.72	0.72
T149	38° 40.441N	23° 10.160E	0.05	0.04	0.035	0.01	0.015	1.25	0.87
T150	38° 40.439N	23° 10.156E	0.18	0.24	0.12	-0.06	0.06	0.75	0.5
T151(150A)	38° 40.439N	23° 10.156E	0.11	0.21	0.08	-0.1	0.03	0.52	0.38
T152(150B)	38° 40.439N	23° 10.156E	0.11	0.02	0.04	0.09	0.07	5.5	2
T153(150Γ)	38° 40.439N	23° 10.156E	0.05	0.09	0.04	-0.04	0.01	0.55	0.44
T154	38° 40.436N	23° 10.160E	0.07	0.04	0.07	0.03	0	1.75	1.75
T155(154A)	38° 40.436N	23° 10.160E	0.045	0.04	0.045	0.005	0	1.125	1.12
T156(154B)	38° 40.436N	23° 10.160E	0.03	0.03	0.025	0	0.005	1	0.83
T157	38° 40.436N	23° 10.159E	0.07	0.06	0.09	0.01	-0.02	1.16	1.5
T158	38° 40.439N	23° 10.160E	0.04	0.045	0.04	-0.005	0	0.88	0.88
T159	38° 40.434N	23° 10.160E	0.07	0.07	0.09	0	-0.02	1	1.28
T160	38° 40.434N	23° 10.159E	0.12	0.1	0.11	0.02	0.01	1.2	1.1
T161	38° 40.435N	23° 10.159E	0.05	0.07	0.06	-0.02	-0.01	0.71	0.85
T162	38° 40.436N	23° 10.159E	0.05	0.06	0.05	-0.01	0	0.83	0.83
T163	38° 40.433N	23° 10.142E	0.12	0.07	0.1	0.05	0.02	1.71	1.42
T164	38° 40.447N	23° 10.151E	0.05	0.13	0.1	-0.08	-0.05	0.38	0.76
T165	38° 40.447N	23° 10.151E	0.06	0.11	0.08	-0.05	-0.02	0.54	0.72

Table 2. Recorded joints, amalgamation, and porosity for each tafoni

Tafoni	Parallel Joints (Yes/No)	Cross Joints (Yes/No)	Amalgamation (Yes/No)	Porosity (Yes/No)
T1	No	No	Yes	No
T2	Yes	Yes	Yes	Yes
T3	Yes	Yes	Yes	Yes
T4	Yes	Yes	Yes	Yes
T5	Yes	Yes	Yes	Yes
T6	Yes	Yes	Yes	Yes
T7	No	No	Yes	Yes
T8	Yes	No	Yes	Yes
T9	Yes	Yes	Yes	Yes
T10	No	No	Yes	Yes
T11	Yes	No	Yes	Yes
T12	No	No	Yes	No
T13	Yes	Yes	Yes	No
T14	Yes	No	Yes	No
T15	No	No	Yes	Yes
T16	No	No	Yes	No
T17	Yes	No	Yes	Yes
T18	No	No	Yes	No
T19	Yes	Yes	Yes	Yes
T20	Yes	Yes	Yes	Yes
T21	No	No	Yes	No
T22	No	No	Yes	Yes
T23	No	No	Yes	Yes
T24	No	No	Yes	No
T25	No	No	Yes	No
T26	Yes	Yes	Yes	Yes
T27	No	No	Yes	No
T28	No	No	Yes	No
T29	Yes	No	Yes	Yes
T30	No	No	Yes	No
T31	No	No	Yes	Yes
T32	No	No	Yes	Yes
T33(9A)	Yes	Yes	Yes	Yes
T34(9B)	Yes	Yes	Yes	No
T35(9F)	Yes	Yes	Yes	Yes
T36(9D)	Yes	Yes	Yes	Yes
T37	Yes	Yes	Yes	Yes
T38	No	No	Yes	No
T39	No	No	Yes	No
T40	Yes	Yes	Yes	Yes
T41(7A)	No	No	Yes	Yes
T42(7B)	No	No	Yes	Yes
T43(7I)	No	No	Yes	No
T44(7Δ)	No	No	Yes	No
T45	No	No	Yes	No
T46	No	No	Yes	No
T47	No	No	Yes	Yes
T48	No	No	Yes	No
T49(48A)	No	No	Yes	No
T50	No	No	Yes	Yes
T51	Yes	No	Yes	Yes
T52	Yes	No	Yes	Yes
T53	Yes	Yes	Yes	Yes
T54	No	No	Yes	Yes
T55	Yes	Yes	Yes	Yes
T56(2A)	Yes	Yes	Yes	Yes
T57	Yes	No	Yes	No
T58	No	No	Yes	No
T59	No	No	Yes	Yes
T60	No	No	Yes	Yes
T61(5A)	Yes	No	Yes	Yes
T62(5B)	Yes	No	Yes	Yes
T63	No	No	Yes	No
T64(63A)	No	No	Yes	No
T65	Yes	Yes	Yes	Yes
T66(65A)	Yes	Yes	Yes	Yes
T67(65B)	Yes	Yes	Yes	Yes
T68	No	No	Yes	No
T69	No	No	Yes	No
T70	No	No	Yes	No
T71	No	No	Yes	No
T72	No	No	Yes	No
T73	No	Yes	Yes	Yes
T74	No	No	Yes	Yes
T75	No	No	Yes	No
T76	No	Yes	Yes	Yes
T77	No	Yes	Yes	Yes
T78	No	No	Yes	No
T79	Yes	Yes	Yes	Yes
T80	No	No	Yes	Yes
T81(80A)	No	No	Yes	Yes

T82(80B)	No	No	Yes	Yes
T83(80Γ)	No	No	Yes	No
T84	No	Yes	Yes	Yes
T85	No	Yes	Yes	Yes
T86	Yes	No	Yes	Yes
T87	Yes	No	Yes	Yes
T88	Yes	Yes	Yes	Yes
T89	Yes	Yes	Yes	No
T90	No	Yes	Yes	No
T91(90A)	No	Yes	Yes	No
T92(90B)	No	Yes	Yes	No
T93	Yes	Yes	Yes	No
T94	Yes	Yes	Yes	Yes
T95(94A)	Yes	Yes	Yes	Yes
T96	No	No	Yes	No
T97	No	No	Yes	No
T98	Yes	No	Yes	Yes
T99(98A)	Yes	No	Yes	Yes
T100(98B)	Yes	No	Yes	Yes
T101	Yes	No	Yes	No
T102	Yes	No	Yes	Yes
T103(102A)	Yes	No	Yes	Yes
T104(102B)	Yes	No	Yes	Yes
T105	No	No	Yes	No
T106	No	No	Yes	Yes
T107	No	No	Yes	Yes
T108	Yes	No	Yes	Yes
T109(108A)	Yes	No	Yes	No
T110	Yes	Yes	Yes	Yes
T111	Yes	Yes	Yes	Yes
T112	Yes	Yes	Yes	Yes
T113	Yes	Yes	Yes	Yes
T114	Yes	Yes	Yes	Yes
T115	No	No	Yes	Yes
T116	No	No	Yes	No
T117	No	No	Yes	Yes
T118	No	No	Yes	Yes
T119	No	No	Yes	Yes
T120	No	No	Yes	Yes
T121	No	No	Yes	No
T122	No	No	Yes	No

T123	No	No	Yes	No
T124	No	No	Yes	Yes
T125	No	No	Yes	Yes
T126	No	No	Yes	Yes
T127	No	No	Yes	Yes
T128	Yes	Yes	Yes	No
T129	No	No	Yes	Yes
T130	No	No	Yes	Yes
T131	Yes	Yes	Yes	Yes
T132	No	No	Yes	No
T133	Yes	Yes	Yes	No
T134(19A)	Yes	Yes	Yes	Yes
T135(19B)	Yes	Yes	Yes	Yes
T136(19Γ)	Yes	Yes	Yes	No
T137(19A)	Yes	Yes	Yes	Yes
T138	Yes	Yes	Yes	Yes
T139(138A)	Yes	Yes	Yes	Yes
T140(138B)	Yes	Yes	Yes	Yes
T141	No	No	Yes	Yes
T142(141A)	No	No	Yes	Yes
T143	No	No	Yes	Yes
T144	No	No	Yes	Yes
T145	No	Yes	Yes	No
T146	No	Yes	Yes	Yes
T147	No	Yes	Yes	Yes
T148	Yes	No	Yes	Yes
T149	No	No	Yes	Yes
T150	Yes	Yes	Yes	Yes
T151(150A)	Yes	Yes	Yes	Yes
T152(150B)	Yes	Yes	Yes	Yes
T153(150Γ)	Yes	Yes	Yes	Yes
T154	Yes	Yes	Yes	Yes
T155(154A)	Yes	Yes	Yes	Yes
T156(154B)	Yes	Yes	Yes	Yes
T157	Yes	Yes	Yes	Yes
T158	Yes	Yes	Yes	Yes
T159	No	No	Yes	Yes
T160	No	No	Yes	Yes
T161	No	No	Yes	Yes
T162	No	No	Yes	Yes
T163	Yes	Yes	Yes	Yes
T164	Yes	Yes	Yes	Yes
T165	Yes	Yes	Yes	Yes

Table 3. Other surface elements

Tafoni	Cavern visor	Flakes	Lichens	Debris	Salt
T1		■			
T2	■	■		■	
T3		■		■	
T4		■			
T5					
T6		■		■	
T7		■		■	■
T8		■			
T9		■		■	
T10					
T11	■				
T12		■			
T13		■		■	
T14		■			
T15		■			
T16				■	
T17					
T18				■	
T19		■			■
T20		■			■
T21			■		
T22		■			■
T23		■			■
T24					
T25					
T26	■				
T27					
T28					■
T29					
T30					
T31					
T32					
T33(9A)		■			■
T34(9B)		■			■
T35(9Γ)	■				
T36(9Δ)					
T37		■			■
T38				■	■
T39					
T40					
T41(7A)					
T42(7B)					
T43(7Γ)					
T44(7Δ)					
T45		■			
T46		■		■	
T47					
T48		■			
T49(48A)		■			
T50		■		■	
T51				■	
T52					
T53				■	
T54				■	
T55					
T56(2A)		■			
T57		■			■
T58		■		■	
T59		■		■	■
T60		■		■	
T61(5A)		■		■	
T62(5B)				■	
T63		■			
T64(63A)		■			
T65		■			
T66(65A)					
T67(65B)					
T68				■	
T69					
T70					
T71					
T72					
T73					
T74				■	
T75					
T76		■			
T77					
T78					
T79		■			■
T80					
T81(80A)					

T82(80B)					
T83(80Γ)					
T84					
T85					
T86					
T87					
T88		■			
T89		■			
T90					
T91(90A)					
T92(90B)					
T93		■			
T94		■			
T95(94A)					
T96		■			
T97					
T98					
T99(98A)				■	
T100(98B)				■	
T101					
T102	■	■			■
T103(102A)					■
T104(102B)					■
T105					
T106		■			
T107		■			
T108					
T109(108A)				■	
T110	■	■			
T111					
T112					
T113		■			
T114					
T115		■			
T116		■			■
T117		■			
T118		■		■	
T119		■			
T120		■			■
T121		■			■
T122		■			

T123					■
T124		■			
T125					
T126		■			■
T127		■			
T128			■		
T129		■			■
T130					
T131		■		■	■
T132				■	■
T133				■	■
T134(19A)		■			
T135(19B)					■
T136(19Γ)					■
T137(19Δ)					
T138		■			
T139(138A)					
T140(138B)		■		■	
T141					
T142(141A)					
T143					
T144		■			
T145		■			
T146		■			■
T147		■			
T148			■		■
T149		■			■
T150				■	■
T151(150A)		■			■
T152(150B)					■
T153(150Γ)					■
T154		■			
T155(154A)		■			■
T156(154B)		■			
T157		■			
T158				■	
T159					
T160			■		
T161		■		■	
T162				■	
T163		■			■
T164					■
T165					■

Table 4. Schmidt hammer measurements in R-values

Tafoni	Backwall (MPa)	Floor (MPa)	Visor (MPa)	Ceiling (MPa)	Outer Roof (MPa)	Unweathered Rock (MPa)
T1	14					16
T2	13	14	9		11	15
T3	16	16				17
T4						17
T5						
T6		10			6	
T7	13			11	10	15
T8				13		17
T9	16	18		11		17
T10	10					12
T11						13
T12						14
T13						12
T14	9	11				12
T15						13
T16						10
T17						10
T18						10
T19	12			9		15
T20						11
T21						14
T22	14	14				16
T23						16
T24						15
T25						15
T26			17			
T27						15
T28						14
T29						13
T30						14
T31						11
T32						15
T33(9A)	16					17
T34(9B)	15					17
T35(9Γ)	15		11		9	16
T36(9Δ)						17
T37						16
T38						16
T39						16
T40						13
T41(7A)						15
T42(7B)	6					15
T43(7Γ)						15
T44(7Δ)						15
T45						14
T46						14
T47						14
T48	13					14
T49(48A)						14
T50						14
T51		11				15
T52						15
T53						12
T54						13
T55						11
T56(2A)	12					15
T57						14
T58						14
T59						10
T60						10
T61(5A)						
T62(5B)						
T63						12
T64(63A)						14
T65	11					14
T66(65A)						14
T67(65B)						14
T68	10					12
T69						12
T70						12
T71						13
T72						13
T73		12				16
T74		14				16
T75						16
T76						14
T77						14
T78						13
T79						10
T80	11					13
T81(80A)						13

T82(80B)						13	T123								13
T83(80F)						13	T124								11
T84						16	T125								13
T85						16	T126		10						12
T86						17	T127								9
T87						17	T128								13
T88						14	T129								17
T89						14	T130								16
T90	15					17	T131								16
T91(90A)	15					17	T132								11
T92(90B)	15					17	T133	7	9						12
T93						12	T134(19A)	12	12						15
T94	9	5				13	T135(19B)								15
T95(94A)						13	T136(19F)								15
T96	12					14	T137(19Δ)								15
T97						14	T138								13
T98						13	T139(138A)								13
T99(98A)						13	T140(138B)								13
T100(98B)						13	T141								11
T101						17	T142(141A)								11
T102						15	T143								13
T103(102A)						15	T144								12
T104(102B)						15	T145	13							16
T105						11	T146								12
T106						11	T147								12
T107	11					13	T148								17
T108	8					10	T149								17
T109(108A)						10	T150	11							14
T110	14		9	13	10	17	T151(150A)								14
T111						14	T152(150B)								14
T112						13	T153(150F)								14
T113						12	T154								12
T114						13	T155(154A)								12
T115						13	T156(154B)								12
T116	11					14	T157								16
T117	4					14	T158								
T118						11	T159		10						13
T119						12	T160								16
T120						14	T161								16
T121	14					17	T162								14
T122						13	T163		14						
							T164								
							T165								
Min							4	5	9	9	6	9			
Max							16	18	17	13	11	17			

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Estimation des paramètres de l'érosion hydrique à l'aide de la télédétection et du SIG : cas du bassin-versant de l'Oued Tlil (Nord-Est de la Tunisie)

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Résumé : L'érosion hydrique constitue l'une des premières causes de la dégradation du patrimoine agro-pédologique. Ce phénomène est très connu dans le bassin-versant d'Oued Tlil, secteur concerné par cette étude. Situé dans le Nord-Est de la Tunisie, ce bassin présente un relief très accidenté avec des altitudes qui varient de 50 m à 420 m et des pentes fortes allant de 2 à 25% et parfois plus. Il s'étend sur une superficie de 45 km² drainée par un ensemble d'oueds et principalement l'Oued Tlil.

L'application de l'Equation Universelle des Pertes en Sol vise trois objectifs essentiels :

- L'estimation des paramètres de l'érosion hydrique à savoir, l'agressivité des pluies, l'érodibilité des sols, le facteur topographique, l'indice du couvert végétal et le facteur des pratiques antiérosives.
- L'identification des zones sensibles et à haut risque d'érosion, ainsi que les régions d'urgence d'intervention dans le bassin versant.
- La quantification des pertes en terre par ruissellement.

La cartographie de ces zones est effectuée à l'aide de la télédétection et des systèmes d'information géographique.

Ceci permettra d'orienter les différentes actions d'intervention possible de conservation des eaux et du sol programmées dans la région.

Mots clés : Érosion hydrique - Equation Universelle des Pertes en Sol – bassin-versant oued Tlil – Télédétection – SIG.

Abstract: Water erosion parameter estimation using remote sensing and GIS: the case of the watershed of Tlil river (North-East of Tunisia). Water erosion is one of the main causes of degradation of the agro-soil assets. This phenomenon is well known in the catchment area of the Tlil river sector involved in this study. Located in the north-east of Tunisia, this basin has a hilly terrain with altitudes ranging from 50 m to 420 m and steep slopes ranging from 2 to 25% and sometimes more. It covers an area of 45 km² and is drained by a series of rivers, of which the Tlil river is the main one.

The application of the universal soil loss equation has three key objectives:

- The estimation of parameters involved in water erosion: the aggressiveness of rainfall, soil erodibility, topographic factor, the index of vegetation cover and erosion control practices factor.
- The identification of sensitive areas and at high risk of erosion as well as of those in need for an urgent response in the watershed.
- Quantification of soil loss by runoff.

The mapping of these areas is done using remote sensing and geographic information systems. This will guide the various possible measures of intervention programmed for water and soil conservation in the region.

Keywords: Water erosion - Universal Soil Loss Equation - Tlil river watershed - Remote Sensing - GIS.

Introduction

La dégradation des terrains se matérialise généralement par l'érosion gravitaire dont la pente, en plus du couvert végétal, représente un paramètre prédominant. Les causes principales de la dégradation des terres trouvent leur origine dans les facteurs naturels physico-climatiques et hydrologiques. Elles sont aggravées notamment par les facteurs géo-climatiques tels que la lithologie et la morpho-pédologie des bassins, l'agressivité des averses, l'intensité et l'irrégularité du ruissellement,

ainsi que les amplitudes thermiques et la sévérité des débits de pointe des crues. La cartographie de l'érosion et du ruissellement se fonde sur des mesures hydrologiques et l'application des modèles appropriés. Toutefois, l'application d'un modèle ou d'un autre dépend de la variabilité de la surface du bassin et de la disponibilité des données ponctuelles des types de sol et des précipitations.

Cette étude a pour but d'identifier les zones sensibles et à haut risque d'érosion ainsi que les régions d'urgence d'intervention dans le bassin-versant Oued Tlil.

1. Présentation de la zone d'étude :

Le bassin versant objet de la présente étude est celui d'Oued Tlil. Il s'étend sur une superficie de 45 km² drainée par un ensemble d'oueds et principalement l'Oued Tlil.

Il est situé dans le Nord Est de la Tunisie (figure 1) et délimité à l'est par la route nationale n° 8 qui relie la capitale à la ville de Bizerte et par le domaine d'Utique (zone humide).

A l'ouest le bassin versant est délimité par Jebel Kechabta orienté du sud-ouest vers le nord-est avec des altitudes culminant à 421 m. Au sud il est délimité par le Jebel Besbessia orienté est-ouest avec des altitudes culminant à 234 m, par le Jebel Duimis orienté nord-ouest – sud-est avec des altitudes culminant à 177 m et Jebel Menzel Ghoul orienté du sud-ouest vers le nord-est avec des altitudes culminant à 170 m.

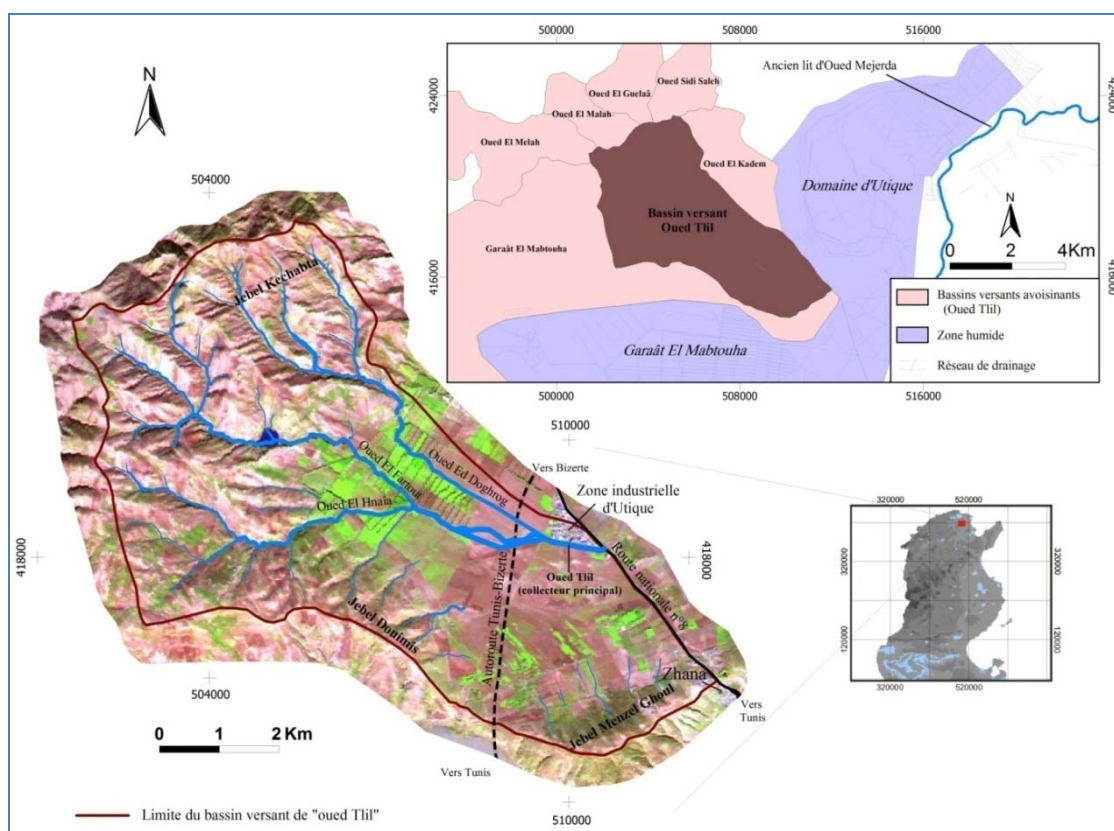


Figure 1 : Localisation du bassin-versant d'Oued Tlil

Le bassin versant de "Oued Tlil" présente un relief très accidenté et des pentes fortes allant de 2 à 25 % et parfois plus. La dénivellation varie entre 50 m à 420 m.

Les précipitations moyennes annuelles varient entre 450 mm et 525 mm avec une dominance de l'étage bioclimatique subhumide à hiver chaud.

La lithologie du bassin est constituée principalement par des calcaires, marnes, argiles et localement par des gypses (Jauzein A., 1967).

Quant à l'utilisation des terres, elle s'articule principalement autour de la céréaliculture et localement la plantation d'olivieraie et arbres fruitiers (Samaali, 2011).

2. Données et matériels utilisés

2.1. Documents

Un ensemble de documents ont été utilisés tels que une scène SPOT XS multi-spectrale datée du 09/12/1999, des cartes topographiques à l'échelle 1/25000, des cartes pédologiques à l'échelle 1/20000, des cartes géologiques à l'échelle 1/50000, une série de photographies aériennes au 1/20000 (2000), la carte des étages bioclimatiques de la Tunisie (Gounot et Le Houerou, 1955), la carte phytécologique de la Tunisie septentrionale (feuille n° II, Tunis-Bizerte), au 1/200000, les précipitations enregistrées entre 1993 et 2006

(DRE, 2010) et la carte de végétation de la Tunisie au 1/2000000 (Gammar, 2002).

Le but d'utiliser des données multi-scalaires et multi-échelles est de construire une base de données nécessaire pour l'estimation des paramètres de l'érosion hydrique.

2.2. Matériels

- Systèmes de traitement numérique des images satellite (ENVI).
- Système de traitement des données cartographiques (Arc/info et Arc view).

3. Méthodologie

L'Equation Universelle de Perte en Sol (USLE) a été choisie pour évaluer la perte en sol provoquée par l'érosion en nappe (Wischmeier et Smith, 1978). Pour évaluer le ruissellement et l'érosion, on a appliqué le modèle U.S.L.E qui permet de déterminer la sensibilité à l'érosion.

Des valeurs théoriques de pertes de sol annuelles par hectare sont déterminées en fonction des facteurs suivants :

- Facteur climatique (R) ou agressivité des pluies ;
- Facteur topographique (LS) indiquant la pente et la longueur de pente ;
- Facteur lithologique ou érodibilité des sols (K) ;
- Facteur cultural (C) déterminé à partir de l'occupation du sol ;
- Pratiques agricoles antiérosives (P).

La perte en sol (A) est déterminée par le produit des six facteurs précédents selon l'équation :

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

3.1. Elaboration des données

Elle consiste en :

- La numérisation de l'orographie et l'hydrographie à partir de la carte topographique au 1/25000 qui permet de produire le modèle Numérique de Terrain (MNT) et ses dérivées, ainsi que le réseau hydrographique ;
- La numérisation de la carte pédologique et géologique couvrant le bassin versant afin d'élaborer les couches d'érodibilité des sols ;
- Les traitements numériques de l'image satellitale SPOT XS donnant la carte d'occupation des sols ;

L'intégration de ces données dans le Système d'Information Géographique (SIG) piloté par le logiciel ArcView.

Les cartes obtenues sont: la carte d'occupation du sol, le Modèle numérique du terrain (MNT), la carte du réseau hydrographique, la carte lithologique, la

cartographie de l'érosion et la carte pédologique. Les classes des sols obtenues après interprétation sont: les sols bruns calcaires, les sols châtaîns rouges, modaux, les sols bruns méditerranéens, les régosols, les vertisols des glaciés, les sols bruns calcaires vertiques des glaciés, les sols isohumiques vertiques des glaciés, les rendzines, les sols isohumiques châtaîns et modaux, les lithosols, les sols peu évolués des terrasses, les sols vertiques des terrasses et les sols hydromorphes.

Il s'agit de quantifier les matériaux solides provenant de l'érosion des sols. Elle est exprimée en tonne par hectare et par année.

La carte d'érosion exprime les tranches de terre perdues en moyenne chaque année au niveau du bassin versant et dont une partie pourrait contribuer à l'envasement des barrages se trouvant à l'aval.

L'expression de la formule mise en œuvre est :

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

avec :

- A : quantité de sol perdue
- R : agressivité de pluie
- K : facteur d'érodibilité des sols
- L : facteur lié à la longueur de la pente
- S : facteur lié à l'inclinaison de la pente
- C : indice cultural
- P : facteur de mode d'aménagement

A partir de ces paramètres, on peut définir l'érosion potentielle et l'érosion actuelle.

3.2. Érosion potentielle

Le potentiel érosif est déterminé par la combinaison des facteurs suivants :

- Facteur d'agressivité des pluies, R ;
- Facteur d'érodibilité des sols, K ;
- Facteur physiographique lié à la pente et la longueur de pente, LS.

Le potentiel érosif (Ap) est déterminé selon la formule suivante :

$$Ap = R \cdot K \cdot LS$$

- **Agressivité de la pluie, R** (figure 2)

Ce facteur est obtenu à partir du dépouillement des données de la pluviométrie portant sur plusieurs années. Les valeurs du facteur R sont déterminées pour la zone d'étude à l'aide de la formule suivante (Cormary et al., 1964).

$$R = k \cdot A \cdot B \cdot C$$

où :

- R : agressivité de pluie
- k : coefficient régional (en Tunisie, $k = 35 \cdot 10^{-5}$ selon Masson, 1971)
- A : pluviométrie moyenne inter-annuelle
- B : pluie maximale d'une heure et de période de retour 2 ans
- C : l'intensité maximale de 24 heures et de période de retour 2 ans.

• Erodibilité des sols, K (figure 3)

L'érodibilité d'un sol est sa résistance à deux sources d'énergie, la battance des gouttes de la pluie à la surface du sol et l'entaille du ruissellement entre les mottes dans les griffes ou les rigoles.

Elle peut être déterminée selon trois façons :

- recodage d'après les valeurs de K des zones voisines
- recodage d'après les valeurs bibliographiques
- valeurs déterminées sur le terrain

Les sols rencontrés dans la zone sont principalement les sols peu évolués, les sols très évolués, les vertisols, les sols hydromorphes et les sols à sesquioxides sur calcaire lacustre et localement les sols calcimorphes, les sols isohumiques.

Les valeurs de K adoptées pour le bassin-versant d'Oued Tlil sont respectivement 0,1 ; 0,01 ; 0,05 ; 0,05 ; 0,15 ; 0,2 et 0,13.

Certains auteurs, dont Wischmeier (1978), ont trouvé une corrélation entre ce facteur et les paramètres liés à la structure des sols. Wischmeier, Johnson et Cross (1971) proposèrent un modèle pour calculer le facteur K selon l'équation :

$$1000 K = 2,1 M^{1,4} \cdot 10^{-4} (12 - a) + 3,25 (b - 2) + 2,5 (c - 3)$$

où :

- K : facteur d'érodibilité
- a : pourcentage de matière organique
- b : le code de structure
- c : la classe de perméabilité
- M : (% sable fin + % limon) (100 - % argile)

La valeur de (K) est alors cataloguée sur des abaques en fonction de la structure des sols et du taux de matières organiques qu'ils contiennent (Wischmeier et al, 1971).

• Le facteur topographique, LS (figure 4)

Le facteur LS est le produit de deux sous facteurs à savoir le sous facteur longueur de la pente et le sous facteur gradient de la pente. Ils proviennent du Modèle Numérique du Terrain (MNT). La longueur de la pente (L) est définie comme étant la distance parcourue par une goutte d'eau depuis la source de ruissellement jusqu'à un point donné du bassin.

Un programme développé sur la base des routines d'ArcView a permis de déterminer la carte de potentiel érosif (figure 5) du bassin selon l'expression suivante :

$$Ap = R \cdot K \cdot LS$$

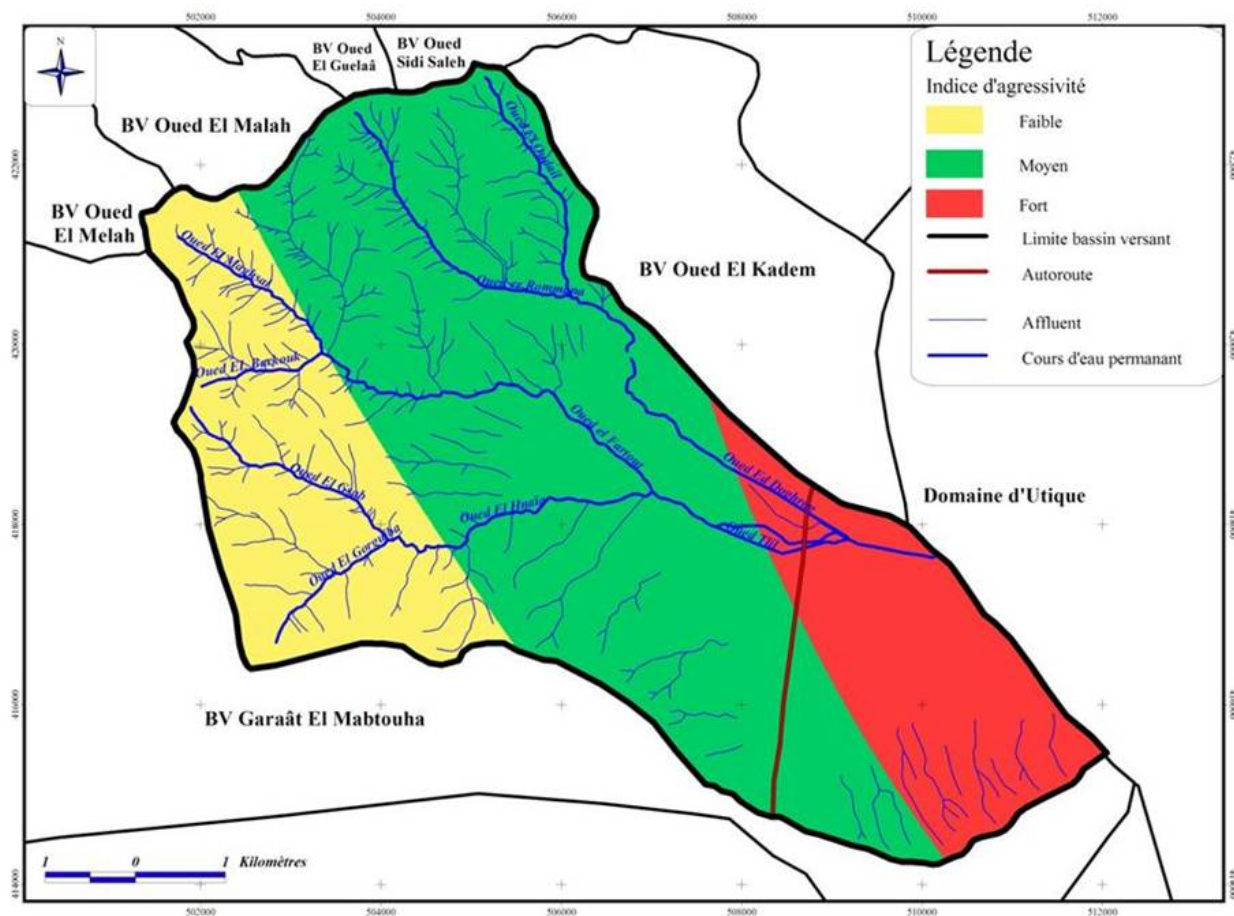


Figure 2 : Indice d'agressivité des pluies du bassin-versant d'oued Tlil

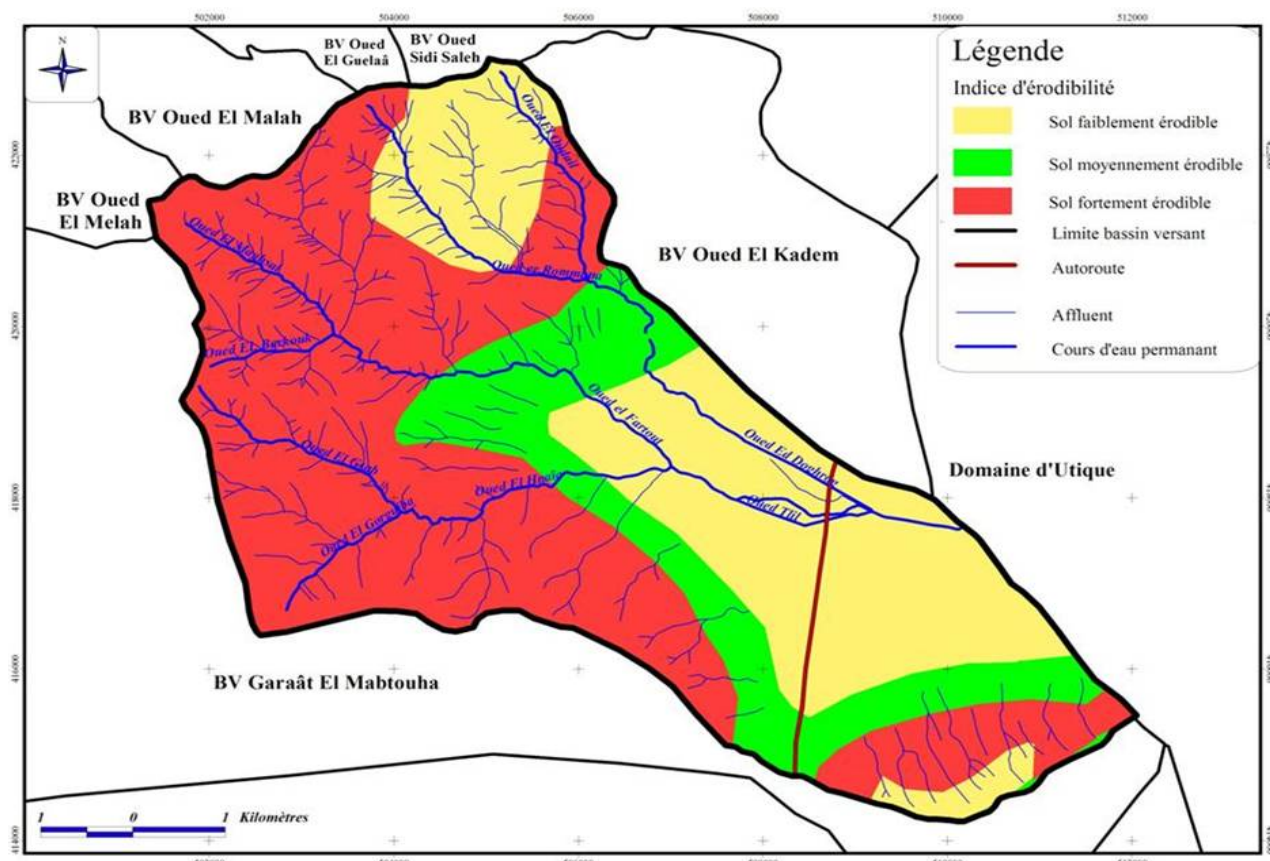


Figure 3 : Indice d'érodibilité des sols du bassin-versant d'oued Tlil

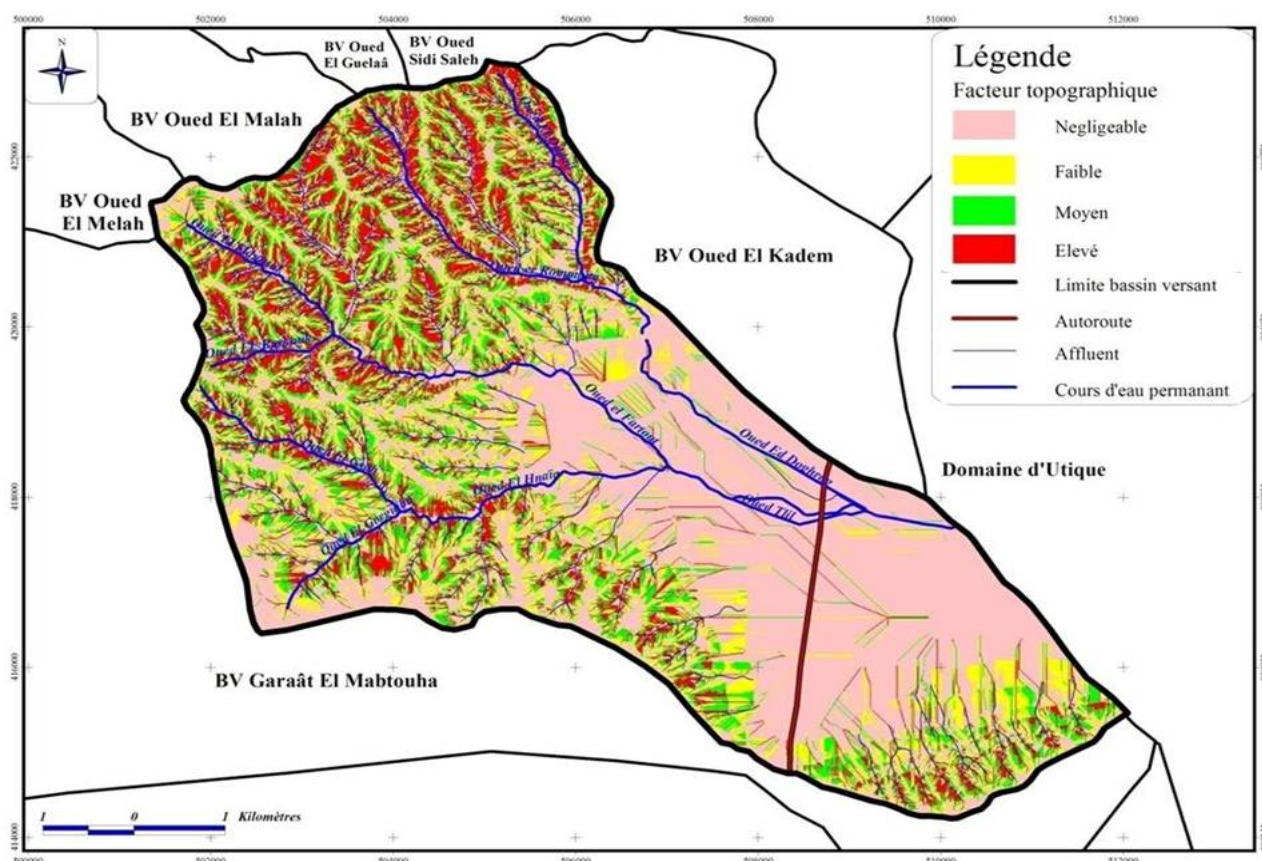


Figure 4 : Facteur topographique du bassin-versant d'oued Tlil

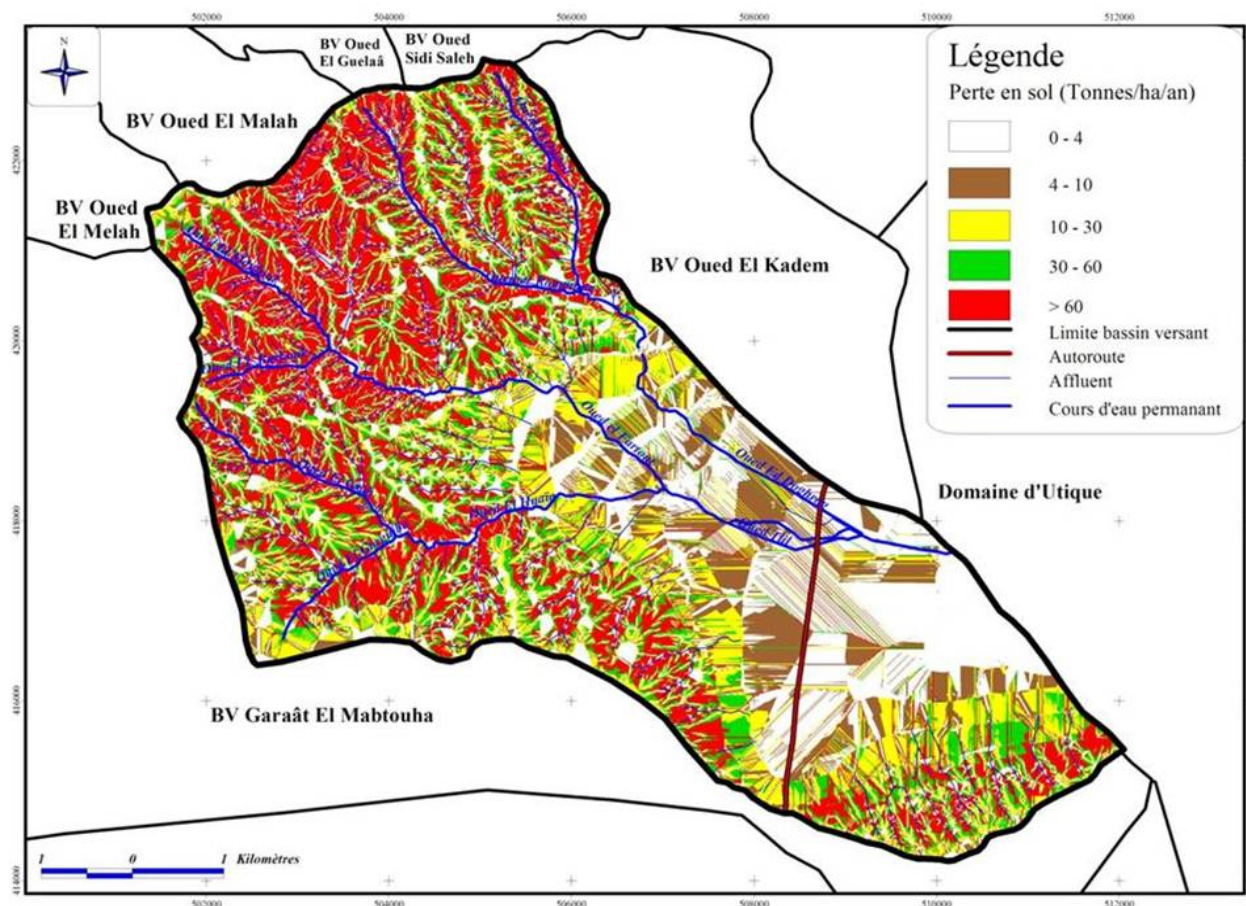


Figure 5 : L'érosion potentielle du bassin-versant d'Oued Tlil

3.2. Érosion actuelle

L'érosion actuelle est définie comme étant la perte en sol découlant de l'interaction des facteurs R, K, LS, C et P.

L'expression du calcul de

$$Aa = R \cdot K \cdot LS \cdot C \cdot P = Ap \cdot C \cdot P$$

Elle est donc fonction de l'érosion potentielle (Ap), du mode cultural (C) et des aménagements antiérosifs de la pente (P).

- **Le facteur cultural, C** (figure 6)

C'est un simple rapport des pertes de terre d'un sol dans un système de production sur les pertes de ce même sol traité en jachère nue continuellement travaillée.

Il prend en considération le fait que la pluie agit proportionnellement sur un sol nu que sur un sol couvert.

On confond dans le même facteur C, à la fois le couvert végétal, son niveau de production, les techniques culturales qui y sont associées, la qualité de la couverture et la croissance des racines, l'utilisation de l'eau par les plantes en cours de croissance et le mode des traitements des résidus. La détermination de ce facteur se base sur l'occupation des terres.

Les valeurs de C varient de 1 pour les sols nus à 0,001 pour les forêts denses et cultures paillées abondamment (Roose, 1994).

Le tableau 1 donne les valeurs de C de quelques cultures (Masson, 1971) selon des études adoptées en Tunisie.

Tableau 1 : Indice cultural C de quelques cultures (Masson, 1971)

Type de végétation	C
Terre nue, jachère nue	1
Arboriculture fruitière	0,9
Blé d'hiver	0,7
Assolement céréalière	0,4
Fourrages	0,2
Assolement céréalière + fourrages	0,1 à 0,01
Pâturages améliorés	0,01

Les valeurs de C adoptées pour le bassin-versant d'Oued Tlil proviennent à la fois du tableau 1 et des études sur les pertes en sol effectuées par Avenard en 1965.

Sol nu	C = 1
Les forêts	C = 0.055
Maquis et broussailles	C = 0.15
Arboriculture et olivier	C = 0.9
Parcours	C = 0.1
Terre de culture	C = 0.5

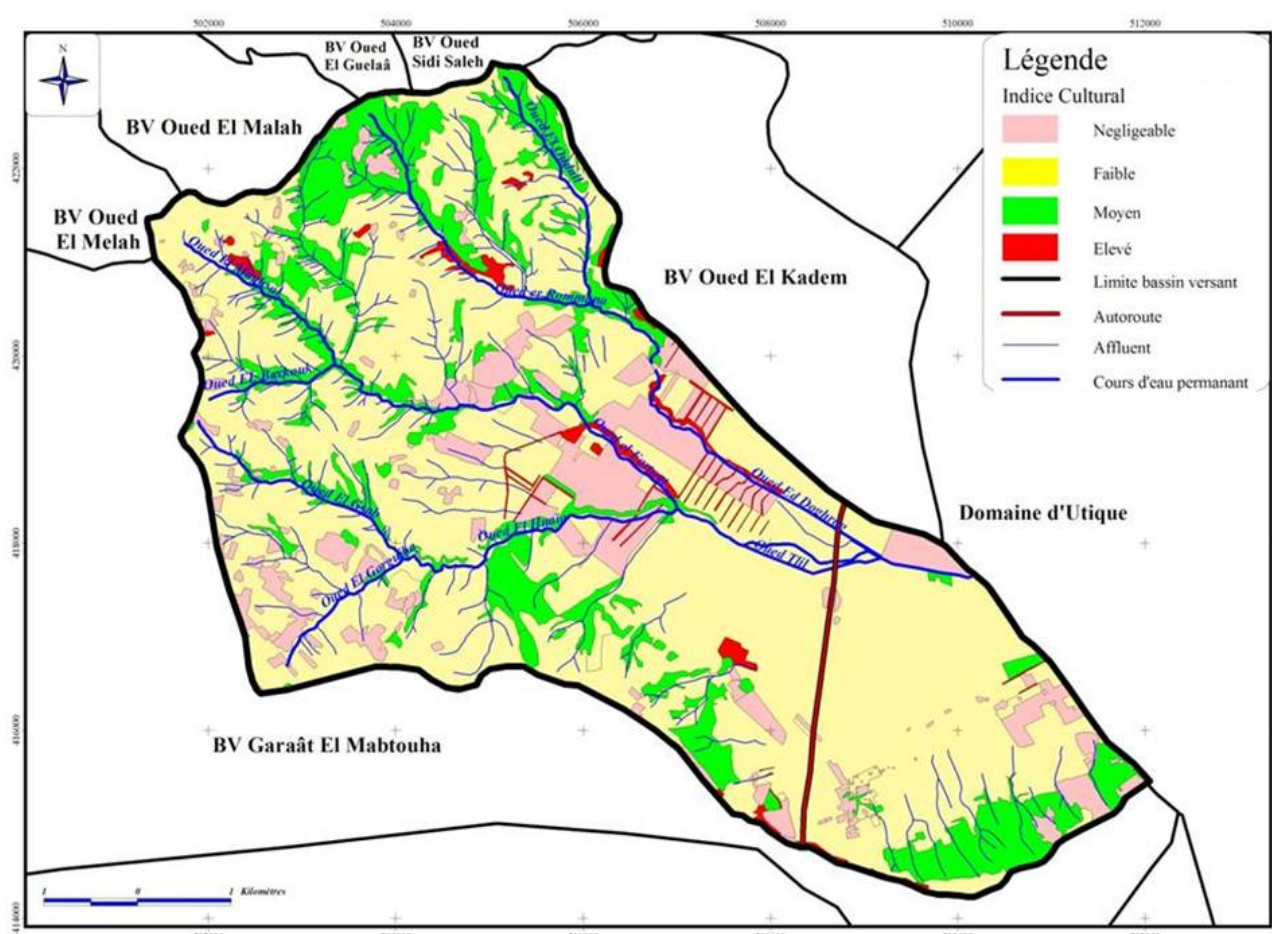


Figure 6 : Indice culturel du bassin-versant d'oued Tlil

• Le facteur aménagement anti - érosif, P (figure 7)

Le facteur anti – érosif P est déterminé à partir de la carte des aménagements existants. Il varie en fonction de l'aménagement effectué sur la pente et de la valeur de la pente elle même.

La cartographie des aménagements existants dans la région d'étude se fait sur la base des photos aériennes suivie d'une prospection de validation sur terrain.

Une fois les aménagements ont été cartographiés, on combine la carte des aménagements avec celle de la pente afin de déterminer sur quel niveau de pente l'aménagement en question a été effectué.

Les valeurs d'indice P retenues pour le bassin-versant d'Oued Tlil sont déterminées en se basant sur les études faites par la FAO en Tunisie en 1977 (tableau 2).

Tableau 2 : Valeurs d'indice P pour le bassin-versant d'Oued Tlil

Pente	Valeurs de P		
	Courbes de niveau	Bandes alternées	Non aménagée
0 – 2	0.45	0.2	1
2 – 8	0.5	0.25	1
8 – 12	0.6	0.30	1
12 – 18	0.8	0.40	1
18 – 24	0.9	0.45	1
> 24	0.95	0.5	1

La représentation cartographique de ce que pourrait être l'érosion actuelle (Aa) (figure 8) se fait par la combinaison des trois facteurs Ap, C et P selon l'expression suivante :

$$Aa = Ap \cdot C \cdot P.$$

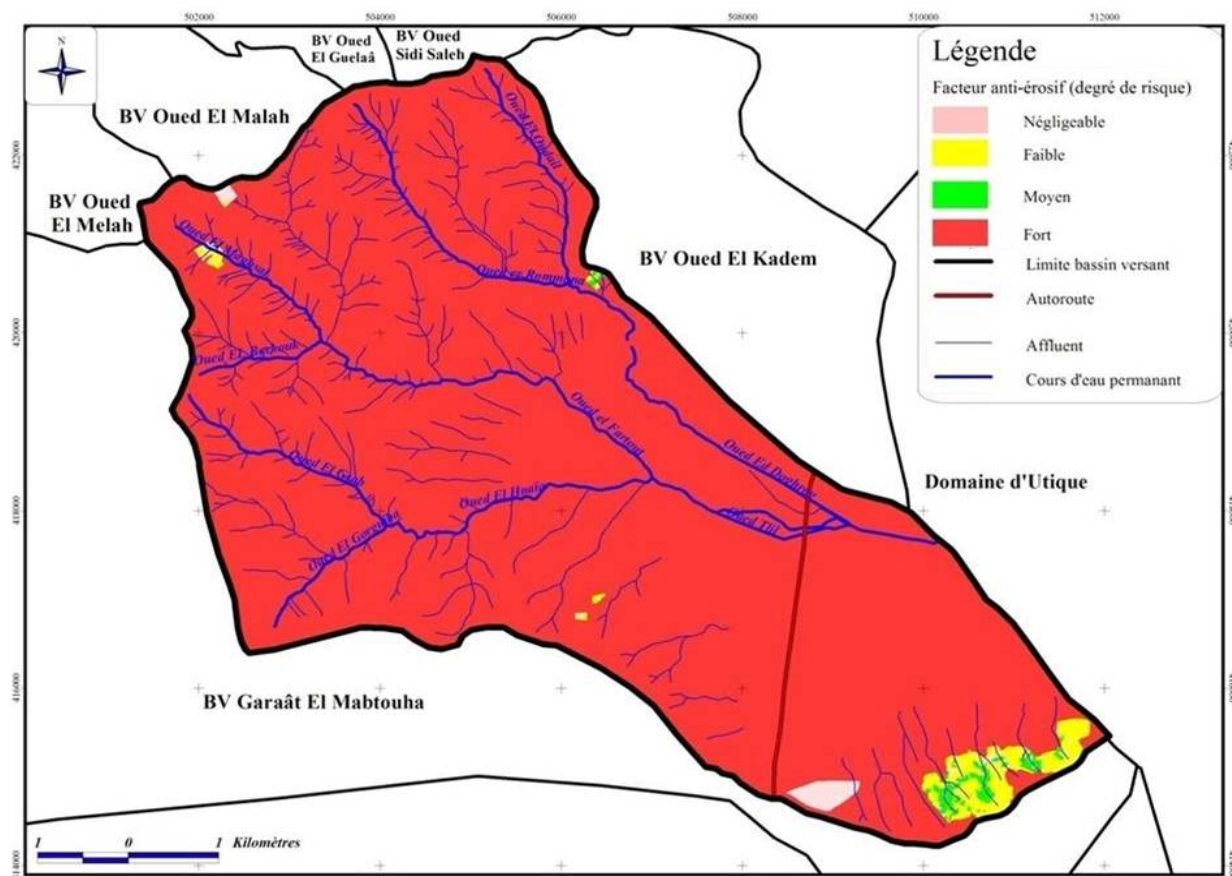


Figure 7 : Facteur aménagement anti-érosif du bassin-versant d'oued Tlil

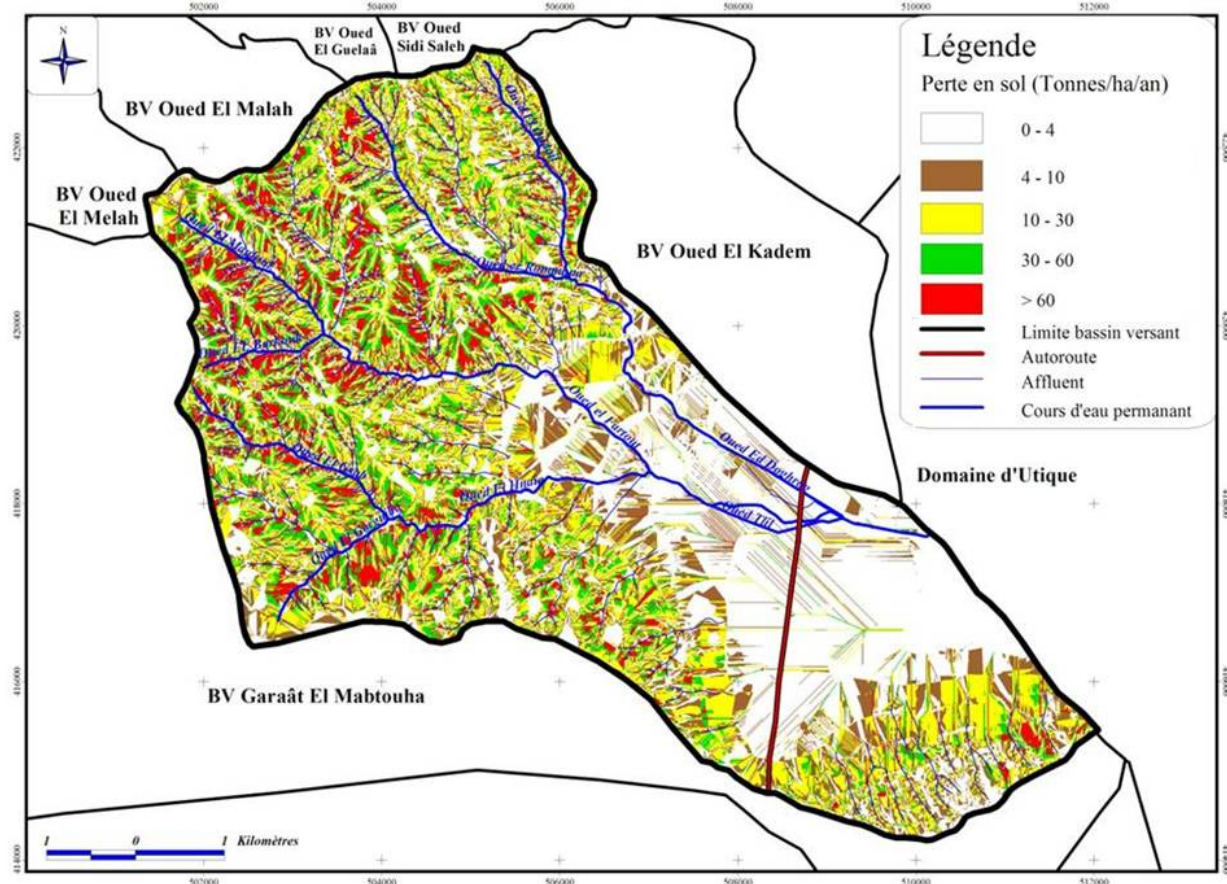


Figure 8 : Valeurs théoriques de l'érosion actuelle du bassin-versant d'oued Tlil selon la démarche adoptée

Conclusion :

L'érosion est un phénomène témoin d'une dégradation de la qualité du sol qui est un capital non renouvelable. Cette dégradation est considérée comme une perte économique. L'intervention pour tolérer cette perte doit se faire dans des contextes tenant compte des conditions naturelles et celles agro-socio-économiques.

La quantification des pertes en terre se fait par le biais des modèles de perte en sol. Dans notre travail, nous avons utilisé le modèle de Wischmeier qui devrait prédire les pertes en terre dues à l'érosion.

Cependant, ce modèle présente quelques limites, il ne tient compte que des pertes en sol dues à l'érosion en nappe et nécessite pour son application une base de données importante et mise à jour.

L'utilisation de la télédétection et des systèmes d'information géographique nous a permis de modéliser le phénomène de l'érosion à l'échelle d'un bassin versant. Cette modélisation a été faite sur la base des unités de taille égale à la résolution définie par les documents utilisés. Le choix de la résolution peut influencer la précision des résultats obtenus.

L'application du modèle de Wischmeier associé à l'utilisation des systèmes d'information géographique nous permet de prédire les pertes en sol d'un bassin versant soit par an, soit par cycle de rotation ou avec une périodicité de retour en X années.

Elle permet aussi de choisir les techniques culturales et les méthodes anti-érosives adaptées en tenant compte de la nature de risque (faible, fort ou très fort).

LA BIBLIOGRAPHIE

- AVENARD J. M., 1965, "La conservation et la restauration du sol", *Projet Sebou*, 47-68.
- CORMARY Y. et al, 1964, "Erosion, ruissellement, travail du sol : Résultats de 18 mois d'expérimentation sur parcelle, C. E. S. D. 15, No 91, 22 p.
- DRE, 2010, *Précipitations enregistrées entre 1993 et 2006*.
- F.A.O., 1977, "Erosion et aménagement des bassins versants dans les pays méditerranéens", *Terre, Eaux et Hommes*, No 30, Vol 9, 27- 45.
- GAMMAR A.M., 2002, *La carte de végétation de la Tunisie au 1/ 2000000*.
- GOUNOT M. et Le HOUEROU H.N., 1955, *La carte des étages bioclimatiques de la Tunisie*.
- JAUZEIN A., 1967, "Contribution à l'étude géologique des confins de la dorsale tunisienne", *Annales des Mines et de la Géologie*, No 22, 470 p.
- MASSON J. M., 1971, *L'érosion des sols par l'eau en climat méditerranéen. Méthode expérimentale pour l'étude des quantités érodées à l'échelle du champ*. Thèse, Université des Sciences et Techniques de Languedoc, 213 p.
- ROOSE E., 1994, "Introduction à la gestion conservatoire de l'eau, de la biomasse et de la fertilité des sols (GCES)", *Bulletin pédologique de la F.A.O.*, No 70, Rome, 420 p.
- SAMAALI H., 2011 *"Etude de l'évolution de l'occupation et de l'utilisation du sol dans le delta de Mejerda par télédétection et systèmes d'informations géographiques (SIG)"*, Thèse de doctorat, Faculté des Sciences humaines et Sociales de Tunis, 377 p.
- WISCHMEIER W. H. and SMITH D. D., 1978, "Predicting rainfall erosion losses : A guide to conservation planning", U.S.D.A, *Agricultural handbook*, No 537, 58 p.
- WISCHMEIER W. H., JOHNSON C. B. and CROSS B. V., 1971, "A soil erodibility nomograph for farmland and construction sites" *Journal of soil and water conservation*, vol. 26, 189 -193.

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Protection des milieux naturels contre l'érosion hydrique et développement durable en milieu Atlasique algérien

Cas de quelques bassins de l'Aurès central (Algérie)

HAFIZA TATAR¹, SABAH TOUIL², HAMZA AMIRECHE³

Résumé. A l'instar des autres territoires, le capital précieux des bassins versants de l'Atlas Saharien algérien demeure le sol. Il est impératif alors de s'appliquer à le préserver sachant que dans ces espaces les sols sont minces et sont soumis au danger de l'érosion hydrique. Ce processus actif constitue un agent de dégradation du sol et ses effets nocifs sont renforcés par une dégradation de la végétation.

Ainsi, au seuil de la restauration de ce capital s'inscrit la conservation proprement dite. L'intervention marquée dans ces espaces passe inéluctablement par un aménagement rigoureux dans la durée. Les structures économiques et sociales doivent conduire à cet effet au mieux l'aménagement de ces bassins versants.

Mots-clés : Algérie, Atlas saharien, Préservation des terres, Erosion hydrique, Dégradation, Transports solides.

Introduction

Les montagnes atlasiques algériennes, peuplées, constituent des écosystèmes vulnérables où la dégradation demeure un processus difficile à maîtriser. Les projets d'aménagement visant à rétablir ou à améliorer l'équilibre écologique de ces milieux, ainsi que l'amélioration des conditions de vie et des revenus des populations, se succèdent mais souvent sans succès.

La lutte contre l'érosion des terres, principale préoccupation des services concernés, reste inefficace et grandement insuffisante.

En Algérie, les pertes en terre sont estimées à 120 millions de tonnes par an et la quantité de sédiments déposés, dans les barrages ne cesse d'augmenter, passant de 484 millions de m³ en 1996 à 700 millions de m³ en 2000.

Les multiples programmes publics de maîtrise de l'érosion menés depuis l'époque coloniale n'ont pas eu les effets escomptés, et ce en dépit de leur coût élevé. Leur inefficacité, en grande partie liée à l'absence d'une intégration d'actions sectorielles dans la politique de l'aménagement de la montagne, c'est-à-dire d'une prise en compte des dimensions des problèmes sur la base de rapports hommes/milieu plus harmonieux, est à l'origine des nombreux déséquilibres actuels.

Les insuffisances enregistrées à ce jour dans ce sens, ont fait prendre conscience de la gravité de la

situation. Il a été, ainsi, décidé de redonner vie à ces espaces montagneux. Pour ce faire, un conseil national de la montagne a été installé par le Ministère de l'Environnement et de l'Aménagement du Territoire, visant la protection des géo systèmes montagneux et notamment leur promotion socio-économique.

Dans les territoires de l'Atlas Saharien, représentés dans cette étude par les bassins versants des Oueds El Gueiss et El Abiod dans l'Aurès central, l'érosion hydrique des sols constitue la principale dynamique. Favorisée par des pluies agressives et concentrées dans le temps, par des formations lithologiques plus ou moins tendres, un relief énergique, escarpé et fortement disséqué, une couverture végétale profondément dégradée par l'homme, elle concerne plus des 2/3 de la superficie de eux bassins.

1. Caractéristiques du relief

Les deux bassins font partie de l'Aurès central, qui appartient à l'Atlas Saharien. Leur relief est dissymétrique : un amont montagneux et un aval à pente faible. Les massifs présentent des alignements orientés SW-NE où gros anticlinaux et larges synclinaux se succèdent et sont souvent perchés. C'est là où s'élève le plus haut massif de l'est Algérien : le Djebel Chélia avec 2328 m.

Leurs aspects physico-géographiques se résument dans les points suivants:

1.1. Bassin de l'Oued El Gueiss: présentant une forme pseudo circulaire, il est orienté SW-NE. Le cours d'eau principal prend naissance à la cote 2177 m au Dj Aidel au sud du bassin. L'oued coule suivant une direction S-N et reçoit en rive gauche et droite ses principaux affluents notamment les oueds Benber, Tarchin, Kerfadjia et Kebass. Sa morphologie permet de distinguer trois types de relief :

- Une chaîne montagneuse de calcaire et de calcaire – marneux, massive et homogène. Elle est formée par des plis parallèles orientés SW-NE. Les dénivellations sont importantes et les principaux

sommets sont localisés au nord et au centre du bassin : Djebel Tizi Ala avec 1282 m et Dj. Tarzout avec 1457 m, au sud, Djebel Aoures culmine à 1521 m et Dj. Feraoun à 2093 m. Cette chaîne s'étend sur 6.6 km² soit 4.6% de la superficie totale du bassin versant. Elle est accidentée ayant des pentes dépassant 25% au S-E et en quelques secteurs localisés à l'ouest.

- Les piémonts, constitués par un substratum calcaire – marneux et de marnes, forment des surfaces d'accumulation à pente douce. L'altitude moyenne varie entre 1100 et 1400 m. Cet ensemble a un aspect de hautes collines comme celle de Ras Tafer à l'est du bassin versant avec une altitude de 1280 m.

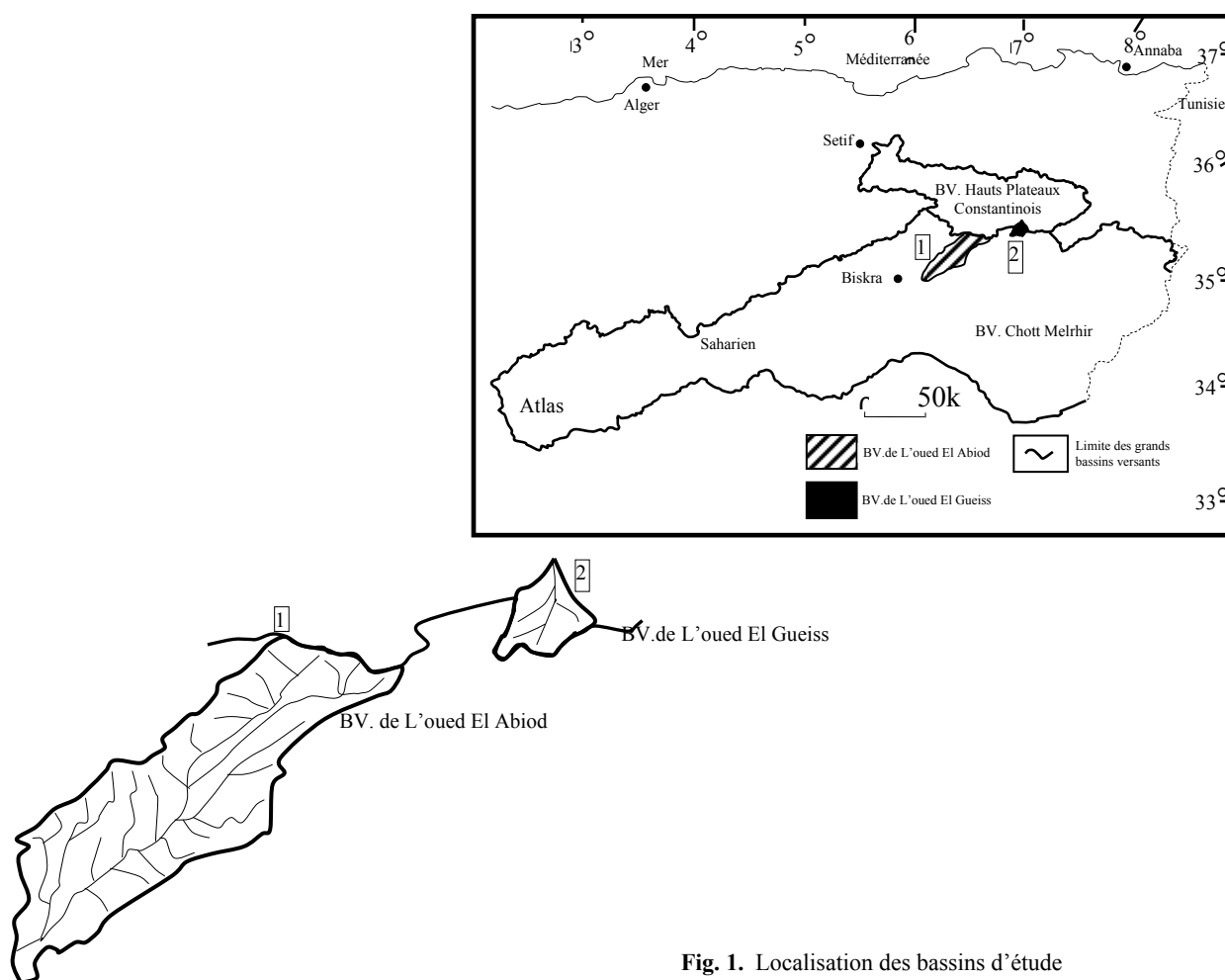


Fig. 1. Localisation des bassins d'étude

- Cônes de déjection et glacis s'observent sur les piémonts et font le raccordement entre les versants et les plaines qui ne sont autre que des surfaces planes, légèrement vallonnées, encadrées par les massifs calcaires, d'une altitude moyenne de 800 à 950 m. Elles correspondent à des fossés d'effondrement et constituent la zone basse. Elles

se localisent au centre du bassin versant, occupant une surface de près de 100 km².

La couverture végétale permanente du bassin versant de l'oued el Gueiss est dominée par les forêts de chêne vert, de pin d'Alep, de cèdre et de genévrier. La densité de ces associations intervient comme un élément de différenciation de la

dégradation du sol. Pour cela, il a été utile d'adopter la classification des types de végétation par ordre de protection selon la grille proposée par J. Tricart (1963). Ainsi, trois principales classes se dégagent:

- les surfaces bien protégées: sont constituées par les forêts de pin d'Alep d'Ouled Yakoube et de Béni Oudjna et couvrent 81% de la surface totale du bassin versant. Cette couverture végétale s'observe dans les secteurs recevant plus de 600 mm/an et 14°C, ce qui classe le bassin dans l'étage bioclimatique semi aride à hiver froid avec une température minimale comprise entre (-1.0 et 17 °C).
- les surfaces partiellement protégées: sont occupées par les vergers (arboriculture), sur une surface de 17 % du bassin, laissant les sols partiellement nus en permanence entre les plantes.
- Les surfaces mal protégées: constituant 2% de la surface totale du bassin versant.

1.2 Bassin de l'Oued El Abiod

Ce bassin présente une forme longiligne à orientation SW-NE. Le réseau hydrographique est constitué par le cours principal : oued el Abiod qui reçoit une série d'affluents (Oued Zellatou, Oued Telbeida, Oued el Atrous...). Coulant du nord au sud, il reçoit ses principaux affluents en rive droite et en rive gauche avant d'atteindre le Chott Melghir dans le Bas Sahara.

La lithologie montre que le bassin est composé par des formations du Quaternaire : alluvions des oueds et dépôts de pente à résistance faible occupent 33% de la surface totale du bassin versant, les marno- calcaires 31%, le calcaire massif et les grès avec 13%. Le relief de ce bassin se subdivise en trois grands ensembles :

- Les montagnes :Elles se caractérisent par un enchainement de massifs calcaires et gréseux. On peut citer à titre d'exemple, les sommets du Chelia et d'Ichmoul au nord avec des altitudes variant entre 2000 et 2328m et des pentes supérieures à 25%;
- Les piémonts : développés dans un matériau marno-calcaire, moyennement résistant, ils occupent 31% de la surface totale du bassin versant. Ils représentent les pentes moyennes (3-12.5%);
- Les plaines, qui se développent sur la plateforme saharienne, avec des pentes inférieures à 10% se situant surtout au sud du bassin entre M'chouneche et Foum el Gherza. Elles sont caractérisées par des formations quaternaires et occupent 33% de la surface totale.

La végétation est composée d'une couverture permanente de forêts de cèdre, de chêne vert et de pin d'Alep, occupant respectivement 18 et 24% de

la surface totale du bassin. Le reste est occupé par du maquis, de l'alfa et les terrains mal protégés ou nus.

Avec une pluviométrie moyenne annuelle de 276 mm et une température moyenne annuelle variant entre 16 et 23°C, le bassin versant de l'oued el Abiod est dominé par deux types de climat : le semi aride à hiver tempéré à l'amont et le semi aride à hiver chaud à l'aval.

2. Estimation des transports solides en suspension

Le bilan a été réalisé à partir des mesures instantanées des débits liquides (Ql) et des concentrations (C) aux stations hydrométriques de M'chouneche et de Foum el Gueiss, situées à l'amont des barrages de Foum el Gherza et de Foum el Gueiss. Les mesures couvrent une période de 30 ans soit du 1^{er} septembre 1975 au 31 Août 2005.

Le débit solide en suspension est calculé par la méthode classique :

$$Q_s = C * Q_l \text{ où:}$$

Qs: représente le débit solide mesuré.

Ql: la valeur du débit liquide.

C: la concentration.

La relation en puissance $Q_s = a * Q_l^b$ reliant le débit solide au débit liquide (où les paramètres (a) et (b) sont des coefficients), (a) a été vérifiée pour la plupart des cours d'eau dans le monde, l'exposant (b) fonction des caractéristiques physiques, climatiques et hydrologiques des bassins versants, ou des conditions hydrauliques de l'écoulement dans les cours d'eau.

Le taux de transport solide spécifique obtenu à partir des mesures de sédiments fins et très fins en suspension est ramené à la superficie totale de chaque bassin. Ces sédiments représentent dans chaque bassin les produits d'une dynamique érosive qui affecte, par diverses formes d'érosion, des zones d'ablation observables sur des versants instables.

S'agissant du bassin de l'oued el Abiod, il se caractérise par des conditions géomorphologiques beaucoup plus favorables à une érodibilité élevée. Le coefficient d'écoulement est de 4.42%. Il est inférieur à celui du bassin versant de l'oued el Gueiss. La pluviométrie et l'écoulement annuels de ce bassin sont respectivement de 275.6 mm et de 12.17 mm et sont inférieurs à ceux de l'oued el Gueiss.

Le coefficient orographique, moins élevé que celui de l'oued el Gueiss, exprime un potentiel énergétique élevé du relief et d'une morphométrie favorable à l'érosion.

Le rapport de la classe de pente dominante (12.5-25%) ramené à la superficie totale du bassin versant, donne un taux de 52% dans le bassin versant de l'oued el Abiod et 50% dans celui de l'oued el Gueiss. En effet, la dynamique érosive résultant de ces différences de comportement hydromorphométrique montre à l'échelle annuelle deux principales caractéristiques:

- Un rapport de 2 fois entre la charge solide moyenne de l'oued el Abiod (364 T/km²/an) et celle de l'oued el Gueiss (157T/km²/an).

Par ailleurs, les différences du comportement morphologique et du fonctionnement hydrologique peuvent être mieux expliquées par les types de relation dans chaque bassin versant entre les pluies, l'écoulement et les transports solides.

3. Types de relations entre pluies-écoulement et transports solides en suspension

3.1 A l'échelle annuelle: les transports solides spécifiques représentent les produits du comportement géomorphologique et du fonctionnement hydrologique conditionnés par des combinaisons complexes des différents facteurs de l'érosion dans chaque bassin versant. A cet effet, les relations entre les pluies et les transports solides spécifiques sont exprimées par des corrélations polynomiales qui reflètent beaucoup les caractéristiques suivantes:

- Les valeurs annuelles des pluies et de l'écoulement de l'oued el Abiod sont inférieures à celles de l'oued el Gueiss, par contre les valeurs des transports solides spécifiques sont supérieures à celles de l'oued el Gueiss.

- La valeur du coefficient de corrélation entre les pluies et les transports solides spécifiques s'élève à 0.53 dans le bassin versant de l'oued el Gueiss alors qu'il ne dépasse pas 0.22 dans le bassin de l'oued el Abiod.

- La valeur du coefficient de corrélation entre l'écoulement et les transports solides spécifiques s'élève à 0.8 dans le bassin versant de l'oued el Abiod de même que pour le bassin versant de l'oued el Gueiss, elle ne dépasse pas 0.79 .

- les valeurs maximales annuelles des pluies et des transports solides spécifiques de l'oued el Abiod sont supérieures respectivement de 2 et 4 fois à celles de l'Oued El Gueiss.

- les années hydrologiques 1991-1992 dans le bassin versant de l'Oued El Abiod et 1980-1981 dans le bassin versant de l'Oued El Gueiss, montrent une discordance entre des précipitations, supérieures à la moyenne annuelle, et des transports solides spécifiques inférieurs au tonnage moyen annuel. Ces irrégularités montrent que le seul

facteur pluviométrique reste insuffisant à l'échelle annuelle pour expliquer les variations des transports solides.

- une relation nette entre les trois variables, pluies, écoulement et transports solides existe dans les deux bassins versants durant l'année hydrologique 1976-77, excédentaire et humide, et également durant l'année hydrologique 1980-81 déficitaire et sèche.

Les relations qui existent entre l'écoulement et les transports solides reflètent une concentration dans le temps des processus érosifs. Le régime d'écoulement est caractérisé dans les deux bassins versants par une période d'étiage qui est aussi une période de répit pour la dynamique érosive. De ce fait, il est intéressant de déterminer les périodes d'érosion pour mieux comprendre les variations spatio-temporelles des transports solides.

3.2 A l'échelle mensuelle:

- les valeurs moyennes de la période choisie montrent une dynamique érosive concentrée en automne avec 48T/km² dans le bassin versant de l'oued el Abiod et près de 60T/Km² au printemps dans le bassin versant de l'Oued El Gueiss .

- Une concordance dans le temps entre les valeurs mensuelles moyennes des pluies, de l'écoulement et du transport solide spécifique, en Automne dans le bassin versant de l'oued el Abiod, et au Printemps dans le bassin versant de l'Oued El Gueiss (fig. 2).

- La valeur du coefficient de corrélation montre que la relation entre le transport solide et l'écoulement est supérieure à celle obtenue par la relation entre le transport solide et les pluies dans le bassin versant de l'oued el Abiod. Par contre, le bassin versant de l'oued el Gueiss montre un coefficient de corrélation entre le transport solide et les pluies, supérieur à celui obtenu par la relation entre transport solide et écoulement (fig. 3).

- le coefficient de corrélation entre les pluies et les transports solides spécifiques, s'élève respectivement de 0,53 à 0,71 dans le bassin versant de l'Oued El Gueiss et de 0,22 à 0,50 dans le bassin versant de l'Oued El Abiod. Ces valeurs sont supérieures à celles obtenues par la relation écoulement/transports solides qui ne dépassent pas 0,59 dans le bassin versant de l'Oued El Gueiss et inférieures à 0,83 dans le bassin versant de l'Oued El Abiod.

Ainsi l'importance des transports solides en suspension des deux oueds est une réalité incontournable. Favorisée par des débits forts en rapport avec la pluviométrie élevée et aussi par la saturation quasi-totale des sols, elle revêt des aspects inquiétants.

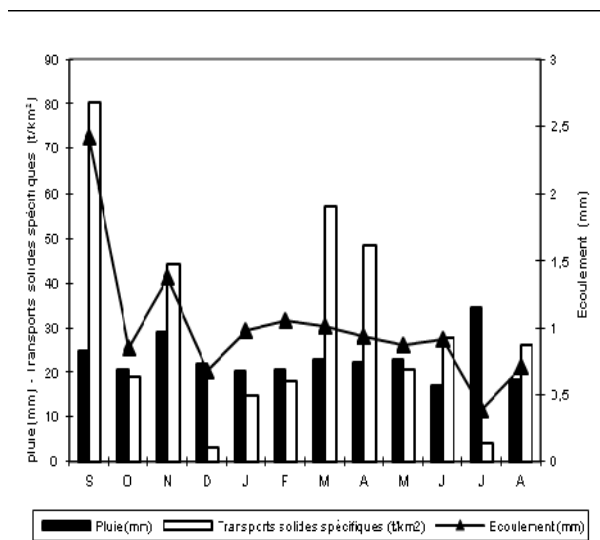


Fig. 2a. Variations des pluies, de l'écoulement et des transports solides spécifiques moyens mensuels de l'oued el Abiod à la station M'chouneche, période (1975-1976/2004-2005)

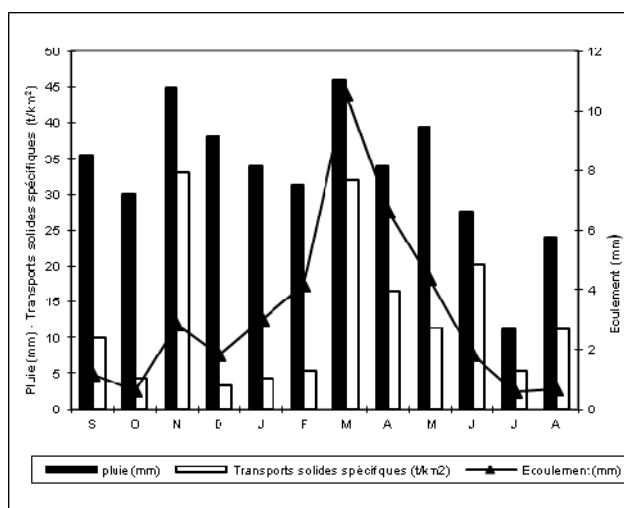


Fig. 2b. Variations des pluies, de l'écoulement et des transports solides spécifiques moyens mensuels de l'oued el Gueiss à la station Foum el Gueiss, période (1975-1976/2004-2005)

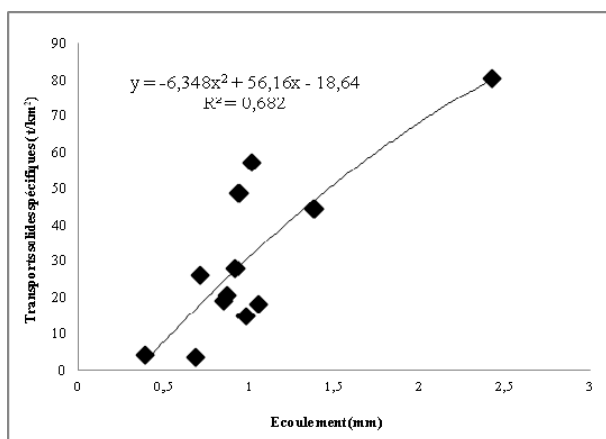


Fig. 3a: Corrélation entre l'écoulement et les transports solides spécifiques moyens mensuels dans le bassin versant de l'oued el Abiod

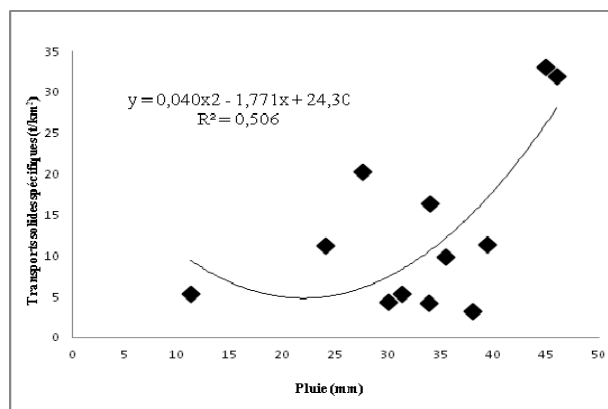


Fig. 3b: Corrélation entre la pluviométrie et les transports solides spécifiques moyens mensuels dans le bassin versant de l'oued el Gueiss

La dynamique érosive est intense, notamment au moment des crues, et elle est caractérisée par des formes variées (érosion linéaire, sapement des berges). Elle est conditionnée par :

- L'exposition des versants de ces bassins aux flux d'air polaire qui sont caractérisés par des pluies exceptionnelles de forte intensité.
- La dominance d'une lithologie tendre (marne, gypse et sable).
- La faiblesse de la couverture végétale, notamment pour le bassin versant de oued El Abiod où 58% de la surface totale sont nus ou mal protégés.

Le bassin versant de oued Labiod, plus que celui de Oued El Gueiss est ainsi de par ses composantes physiques, plus sensible à la dynamique érosive. La pression anthropique, à laquelle il fait face depuis quelques temps va activer cette sensibilité et permettre aux processus érosifs de se développer et de prendre des dimensions inquiétantes.

4. Influence de l'utilisation des terres sur les risques d'érosion

Les territoires des deux bassins sont fondamentalement ruraux et leur principale activité est axée sur l'agriculture (céréaliculture extensive, arboriculture, pâturage...), pratiquée sur les pentes légères (0-3%) sur les terrasses ainsi que sur de petites enclaves en forêt.

Elle est le facteur important par lequel l'homme peut intervenir pour modifier la sensibilité des sols face à l'agressivité des pluies.

Dans les bassins de oued El Abiod et oued El Gueiss, l'agriculture minière menée depuis plus d'un demi siècle, suite à la pression démographique, a enclenché divers processus d'érosion comme

l'érosion en nappe et le ravinement, processus induits par la déforestation, le surpâturage, la mise en culture de terres fragiles..... Ces derniers, entraînant l'augmentation du ruissellement et la diminution des eaux utiles, fragilisent la résistance du milieu.

L'interférence de la pente, la lithologie, la densité de drainage, la couverture végétale et les formes de l'érosion a permis de déterminer la vulnérabilité des bassins versants de l'Atlas Saharien (fig. 4).

Ainsi trois zones se dégagent :

- *Les zones à stabilité précaire*: se situant à l'amont du bassin versant. Elles présentent un type d'érosion à entaille linéaire surtout, aussi les chutes de blocs, les éboulements et les éboulis aux pieds des corniches calcaires sont fréquents.

- *Les zones pénée-stables*: elles se limitent au centre du bassin. Les processus dominants sont surtout gravitaires, tels les éboulements et éboulis. Au débouché des torrents s'édifient des cônes de déjection plus ou moins larges.

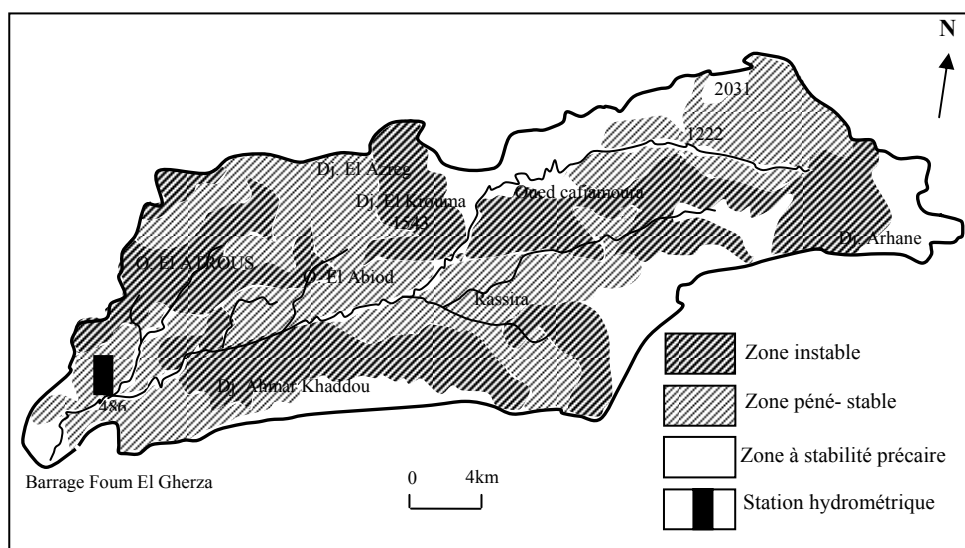


Fig. 4 a. Bassin versant de l'oued el Abiod- Vulnérabilité à l'érosion

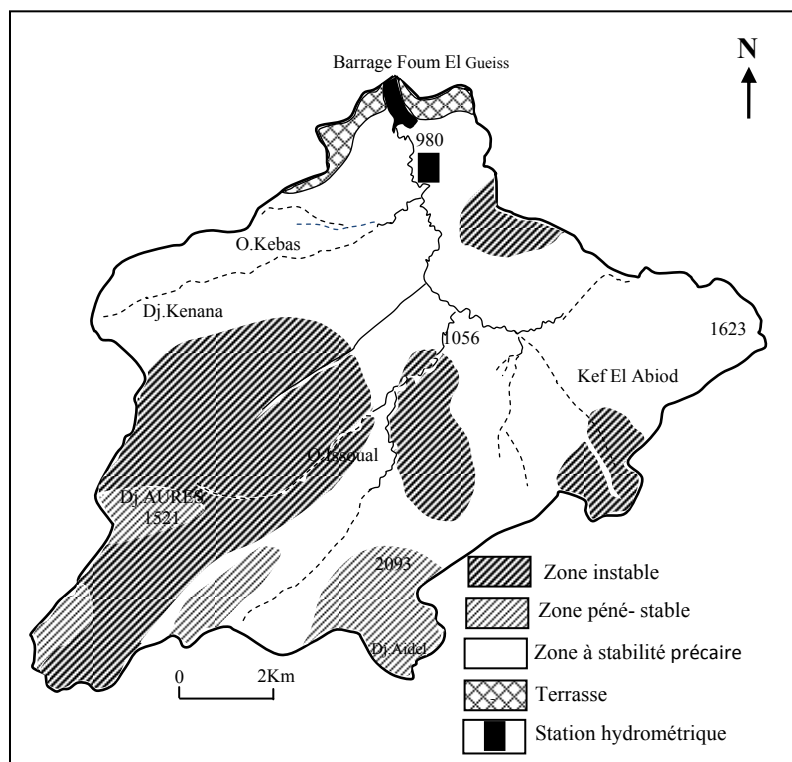


Fig. 4b: Bassin versant de l'oued el Gueiss- Vulnérabilité à l'érosion

- *Les zones instables*: sont caractérisées par quelques mouvements de masses (mouvements humides), ravinements et bad-lands, dans les marnes grises épaisses. Elles se localisent dans la partie N-O et à l'aval du bassin versant.

La superposition des différentes cartes (pente, lithologique, densité de drainage, couverture végétale, formes de l'érosion) a permis de déterminer la vulnérabilité du bassin présenté ci-dessus. Celle-ci varie entre faible et très forte. Les valeurs obtenues, malgré leur apparente hétérogénéité présentent une structure spatiale définie par la localisation topo-paysagère dans laquelle elles s'inscrivent. En effet, les sommets subissent toujours la plus forte érosion, et ont donc les valeurs les plus élevées les valeurs moyennes s'observent sur les versants et les valeurs les moins élevées se localisent vers l'aval.

Les fortes valeurs enregistrées en amont du bassin (théoriquement bien couvert) sont dues essentiellement à la dégradation de la forêt qui a subi de grands dommages du fait des incendies répétés et des défrichements, aux fluctuations pluviométriques liées aux grandes modifications climatiques mondiales et qui prennent toute leur signification ici, conditionnant et contraignant le couvert végétal déjà affaibli, conditionnant également l'écoulement, aux pentes raides qui influent sur la vitesse des écoulements et l'énergie de déplacement des particules issues de matériaux meubles et enfin à la pression anthropique sous toutes ses formes (parcours, modes de culture.....).

Face à cette situation de multiples actions ont été entreprises par les différentes instances concernées, afin de ralentir cette dynamique érosive, et pourquoi pas de la renverser.

Un certain nombre d'aménagements a été proposé visant à la fois le développement rural et l'amélioration de la production grâce à une meilleure gestion de la biomasse et de la fertilité des sols par une diversification des espèces végétales

5. Conservation de l'eau et des sols

Des efforts importants ont été consentis pour la conservation de l'eau et du sol à l'échelle des bassins versants atlasiques, et même si les résultats escomptés n'ont pas toujours été atteints, ils ont contribué de manière plus ou moins significative à la réduction observée du taux d'érosion ravinante. Parmi les techniques de lutte contre l'érosion hydrique, celles visant la diminution du taux d'envasement du barrage ont été privilégiées. Nous citons :

Au niveau du bassin versant de l'oued el Gueiss

- Le reboisement sur les deux rives de l'oued el Gueiss et aussi au départ de l'oued kerfadja

- La plantation de cyprès dans la zone de Dj Tarzoute et aussi dans la plaine noughisse pour protéger le sol contre les effets des eaux d'écoulement;

- La correction torrentielle des cours d'eau par la fixation des berges au niveau des affluents des oueds issouel et oued kerfadja;

- La construction des gabions sur l'oued el Gueiss et sur les oueds (kerfadja, kebass, benber, issouel);

- La construction des murettes qui ne doit pas dépasser 60cm de hauteur dans l'oued el Gueiss et oued kerfadja où il ya une grande vitesse d'écoulement;

- La création des retenues collinaires sur oued kerfadja qui reçoit une grande quantité d'eau d'écoulement.

Au niveau du bassin versant de l'oued el Abiod

- Les murettes en pierre sèche sur les pentes fortes, constitue un obstacle qui diminue la vitesse d'écoulement;

- Réseau de banquettes dans les zones montagneuse (Ahmer kheddou, Tahammamet, Draa de M'chouneche Takhout);

- La correction du lit des torrents par une successivité des barrages sur l'oued el Abiod et certains affluents comme Zellatou, Theniet el Beida, el Atrous, etc.;

- La correction torrentielle des cours d'eau par :

- La fixation des berges de l'oued Zellatou et oued el Atrous pour protéger les sols contre l'érosion et protéger les berges contre les crues.

- La plantation des zones montagneuses qui dépassent 1000m d'altitude par le cèdre de l'Atlas et le chêne vert et les régions chaudes à faible altitude par le thuya de barbarie (ARAAR), et le genévrier rouge.

- Réalisation des barrages de décantation des apports solides qui empêchent la vase arrivée jusqu'au barrage

- La rotation des cultures sur une même parcelle, successivement, différentes plantes, pour équilibrer le type du sol.

- La pratique du labour devront être exécuté suivant les courbes de niveau sur les pentes inférieures à 3%.

- La construction d'un système d'obstacle en gabion pour piéger les sédiments fins et très fins en amont de cours d'eau principal.

- Améliorer les terres de parcours tout en veillant à éviter le surpâturage.
- Le choix des espèces fourragères à enracinement très profond, utilisée pour la protection des berges et des talwegs.

Conclusion

Ainsi les actions menées ont été variées et multiples durant plus de deux décennies (1974-1998). A partir de l'année 2000, l'évaluation a montré que les interventions publiques menées dans le cadre de politiques sectorielles ou de programme de développement local ont permis certes d'atteindre quelques résultats satisfaisants dans la protection des milieux naturels, mais néanmoins insignifiants par rapport à l'ampleur des phénomènes. Les actions se sont limitées le plus souvent aux seuls ouvrages de lutte anti-érosive, négligeant le volet « pratiques et techniques agricoles » qui permet de fixer les populations et d'accroître leurs revenus. Les activités économiques en place n'ont pas réussi à stabiliser les populations locales.

Pour répondre à cette préoccupation, un programme de développement agricole fut lancé en juillet 2000 et élargi en 2002 aux espaces isolés et marginalisés. Il fut suivi d'un programme national de développement agricole et rural qui est un prolongement du premier. Son contenu et sa conception tient compte plus amplement des contraintes naturelles, techniques organisationnelles et culturelles du monde rural en général.

A partir de 2006, un nouvel instrument de développement rural vit le jour reposant sur une stratégie de développement rural durable. Ce plan de renouveau rural est projeté sur un horizon décennal et se veut être un cadre visant à réaliser les objectifs suivants :

- Mise en place de partenariats effectifs dans les zones rurales.
- Diversification des activités en vue de sécuriser les revenus des ruraux.

- Revitalisation des zones rurales et valorisation des ressources naturelles dans une optique de développement durable.

Les pouvoirs publics sont maintenant conscients que le développement des milieux montagneux doit passer par une gestion rationnelle de ces territoires et de leurs ressources. La stratégie doit être axée sur la durabilité du développement, c'est-à-dire que la gestion des ressources (eau, sols...) ne pourrait être envisagée de manière unilatérale et unitaire. Elle devrait avant tout impliquer les personnes concernées (les fellahs) et tenir compte de critères fondamentaux tels que les spécificités de l'unité, la concertation, l'économie et l'universalité dans la prise en charge des problèmes des géo-systèmes montagnards.

Aujourd'hui, le savoir – faire devrait être repensé dans le sens de l'efficacité, de la rentabilité et de la durabilité. Les pratiques rentables, moins coûteuses, évitant le développement de la dynamique érosive (abandon des terres, surpâturage, travaux des sols inadaptés, le labour suivant la pente, l'inadaptation de l'arboriculture fruitière...) et facilement reproduites par les paysans devraient être privilégiées. Mais avant toute chose :

- un travail de prospection et de délimitation de zones à risques doit être entrepris;
- une détermination des zones nécessitant une action prioritaire;
- une estimation de l'aléa érosion des sols, provenant de n'importe quel modèle qui pourrait être employé dans le contexte de la protection des sols;
- des aménagements visant à la fois au développement rural et à l'amélioration de la production.

Pour cela, il faudrait une approche méthodique et participative impliquant l'ensemble des acteurs. Cette dernière a pour avantage d'intégrer le facteur anthropique, en associant l'homme avec son savoir local, ses attentes et ses besoins.

BIBLIOGRAPHIE

- AICHE M., (2008), *Impacts anthropiques sur la stabilité des milieux physiques et aménagements. Cas du bassin versant de Bouhamdane (N-E algérien)*. Thèse d'Etat. Université Annaba. 305p.
- AMIRECHE H., (2001), *L'eau, le substrat, la tectonique et l'anthropisation dans les processus érosifs du Tell Nord-Constantinois*. Thèse d'Etat. FSTGAT. Université Mentouri Constantine. 227 p.
- BOUROUBA M., (1994), *Bilan de l'érosion des bassins versants de l'Algérie orientale*. Trav. Inst. Géogr. Reims. N° 85.
- BOUROUBA M., (1998), Contribution à l'étude de l'érosion et des transports solides de l'oued Medjerda supérieur Algérie orientale). *Bulletin ORSTOM*, 18, 76-97.

- BOUROUBA M., (2002), Comparaison de la charge solide en suspension dans les oueds algériens : Essai de synthèse. Bulletin réseau érosion, 21, 358-374.
- BRAHMIA K., (1993), Essai sur la dynamique actuelle dans la moyenne montagne méditerranéenne : bassin versant de l'oued Mina. Thèse.
- KHELIL.A., (2000), *La société montagnarde en question*. ANEP.105 p
- LAOUINA A., (1999), *La gestion intégrée des zones rurales périphériques et la problématique de la gestion des ressources*. In Sedjari A : Aménagement du territoire et développement durable. L'Harmattan. pp. 317-321.
- LAOUINA A., (1999), *La participation de la population rurale, critère de succès des interventions de lutte anti érosive en montagne : cas des montagnes pré-rifaines*. Etu. Géogr. Phys. N° XXVIII. Actes Colloque « La montagne méditerranéenne » Octobre 1998. Aix en Provence.
- MAURER G., (1992), *Montagnes et Montagnards au Maghreb : évolution récente du milieu naturel*. Cahiers URBAMA. N°7. pp 37-58.
- SNAT, (2007), *Projet SNAT*. Ministère de l'Aménagement du Territoire et de l'Environnement. Alger. 3 Tomes.

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Landslides Hazard Assessment in the Upper and Middle Sectors of the Strei Valley

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Abstract: The landslides have been identified at the geomorphological units level, included in the study area, beginning with the second half of the 20th century, but a factor based analysis was performed only in the first part of the 21st century.

In some cases, works for stabilizing the affected slopes were made, but by modifying the land use and destroying the existing works, the processes have been reactivated. At present, the process continues to extend and to take out from the agricultural circuit large areas, fact noticed after analyzing maps from different periods as well as during the field activity. Consequently, we considered to make an objective landslides hazard assessment, following the steps from a legal framework, in order to use the results in territorial planning studies.

Key words: landslides, hazard assessment, mean hazard coefficient, upper and middle sectors of the Strei valley.

1. Introduction

With an area of over 1559 sq.km, the upper and middle sectors of the Strei valley stands out as a well-individualised natural entity, almost entirely included in the Southern Carpathians, except the north-western part that belongs to the Western Carpathians, and has a general triangular shape. It is

bordered to the south-east by the Retezat Mts., to the south by Piule Iorgovanu Massif and the Godeanu Mts., to the west and north-west by the Tarcului Mts. and Poiana Ruscai Mts., and by the Sureanu Mts. to the north-east (Fig. 1). From the administrative point of view, within its boundaries there are included 10 communes, dominated by one town.

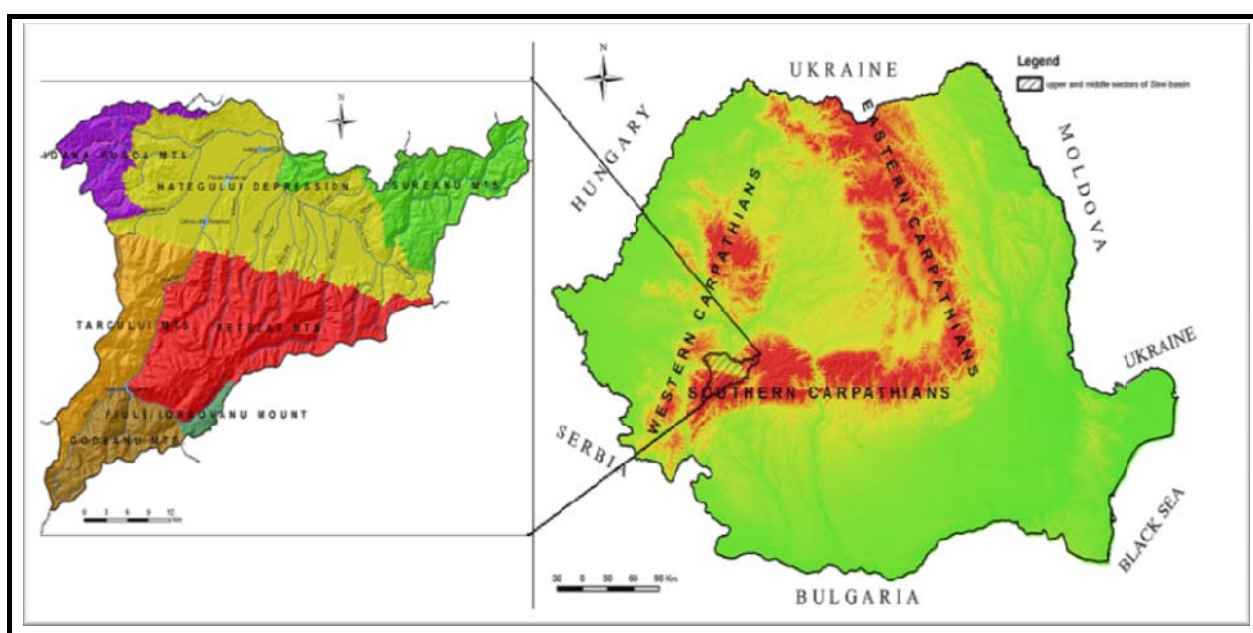


Figure 1. Upper and middle sectors of the Strei valley. Location map

In Romania, the study of landslides has a long tradition. Whether we are talking about the landslides that occurred in the Carpathians, the Sub-Carpathians, the plateaus or depressions, their study focused on issues, such as: triggering factors, morphology, morphodynamics, distribution, age, etc.

The presence of landslide processes in the Hategului Depression was reported by **Grumazescu, 1975**. Also, in the agro-pedological studies conducted in 1976, 1983 and 2003, for certain areas of the upper and middle sectors of the Strei valley, these processes were localized, without putting emphasis on other aspects. The assessment of the slopes' susceptibility to landslides was performed for the first time in Tara Hategului by **Gotiu and Surdeanu, 2008**. The authors conducted a factor analysis of the slopes susceptibility to landslides using the frequency rate method. A synthesis map was obtained by overlaying thematic maps.

2. Methodology

In this study, the landslides **identification and mapping**, based on 1:25,000 scale cartographic materials, edition 1963, studies accompanying soil maps from 1976, 1983 and 2007 and orthophotos, edition 2005 (resolution 0.5m) was conducted. The data obtained was supplemented with information gathered during the field work. To harmonize the results at the national level, in the landslide hazard assessment, we used the methodology set out in the Government Decision no. 447/2003. Thus, the results can be used in planning studies.

To obtain the **landslide hazard map**, we followed these steps:

a) we estimated the value and geographical distribution of risk factors (Ka-h) based on the criteria from Appendix C from the methodological norms: lithology (Ka), geomorphology (Kb), structure (Kc), hydrology and climate (Kd), hydrogeology (Ke), seismicity (Kf), forestry (kg), anthropogenic (Kh);

b) we established the potential degree (low, mean, high) associated with a certain landslides occurring probability (zero, low, mean, mean-high, high and very high);

c) we divided the area into polygonal areas separated so that they present a great homogeneity in terms of lithology and structure;

d) we evaluated, for each polygon, the Ka-h risk coefficients;

e) we calculated the *mean hazard coefficient* (Km), corresponding to each analyzed polygon area, following the equation:

$$K_m = \sqrt{\frac{K_a \times K_b}{6} (K_c + K_d + K_e + K_f + K_g + K_h)}$$

f) we drew the map with the geographic distribution of the Km mean hazard coefficient;

The obtained thematic maps were overlaid and the susceptibility coefficient was calculated using *Spatial Analyst- Raster Calculator* function.

3. Results and Discussions

In the upper and middle sectors of the valley Strei, we identified over 200 areas with stabilized, reactivated landslides or which occurred in the 1963-2011 period. Among the remedial works, performed over time on the landslide bodies, stand out: orchard plantations to stabilize the landforms (right slope of the Galbena river, the left slope of the Breazova, the right slope of the Strei between Pui and Baiesti; Merisor) and the draining wells in the landslide body, walls building, which retain the weight pressure of the main body, to protect rail and road (Baru-Merisor).

The results validation was done by overlaying the map with the landslides mapped in the field over the mean hazard coefficient map. One can see that over 81% of the landslides have been identified in some areas with high potential to landslides occurrence (Fig. 2).

We identified, starting from the value obtained for Km, areas with low, mean and high landslides occurrence potential, associated with a low, mean and high occurring probability (Fig. 3).

Areas with low landslides occurrence potential have the highest percentage and overlap the accumulation piedmonts and the interfluves from the mountainous area protected by vegetation. In these areas, in terms of lithology, we identify a high homogeneity, consisting of unconsolidated rocks (piedmont gravels) and hard, compact rocks. They represent 53.2% of the total analyzed territory.

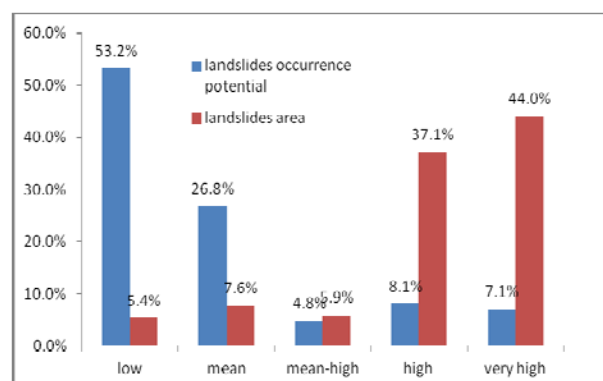


Figure 2. Results validation

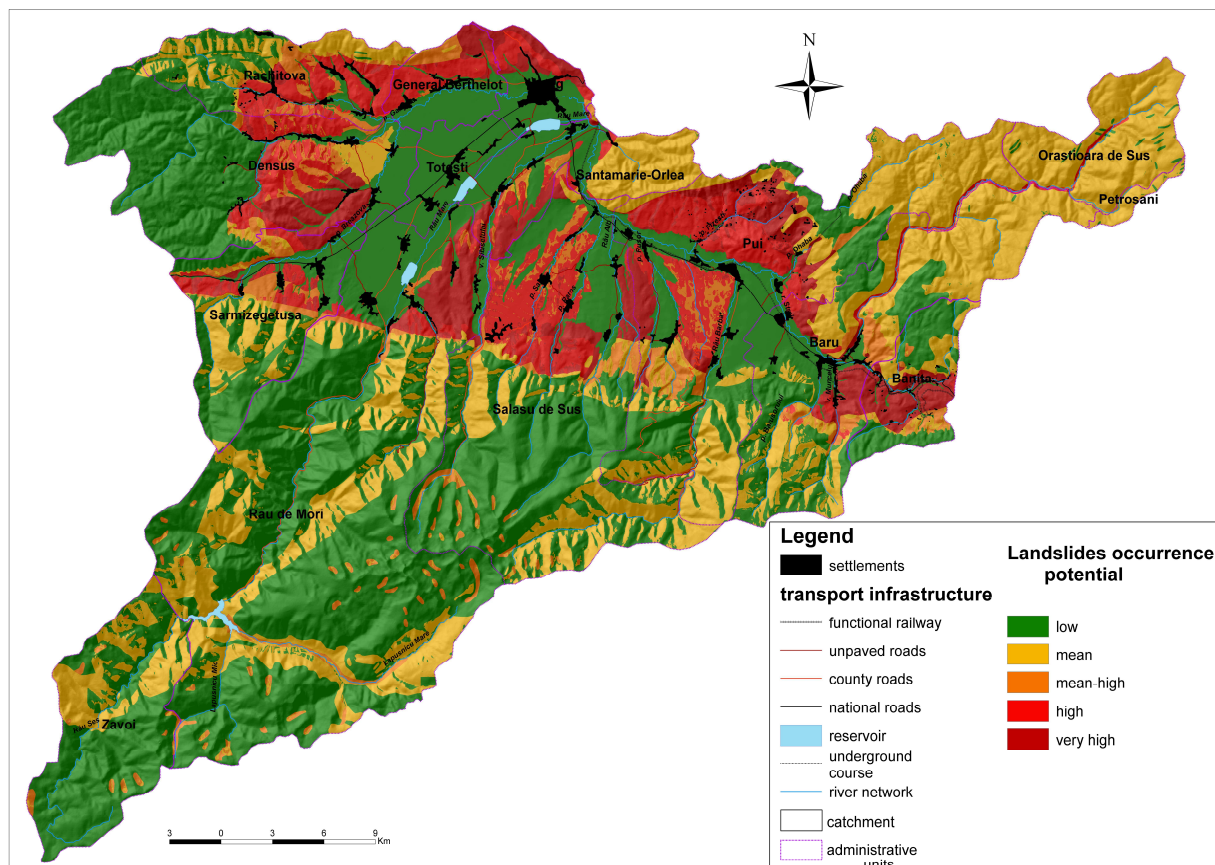


Figure 3. Upper and middle sectors of the valley Strei. Landslides occurrence potential map

Areas with mean landslide occurrence potential represent 31.6% of the area and are characterized, in terms of lithology, by high homogeneity, consisting of weathered or cracked, hard, compact rocks. Over these horizons there are unconsolidated rocks, represented by superficial deposits with thicknesses of 1.5-2.5m. The landslides affect the last deposits, fixed by forests, which are no longer a protective factor, but a preparing one through its own weight (Photo 1).

Areas with high landslides occurrence potential represent 15% of the total area and occur on the erosion piedmonts, consisting of semi-hard, compact (weathered) rocks, which alternate with soft and unconsolidated rocks. The slopes have gradients between 6.1° - 35° and are highly fragmented by torrential bodies. The identified superficial landslides occurred as a consequence of the linear erosion forms evolution. Also, several dormant landslides were reactivated by the inefficient management (erosion works destruction, overgrazing, pastures and orchards conversion into arable land). To these triggers, we add: loading the slopes with buildings, undermining the slopes toe by building roads or through streams lateral erosion etc.



Photo 1. Landslide in the upper sector of the Strei valley. (July, 2010)

Landslide susceptibility analysis at administrative unit.

In the upper and middle sectors of the Strei valley, according to Law 575 published in the Monitorul Oficial, no. 726/14.11.2001, the following communes present a mean potential to landslides occurrence: Densus, Rachitova, Rau de Mori and Salasu de Sus. Compared to the previously highlighted situation, in 2011, we identified areas that also have landslides occurring potential in the communes: Pui, Baru, Banita, Santamaria-Orlea., as well as in Hateg town. Landslide susceptibility analysis was performed at the administrative unit, the lower credit ordinator (Table I).

Table I. Landslides occurrence potential at administrative unit

Communes	Landslide occurrence potential				
	low (%)	mean (%)	mean-high(%)	high (%)	very high(%)
BANITA	44,7	18,7	5,6	0,7	30,3
BARU	36,0	50,2	4,5	3,3	6,0
DENSUS	68,1	4,5	5,2	11,1	11,1
G-RAL BERTHELOT	48,8	1,0	9,2	29,5	11,5
HATEG	58,1	0,2	0,5	17,4	23,7
PUI	32,4	34,4	6,0	16,0	11,2
RACHITOVA	33,6	26,4	10,8	25,7	3,5
RAU DE MORI	69,6	22,6	3,2	0,8	3,8
SARMIZEGETUSA	52,6	21,5	9,1	10,1	6,7
SALASU DE SUS	57,7	18,8	6,1	11,8	5,6
SANTAMARIE-ORLEA	40,2	36,4	4,0	7,8	11,6
TOTESTI	-	-	-	-	-

After performing this analysis, we have revealed the following situations:

- in Totesti village, there are not favorable conditions for landslides occurrence; it overlaps the Rau Mare floodplain and the accumulation piedmont of the Hategului Depression, characterized by low gradients, drainage density and relief energy values;
- over 40% of some administrative units area (e.g. G-ral Berthelot, Hateg) presents a high and very high susceptibility to landslides; these areas overlap slopes that consist of alternating packages of rocks with different degrees of resistance to erosion, declivity and high fragmentation. In the '80s, they were stabilized by orchard plantations.
- a complex of factors compete to landslides occurrence, such as: E and NW aspect, gradients with values ranging from 6.1°-17°, the relief energy of 50.1-150m/sq.km and drainage density of >9 km/sq.km; to this we add the protection offered by forests, favoring deposit overmoisturizing (e.g. Baru) (Photo 1);
- anthropogenic factors reactivate the process by changing the slopes morphology after placing transport infrastructure and buildings (e.g. Banita, Hateg);
- land use conversion from orchards into arable land and pastures also resulted in the reactivation of some dormant landslides which were in morphodynamic equilibrium as a result of the conversions, due to the excessive grazing and based on local favorable factors, the processes were reactivated (e.g. Densus, G-ral Berthelot, Pui, Rachitova etc.);
- the identified shallow, active landslides, which destabilize the semi-shaded and shaded slopes surrounding the villages; they consist of rocks with different degrees of resistance to erosion, and used as poor quality pastures (Photo 3);

By excessive grazing practice, followed by a partial removal of vegetation cover removal, gullies have developed, and not being corrected, they have evolved and competed in triggering landslides (Santamarie-Orlea, Salasu de Sus, Baru, Pui etc.) (Photo 4). This process begins on slopes with gradients between 2.1°-6° and advances regressively to the ridge (Photo 2).

Vulnerability to landslides. We determined the distance between the areas affected by landslides and the anthropogenic elements with the help of *Tools-Proximity Analysis-Multiple Ring Buffer* (= buffer) function of ArcGIS 9.2. software. The same method was used by **Rusu, 2008**. This function allows the automatic formation of polygons around selected vector elements (**Haidu and Haidu, 1998**), at a chosen distance, in this case of 50, 100, 200, 300, 400 and 500m. Then, the raster with settlements and roads was overlaid over buffer zones, illustrating the areas that could be affected by this process. Thus, the larger distance from the landslide area is, the smaller the effects are.

The areas occupied by buildings in several villages from G-ral Berthelot, Rachitova, Baru, Banita, Pui etc. communes are vulnerable to this process (Fig. 4). To stabilize the slopes affected landslides mitigation measures must be adopted.

The transport infrastructure is also vulnerable to landslides. After analyzing these aspects, the following situations were identified:

- from the two roads crossing the study area, national road 66 (E79), in the Baru- Banita sector is highly affected by landslides, which are annually reactivated. The areas with landslides are at less than 50m from the road. So far the slopes have been stabilized by building walls and drains to remove excess moisture.

- in general, the roads are away from these areas, so they are not subject to landslides;
- of the forest roads affected by landslides stands out the one in the upper sector of the Strei valley, upstream Petros village, Baru commune, at km 7, and 16 respectively, which in the summer of 2007 and 2010, was blocked by two landslides (Photo 1);
- the Simeria- Petrosani railway, between Baru and Banita, is affected by landslides due to heavy traffic. In 2005, a rail was destroyed by a landslide. The traffic was stopped and the trains travelled only on a single rail, with speed restrictions. The affected line was put into operation in 2006, after slope stabilization works.

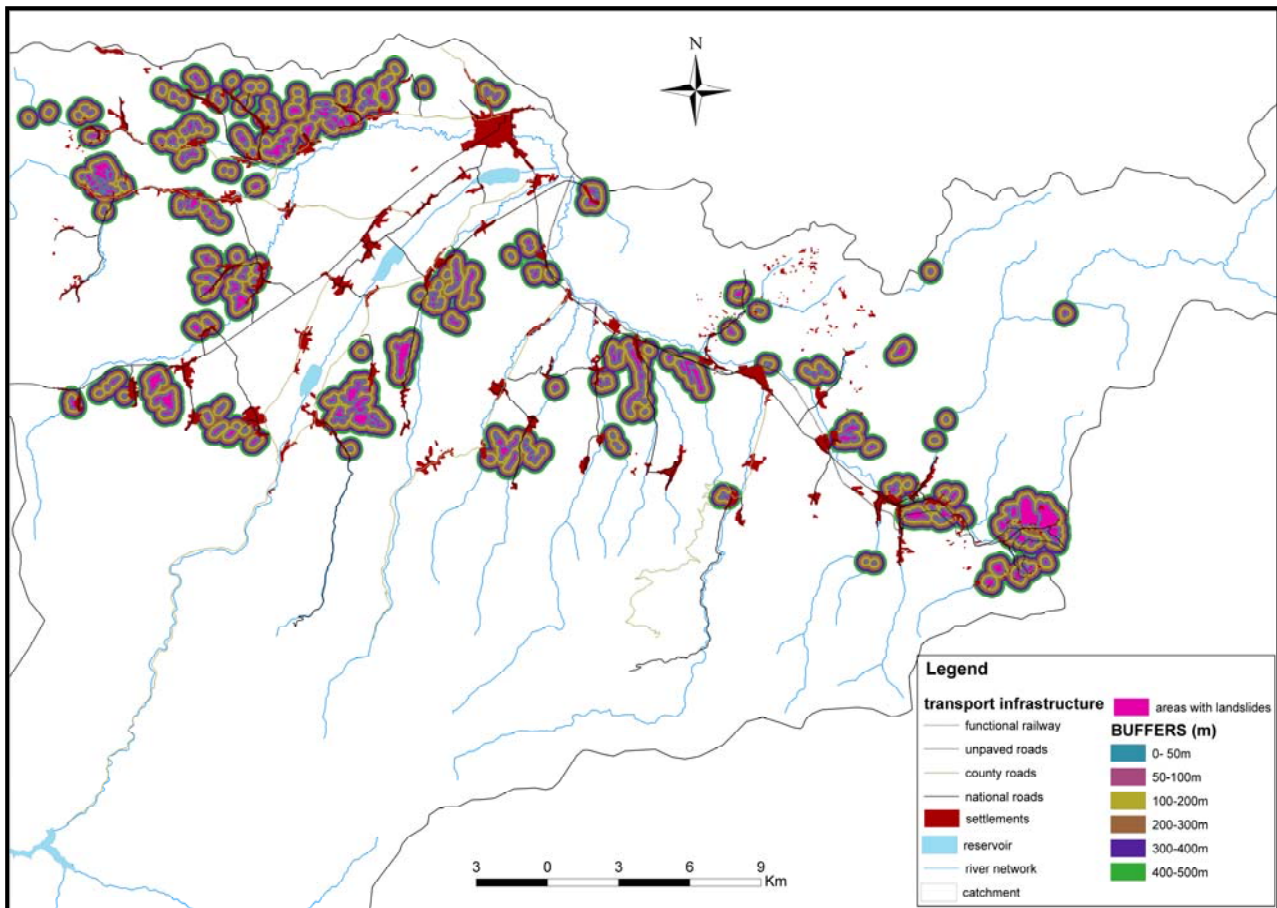


Figure 4. Upper and middle basin of the valley Strei. Vulnerability to landslides.



Photo 2. Landslides on the left slope of the Valceaua valley, Sacel, Santamarie Orlea commune (October, 2010)



Photo 3. Landslides and erosion processes on Glameia Hill, Livadia (July, 2010)



Photo 4. Landslides and erosion processes on the right slope of the Strei valley, Ponor, Pui commune (August, 2010)

4. Conclusions

The methodology for landslide hazard assessment is part of a legal framework so that analysis results can be used in territorial planning study. However, we admit that this methodology has some drawbacks, such as: the evaluator's subjectivity by underestimating/overestimating the factors importance, the difficulty of factors mapping (e.g.

geomorphology), establishing some coefficients according to the maps scale used etc. The generalizations imposed by the maps scale make us overlook some areas with obvious processes. Also, the time factor is not taken into account. However, the method proved to be valid, since over 81% of areas with landslide validated in the field overlap the areas with high susceptibility to landslides occurrence.

REFERENCES

- ALEXANDER, D., (2005), *Vulnerability to landslides*, in *Landslide Hazards and Risk*. Th. Glade, M.G. Anderson, M.J. Crozier (ed.) John Willey & Sons Ltd., London, pp.175-198.
- ARMAS, IULIANA (2006), *Risc si vulnerabilitate. Metode de evaluare aplicate in geomorfologie.*, Editura Universitatii, Bucuresti.
- BALTEANU, D., (1997), *Geomorphological hazards in Romania*. Geomorphological Hazards of Europe. Edited by Embleton & Embelton, Elsevier, Amsterdam, pp. 409-420.
- CROZIER, M.J., (2005), *Management frameworks for landslide hazard and risk: issues and options*, in Glade, Th., Anderson, M.G., Crozier, M.J. (eds.), *Landslide hazard and risk*, John Willey & Sons Ltd, London, pp. 331-350.
- GOTIU, D., SURDEANU, V., (2007), *Noțiuni fundamentale în studiul hazardelor naturale*, Ed. Presa Univ. Clujeană, Cluj-Napoca.

- GOTIU, D., SURDEANU, V., (2008), *Hazardele naturale și riscurile asociate din Țara Hațegului*, Ed. Presa Univ. Clujeană, Cluj-Napoca.
- GRECU, F., GRIGORE, M., COMĂNESCU, L., (2004), *Geomorphological risk in Romanian geomorphological research. A theoretical and applied view*, Anal. Univ. București, anul LIII, pp. 25-37.
- GRECU, FLORINA, (2006), *Hazarde și riscuri naturale* (editia a III-a), Ed. Universitara, Bucuresti.
- GRUMĂZESCU, C., (1975), *Depresiunea Hațegului. Studiu geomorfologic*. Ed. Academiei, București.
- HAIDU, I., HAIDU, C., (1998), *S.I.G. Analiză spațială*, Ed. *H*G*A*, București.
- PANIZZA, M., (1993), *Geomorphologia applicata*, Roma: La Nuova Italia Scientifica.
- PANIZZA, M., (2005), *Manuale di geomorphologia applicata*, Franco Angeli, Milano, Italy.
- RĂDOANE, M., RĂDOANE, N., (2007), *Geomorfologie aplicată*, Ed. Universității din Suceava
- RUSU, C-TIN (coordonator)(2008), *Impactul riscurilor hidro-climatice și pedo-geomorfologice asupra mediului în bazinul Bârladului*, Ed. Performantica, Iași.
- RUSU, C-TIN (coordonator), (2008), *Impactul riscurilor hidro-climatice și pedo-geomorfologice asupra mediului în bazinul Bârladului*, Ed. Performantica, Iași.
- SMITH, K., (2001), *Environmental hazards. Assessing risk and reducing disaster*. Routledge, London and New York.
- SURDEANU, V., (1998), *Geografia terenurilor degradate. I. Alunecări de teren.*, Presa Univ. Clujeană, Cluj-Napoca.
- SURDEANU, V., RUS, I., GOTIU, DANA, (2006), *Integrated Slope Processes Susceptibility Analysis and Risk Assessment of the Cluj County. Case Study Cheia*, The 3rd International Conference RURAL SPACE AND LOCAL DEVELOPMENT, Presa Universitara Clujeana, Editor: Surd Vasile.
- *** (2001), *Legea nr. 575. Zone de risc natural. Metodologia întocmirii hărților de risc. Modul de elaborare.*, publicată în M. Of. 726 din 14.11.2001.
- *** (2003), *H.G. nr. 447 din 10 aprilie 2003, pentru aprobarea normelor metodologice privind modul de elaborare și conținutul hărților de risc natural la alunecări de teren și inundații*, publicată în M. Of. 305 din 7 mai 2003.

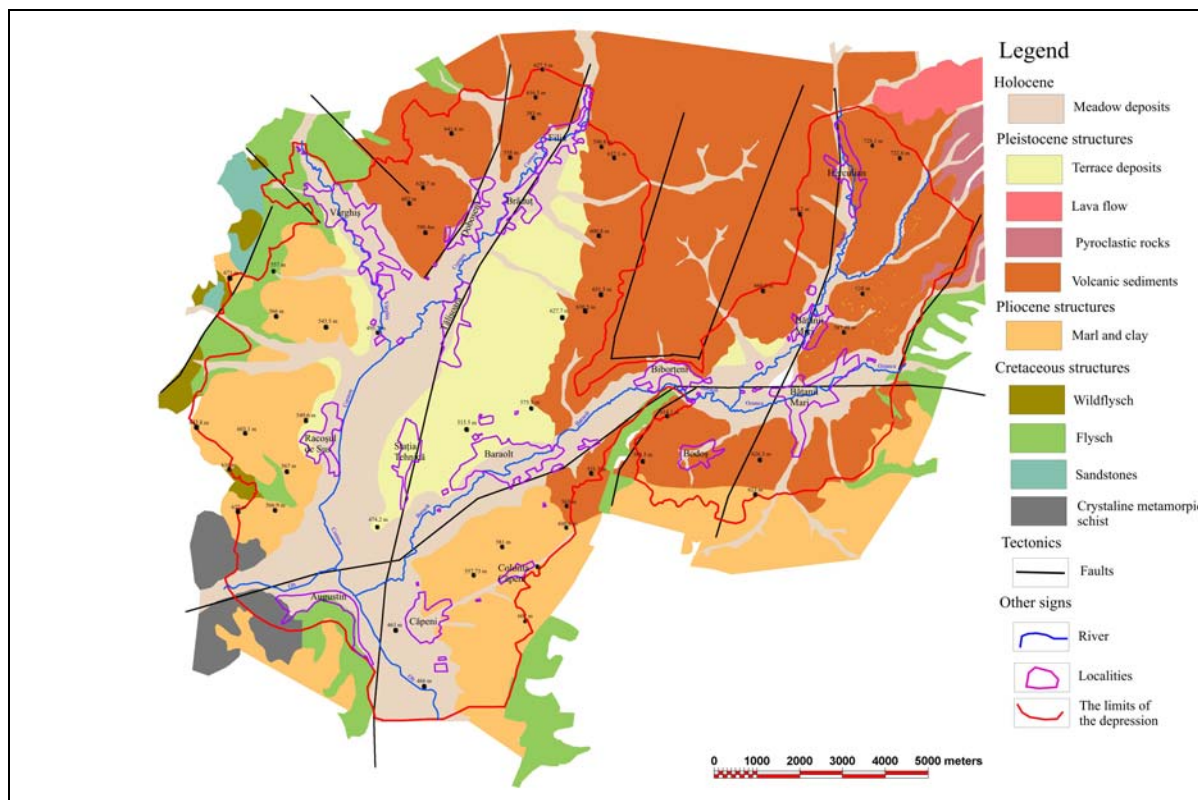
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² Professor, Babes-Bolyai University, Faculty of Geography, Clinicilor Str., no. 5-7, Cluj-Napoca, Romania, surdeanu@geografie.ubbcluj.ro

2. The reflection of the geological structure in the morphology

The horst structure aligned in the N–S direction, stands morphologically for a hilly alignment given by the peaks of the following hills: Dealului (892.7 m), Tirco (662.5 m), Cetății (614.1 m). This causes a strangling for the depression in the area of

Biborțeni village and it materializes the separation strip between the western and eastern parts of the depression. (Figure 1 and Photo 1) These two parts are in fact two main grabens, concretized in the relief by two basins: a Western basin and an Eastern basin.



Map 2. Geologic map of the Baraolt Depression and its surroundings

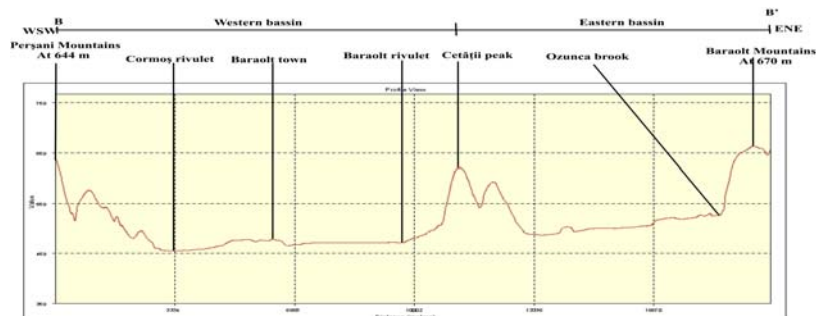
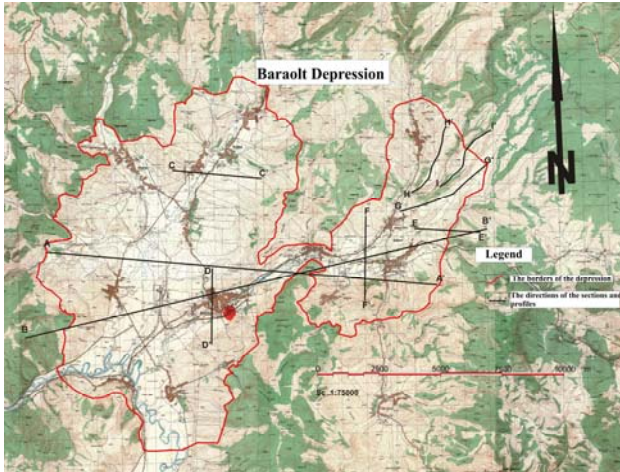


Figure 1. The cross section of the Baraolt Depression



Photo 1. The Southern part of the horst



Map 3. Positions of the cross sections and profiles

The Western basin is the expression on the surface of the Cormoș graben. Its aspect is elongated on N – S direction and it is wider in the South, at the confluence of the Baraolt and Cormoș rivulets with Olt river, and closes gradually towards North in the area of Filia village. The graben, as a geological structure, goes on towards North, under the volcanic structures of the South Harghita range, just the aspect of the relief changes from depression-like, to a mountain-like in this area. The height of the basin decreases from North, where it is around 600 m, to South, where it reaches the minimum altitude of the whole depression: 463 m. The decreasing direction is contrary to that of the

graben itself, given by the surface of the Cretaceous relief, whose lowest level is in the northern part of the basin in the area of Doboșeni village, and it is placed around 50–100 m higher than the actual level of the Black Sea (László A., 1999).

On the Western side, this aspect of a N–S elongated basin, is disturbed by two bays: Vârghiș bay and Racoșul de Sus bay, given by two secondary grabens, which were formed along the NV–SE faults. The basin becomes larger in this area because of them.

The highest points of the basin in Vârghiș bay are around 550–570m, and in Racoșul de Sus bay around 530–550 m and the altitudes decrease towards SE and E till the level of the Cormoș meadow, which is around 480 and 470 m.

At a deep evaluation of the slopes inclination map, it is possible to see the asymmetry between the Western side and Eastern side of the basin. It is not possible to speak about a result of a monoclinical structure, but a result of the fault structure.

On the Western side, the border faults, which are parallel with the Cormoș fault system, imposed a discordance between the depression and the Mesozoic-crystalline structures of Perșani range. The Cretaceous base, which emerges along these faults, conditions a sharper slope angle for the Western side of the basin. (Map 3, Figure 2 and Photo 2).

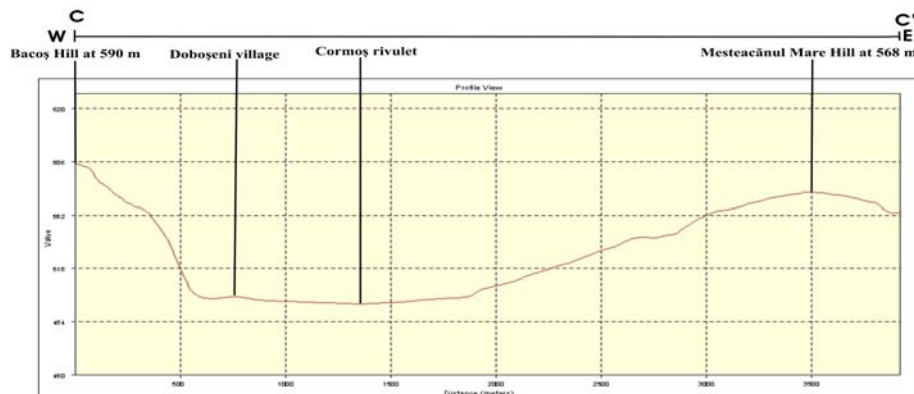


Figure 2. W-E cross section through the Western Basin nearby Doboșeni village



Photo 2. The image of the cross section from Fig. 2

In the Southern part of the basin, the W–E crustal fault (G7) imposes a brink, a higher level of the relief, namely the compartment of Căpeni Colony, having a height of 550–560 m, which represents a level difference of about 80–90m from the bottom of this basin. On the cross section made in N–S direction, one can notice the vault caused by the fault and on the other hand the asymmetry between the slopes. (Figure 3 and Photo 3).

Performing an overlay of the tectonical alignments map of Baraolt area, and South–Western side of Harghita Mountains, made by László A. (1999), with the topographical map of the same area, it will be possible to observe that the lowest spot of the basin and of the whole depression (463 m) is situated at the crossing of the Cormoș fault system with the W–E directed crustal fault. That is the spot where the Cormoș and Baraolt rivulets flow into the Olt river, so it is a confluence site.

On the Eastern side of the horst made up by Dealului, Tirco, Cetății hills, the parallel reply of the Cormoș fault system was formed, which conditioned the individualization of the Eastern basin of Baraolt depression, the area between Bățanii Mari and Herculan villages. This division

of the depression into these two basins is an expression, a conditioning of the structure imposed on the relief. The general aspect of this Eastern basin is similar to the western one, in the sense of the elongated form in N – S direction, with a narrowing and closing at N of Herculan and a widening in South. The closeness of the named horst to the lifted flysch structures of Baraolt Mountains and of the volcanic structures of Harghita Mountains makes that the extension of this basin is smaller than that of the western one.

Following the same assesment method as in the case of the western basin, regarding the angles of the slopes, it is possible to mark that the Eastern (Figure 4) and the Southern side slopes (Figure 5) have a bigger inclination.

As in the case of the western basin, these are conditioned by the border faults having N–S directions, along which the Cretaceous structures of the Baraolt Mountains get to the surface. In this eastern side of the basin further to the North, this discordance can not be seen because it is covered by the upper volcano-sediment layer. In the southern part, the bigger angles of the slopes is imposed by the W–E crustal faults system.

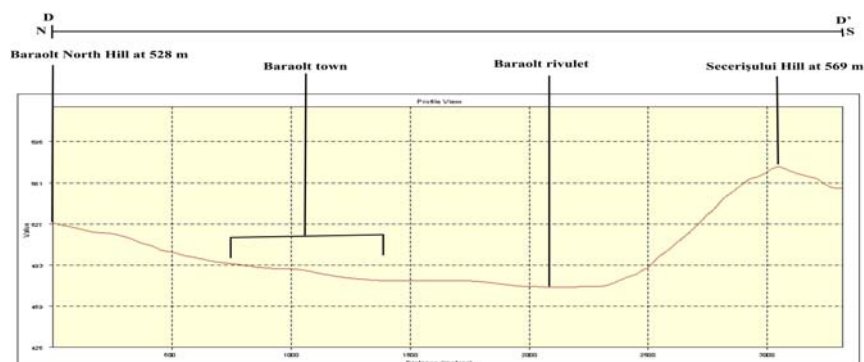


Figure 3. N – S cross section in the Western basin between Baraolt Nord Hill and Secerișului Hill



Photo 3. The image of the cross section from Fig. 3.

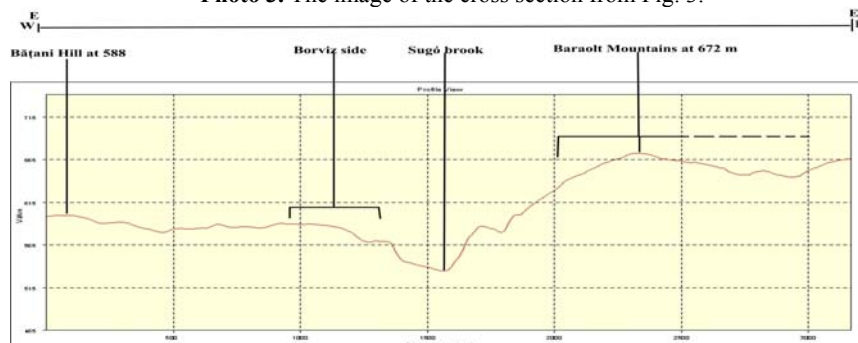


Figure 4. W – E cross section in the Eastern basin nearby Bățanii Mari

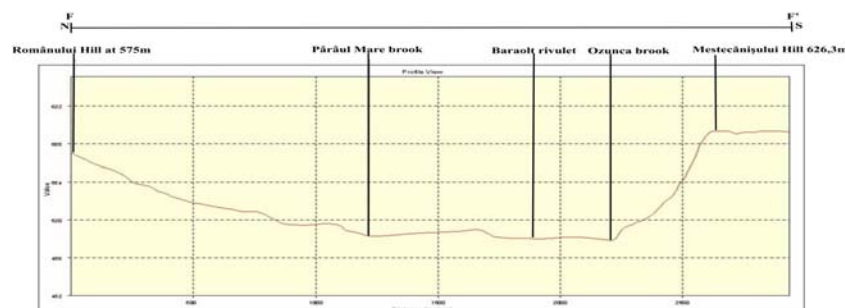


Figure 5. N – S cross section in the eastern basin in Bodoș – Bățanii Mici area

The tectonics of the Cretaceous bed, forced by these faults in the South of the basin together with the delay in the start of the descending movement along the N–S faults conditioned the individualization, in the South-Western side, of the Bodoș cuvette, bordered in South and West by the structures of Baraolt Mountains and with a certain opening towards East and North – East.

The maximum depth of the basin, from Bățani area, having its site in front of the intermediate horst, is the place where the two fault systems, N–S and W–E crosses each other. This fact also conditions a confluence area for the rivulets. Baraolt, Ozunca, Bățani, Bodoș, Pârâul Mare converge towards it, before crossing the strangling of the depression caused by the horst.

The directional lines of the draining, made by the hidrographic network, are given by the direction of the faults. In the western basin, Cormoș and Volal rivulets and partly the Olt river, flow along the Cormoș fault system, having N–S direction. Along the NW–SE faults flow the Vârghiș and Rica rivulets, and along the W–E fault flow Baraolt rivulet and Olt river. The same situation is in the Eastern basin. Along the N–S directed faults flow Baraolt, Bradul Mare, Bățani rivulets and along the W–E fault the Ozunca and Baraolt rivulets. One remarks the existence of the fault shifter rivers: Olt and Baraolt both from the N–S faults to W–E fault.

3. The reflection of the petrography in morphology

In the North and North – Eastern part of the eastern basin, the petrographic structures of the upper layer of the volcano-sediments are imposed in the relief. (Map 4.) As there are some hard rocks – andesite

with pyroxene and dacite – among the components of this layer, the aspect of the relief is a volcanic plateau like. (Figure 6, Figure 7 and Figure 8) The watersheds directed N–S and NNS–SSW, are easily inclined, or curved, having altitudes that go down from 700–670 m in the North to 580–560 m in the South.

During the palaeogeographic evolution of the depression, the forming of the stack of mollasse, there were some periods with proper conditions for the formation of 6 coal layers.

The lignite, as petrographic element, having the status of subsoil resource, conditioned the development and evolution of the anthropogenic relief, due to mining. The open pit exploitation made in the coal fields of Vârghiș and Racoșul de Sus, began in 1954, created excavations having micro-cuvette forms, even 70 m deep, deches for carrying away the underground waters, artificial river beds, artificial hills of 10–15 m high and 1–3 km long serving as depot for the sterile materials, roads, buildings, coal loading facilities. The process through which it is reachable the totality of the ground forms, as a result of the modifications of the preexistent morphology, got the name of “antropogenic parazitization” (Anghel, T., Surdeanu V., 2007).

In the open pits exploitations where there is no coal mining any more – Vârghiș, Racoș bay – the active gravitational, pluvio-denudational and torrentional processes on the surface of the burrows, and of the pits themselves, compensate the excavated material. Immediately after they stopped to pump out the water, the hydrostatic level came back and this gave birth to lakes whose area, depth, form and number changes continually until a state of balance is reached.

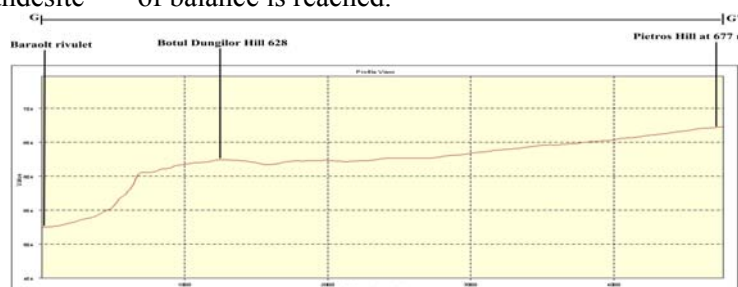


Figure 6. Longitudinal profile of the Pietros Hill – Botul Dungilor Hill

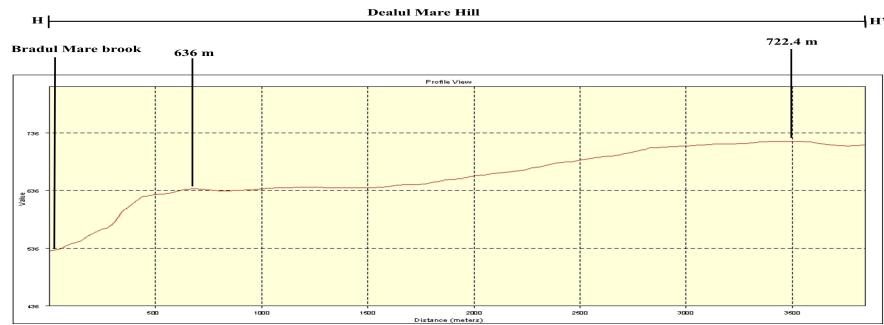


Figure 7. Longitudinal profile of Dealul Mare Hill

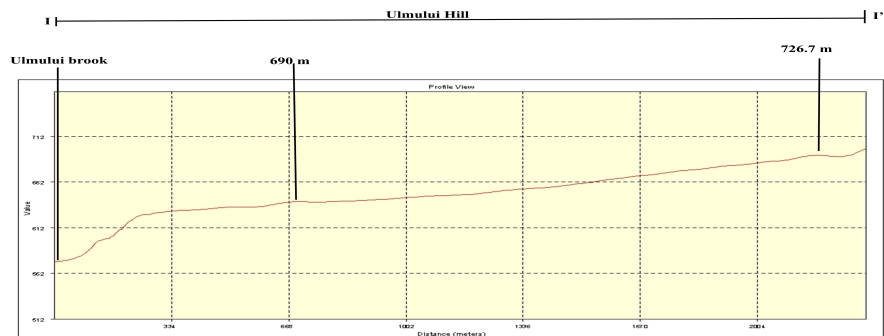
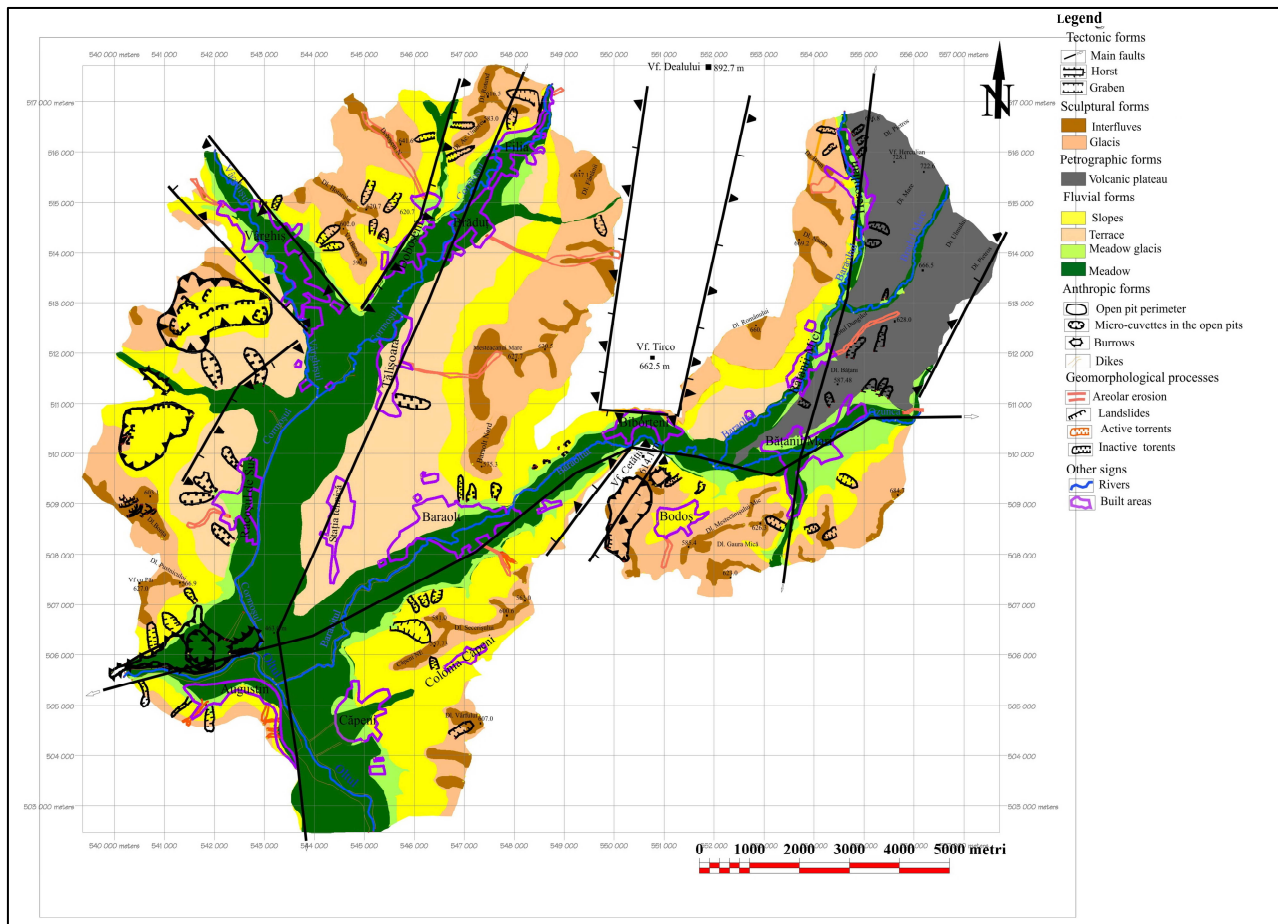


Figure 8. Longitudinal profile of Ulmului Hill



Map 4. The geomorphologic map of Baraolt Depression

At the Racoş Sud open pit, from the flood-plain of Olt river, which is still giving coal, the radical anthropogenic transformation of the natural landscape has begun in 1996. There are stripping works still done, but without using new land, because the waste is put back on the place from where the coal was mined. There are also works for stopping the erosional processes to keep the open pit functional. On the other hand, the surface of the barrows is affected by the erosional processes listed before. The whole area occupied by the anthropogenic parasitization processes is up to 1.4 km², from which the negative form has 311 ha and a relative depth of 86 m (in April 2012). The flood-plain barrows, which strip along the Olt river for 2.8 km, are made up of two depots: one is oriented towards the Olt strait, being 1.9 km long and from 50 to 170 m wide, and the second placed on the East side of the micro-cuvette, having 900 m in length.

Excepting these two landforms (the micro-cuvette and the barrow), one notices the shifting of the river bed of the Cormoş rivulet in a 1.1 km long channel, the ditch digging for carrying away the water from the pit having a length of 2.8 km.

Assessing the geological section and the evolutionary model of the depression, made by László A. in 1999, it is possible to point out that the only area in the eastern basin where the 3rd coal layer was formed is Bodoş cuvette. This process was conditioned by the earlier start of the descending movements of this cuvette then of the other parts of this basin and so, this is the only area here where the lignite could be mined. In spite of the fact that this lignite has the poorest quality, in the whole depression mining started in 1985 in underground as well as in open pits, but all the mines are closed now. In the underground mines, the closing works consisted of refilling the entrance slope to a depth of 50 m and sealing it with concrete. The other anthropogenic elements of the landscape are still there: buildings, roads, loading shafts.

At the open pits much more serious work was done. The barrows were flattened and replaced, the excavations refilled with the material of the barrows, the whole area of the pit was flattened and settled, gaining the form of a single micro-cuvette with a 0.84 ha lake in its deepest place. The ground was planted with white clover (*Trifolium repens*). The reception of the whole work was done in November 2009, but the severe winter and rainy summer of 2010 made that on the surface of the slopes of the pit to occur geomorphological processes like pluvio-denudation, gullyfication, landslides. With all the human efforts to reestablish

the proper angle of the slopes, to remake the broken balance, it seems that the nature will have the final word as in the case of the pits where no work was done.

All the underground mining sites are closed and recultivated as at the Bodoş site, and the surroundings were planted with white clover (*Trifolium repens*). At some pits even the buildings were demolished. Căpeni mining site is the only one where these works have not been made. Here mining stopped in 1967 and in a short time a lake formed. Today this lake is 1.38 ha and 7 m deep.

In 2002 just a part of the closing works were made at Baraolt pit: taking out, from the underground, the reusable materials and refilling the access slopes from 50 m deep until the surface. So the terrain above the galleries, from where there had been taken out a thickness about 5 to 10 m of coal, suffered a subsidence and between 2006 and 2009 a lake of 3.6 ha and 5m deep was formed. These kind of terrain sinking, subsidence processes, with the formation of small endorheic basins in which lakes can occur are a reality and all these processes can happen in the future at the other pits. The only place where they are less possible is at Căpeni where it seems that the balance status was reached.

These small negative landforms, which take birth because of the extraction of any resource from the underground, are not directly modeled by man. They are the result of taking out that quantity of deposit that overtakes the possibility of the surrounding rocks to fill the created hollow and to stop the phenomena of their distortion. So the movement of the rocks reaches the surface and the small endorheic basin is ready. They can be filled by meteoric water or by the natural resaturation of the phreatic level, taken down during the exploitation by pumping. One of the features of these lakes is, that immediately after forming, their surface and depth are growing and they can be a man induced natural hazard.

In the case of open pit exploitation, the man-made forms are more spectacular, being the case of positive or of negative ones. They are distinguished from the previous forms by the fact that they are directly created as a result of decisions and actions of carving of a surface which is already a result of the nature's self-organizing processes.

The four open pits offer four different images of this anthropogenic relief category. They catch three different evolutionary phases: 1) the phase of opening the pit, when man effectively models the surface – Racoş sud open pit –, 2) the phase that immediately follows the giving up of the mining perimeter, when the stripping processes are taking

place and nature imposes its own organizatoric laws – Vârghiș west open pit –, 3) the phase of stabilisation and resettlement of natural balance – Racoș golf open pit. The fourth open pit – Bodoș – offers the image of both success and failure in closure and recultivation of an exploitation micro-cuvette.

4. The reflection of some postvolcanic activities in morphology

There is another factor of geologic origin – post-volcanic activity – which can create spectacular microforms having a very slow evolution. The presence of mineral waters indicates the final stage of volcanic activity of the Harghita range. Post-volcanic gases circulate through crustal and regional faults and at their crossings they can come towards the surface and interfering with the aquifers from the geological structures they generate carbonated mineral waters. The hydrochemistry of these waters depends on the petrographic nature of the geological structures through which they pass and in which they stay.

Taking into account the fact that Cretaceous rocks from the bottom of the depression are mainly carbonic ones, some mineral waters contain important quantities of HCO_3^- . At the 35 analysed mineral water springs this component is between 305 and 2562 mg/l, the Ca^{2+} between 250 and 300 mg/l and the Mg^{2+} between 90 and 110 mg/l. When they reach the surface they lose the free and dissolved CO_2 which leads to deposition, agglomeration, mineralization of the dissolved substances on the surface. So around some mineral water springs small hills, having the shape of a truncated cone, can be formed.

In the flood-plaine of Cormoș rivulet at 100 m from the Dc38 road which connects Racoșul de Sus and Doboșeni there is a small hill of 1.5 m in height and 42 m in circumference, with the shape of a truncated cone. It has a 2 m deep crater through which the mineral water had sprung out until the 1960s. This microform it is known as „The Holed Stone” (Photo 4) and was declared as monument of nature by Covasna County’s Council Decission no. 39/2001.

A similar microform was formed on the bank of the Baraolt rivulet bed opposite the gas pumping station from Bățanii Mici at 100 m from road Dc45, where the waters of the “Szonda borvíz” spring flows into the rivulet. This spring comes out through a geological drilling made in 1982. The total dissolved salt (TDS) in the waters of the spring is between 928 and 947 mg/l, the HCO_3^- between

1403 and 1467 mg/l. In all 30 years of flowing this spring built a half frustrum of a cone – being attached to the bank – of 1.3 m height. (Photo 5) The bottom semicircle is 3.5 m and the top one 1.3 m in diameter.



Photo. 4. The Holed Stone



Photo 5. The cone at Szonda borvíz

4. Conclusions

The geological components of the Baraolt Depression are the conjugate results of the succession of the geological events that followed each other in this region from the formation of Ceahlău Nappe, the napping of the metamorphic structures of the Eastern Carpathians over the flysch up to the present. The tectonic movements along the crustal, regional, local faults, which influence both the Cretaceous bottom and the Pliocene-Pleistocene mollasse stack, the volcanic activity in the Harghita range, which directed each other, conditioned the finishing of the tectonic structure of grabens and horsts. The formation of the grabens along specific fault series together with the same volcanic activity created conditions for a specific sedimentation having the result of mollasse deposits which are up to 450–550 m thick. In this deposit there are layers having a very important self-organizing role: the volcano-sediment layers and the lignite layers.

Some geological factors – tectonics and structure – had the role to divide the depression into

basins, bays, cuvettes and compartments, to give the elongated form to these divisions, to lead the main rivers to make themselves asymmetrical sections. The other one – petrography – imposed the development of some flat, barely inclined landforms, real volcanic plateaus. The energetic resources pushed the human activity to develop anthropogenic parasitism morphology, where it is

the best place to observe the actual dynamics of the relief.

The understanding of any area of the geographic coverage is the starting point in showing out the morphology and dynamics of the relief of that area and the other processes, phenomena, manifestations of growing complexity, which are reflected in the landscape and gives it's individuality.

REFERENCES

- AIRINEI, S., (1963), *Structura fundamentului hercinic al curburii Carpaților Orientali în lumina anomaliilor câmpurilor gravimetrice și geomagnetice*, Lucrările celui de-al V-lea Congres al Asociației Geologice Carpato-Balcanice, București, 1961, VI, Comunicări științifice (Secția V, Geofizică), București.
- AIRINEI, ST., PRICĂJAN, A., (1972), *Corelații între structura geologică profundă și aureola morfologică din jud. Covasna cu privire la zonele de apariție a apelor minerale carbogazoase*, Aluta p. 181 – 190, Sfântu Gheorghe.
- ANDREESCU, I., (1975), *Limitele și subdiviziunile Pontianului*, Stud. Cercet. Geol. Geofiz. Geogr., Seria Geol., vol. 20/2, pp. 235 – 246, București.
- LÁSZLÓ, A., (1999), *Studiul geologic al structurilor vulcanice din partea de sudică a Masivului Harghita*, Teză de doctorat, Universitatea Babeș-Bolyai Cluj-Napoca.
- LÁSZLÓ, A. DÉNES, I., (1997), *Elemente structural – tectonice pentru un model evolutiv în zona Bazinului Baraolt*, Acta Sicularica, Muzeul Național Secuiesc – Muzeul Secuiesc al Ciucului, Sfântu Gheorghe, pp. 9-16.
- BARTMUS, A., (1971), *Cercetări palinologice preliminare în lignitul de la Vârgheș (Bazinul Baraolt)*, în Progrese în Palinologia românească, Editura Academică, pp. 143-152, București.
- BĂCĂINȚAN, N., (1982), *Limitele și subunitățile Munților Baraolt*, Aspecte controversate, BSSGR, VI (LXXVI).
- BĂCĂINȚAN, N. 1999. *Munții Baraolt - Studiu geomorfologic*, Editura Academiei Române, București. 9. Ciupagea, D. et al. 1970: *Geologia Depresiunii Transilvaniei*. – Ed. Academiei RSR, București, 188-205.
- CONȚESCU, I., (1966), *Flișul cretacic din partea de nord a Munților Baraoltului*, Academia RSR, Stud. Cercet. Geol. Geof. Geogr., seria Geol., 11, I, București.
- GHEORGHIEU, C., (1956), *Relațiile dintre sedimentele terțiare și eruptivul lanțului Harghita (fenomene post-vulcanice)*, Dds.sed.CG, XL 1952 -1953.
- GIVULESCU, R., VASILESCU, AL., (1969), *Contribuții la cunoașterea Bazinului Baraolt*, D.S. Inst. Geol. vol. LIV/3, pp. 283 – 293, București.
- HERBICH, F., (1878), *A székesföld földtani és őslénytani leírása*, Földt. Int. Évkönyve, V. k., II. füzet, 297, Budapest.
- IANCU M., (1957), *Contribuții la studiul unităților geomorfologice din depresiunea internă a curburii Carpaților (Bârsa, Sf. Gheorghe, Tg. Secuiesc, Baraolt)* Probl. de geografie, vol. IV, București.
- JERKELIUS, E., (1932), *Die Molluskenfauna der dazischen Stufe des Beckens von Braşov*, Men. Inst. Geol. Rom., vol. II, București.
- JEKELIUS, E., (1923), *Les dépôts de Geyserite du basin dacien de Baraolt (Transylvanie)*, Bull. Sect. Sc. Ac. Roum., VIII, (1922-1923), 168-175, București.
- KRISTO, A., (1972). *Unele probleme privind delimitarea și denumirea formelor de relief din împrejurimile depresiunilor intracarpice ale Oltului Superior*, Aluta, Sf. Gheorghe.
- KUSKO, M., (1983), *Zăcămintul de lignit de la Sf. Gheorghe și poziția lui stratigrafică în suita depozitelor pliocene ale bazinului intramontan al Țării Bârsei*. St. Cercet. Geol. Geofiz., s. Geol., 28, București.
- LITEANU, E. et al., (1962), *Contribuții la studiul stratigrafiei Cuaternarului din Bazinul mijlociu al Oltului (Baz. Baraolt)*. St. Cercet. Geol. Geofiz., s. Geol., 7, ¾, București.
- MUTHAC, V., IONESI, L., (1974), *Geologia României*, Editura tehnică București.
- ORBÁN B., (1868), *A székesföld leírása*, Budapest.
- ORGHIDAN, N., (1965), *Munții Persani, Observații geomorfologice cu privire specială asupra văii Oltului*, St. Cerc. Geofiz. Geol. Geogr., seria geogr. XII, 1.
- ORGHIDAN, N., (1965), *Munții Persani*, Natura – Geogr.- geol. XVII, 4.
- PELTZ, S., (1970), *Contribuții la cunoașterea formațiunii vulcanogen-sedimentare pleistocene din sudul Munților Harghita și nord-estul bazinului Baraolt*, D.S. Inst. Geol. Geofiz., LVII/5.
- PETRESCU, I., FERENCZ, A., (1979), *Contribuții la cunoașterea petrografiei și genezei ligniților de la Racoșul de Sus (Bazinul Baraolt)*, St. Com. Muz. Brukenthal, vol. 23, Sibiu.
- PETRESCU, I. colab., (1987), *Geologia zăcămintelor de cărbuni, vol. II*, Editura Tehnică, București.
- POPOVICI VIORICA, (1959), *Explorări geologice în bazinul Baraolt – Vârgheș – Căpeni – Buduș – Aita Seacă*, STE, A, 5, Inst.geol.

- POSEA, GR., (1981), *Depresiunea Braşovului (caractere geomorfologice)*, AUB – Geogr., XXX.
- SĂNDULESCU, M., (1984), *Geotectonica României*, Editura tehnică, Bucureşti.
- SAVU, M. GH., (1971), *Argumente paleontologice în favoarea susţinerii existenţei pânzei de Baraolt*, D.S. Inst. Geol., LVII/4.
- SAVU, M. GH., (1984), *Studiul geologic al regiunii cuprinse între localităţile Fila – Vârghiş – Baraolt – Aita Mare – Malnaş Băi – Bicsad – Herculan cu privire specială asupra depozitelor de lignit*, Teza de doctorat, Facultatea de Geologie – Geografie, Universitatea Bucureşti.
- SAVU GH. et al., (1980), *Asupra vârstei formaţiunii productive din Bazinul Baraolt*, D. S. Inst. Geol. Gf., LXV, 4, Bucureşti.
- SAVU, GH. M., (1981), *Grupul lacustru-vulcanogen de Baraolt*, D. S. Inst. Geol. Geofiz., vol. LXVI., 1979, 4 (Strat.), Bucureşti.
- ŞTEFĂNESCU, M., (1968), *Pânza de Baraolt*, D.S. Inst. Geol. Geof. vol. LV/5, pp. 107 – 124, Bucureşti.
- SCHREIBER W., (1994), *Masivul Harghita – Studiu geomorfologic* Editura Academiei Române, Bucureşti.
- VADÁSZ E., (1915), *Földtani megfigyelések a Persányban és a Nagyhagyásban.* - Földtani Közlöny, Budapest.

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Comparative evaluation of landslide susceptibility in hill catchments (Săsăuș and Mislea), using GIS techniques

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Abstract: A number of qualitative and quantitative models and methods are available for computing landslide-hazard and susceptibility maps. Though the susceptibility map has usually incorporated the estimated frequency of land sliding in a qualitative sense rather than quantitatively. Landslide susceptibility zoning involves a degree of interpretation. The landslide susceptibility assessment is necessary to prevent terrain degradation and the evaluation of landslide susceptibility requires understanding the factors that influence slope instability.

The susceptibility maps that resulted from this study reflect the terrain conditions and are really useful for identifying the landslide areas within the basins. The spatial distribution and rating of the terrain units according to the propensity to produce landslides is dependent on the topography, geology, geotechnical properties, climate, vegetation and anthropic factors such as development and intensive deforestation.

Key words: susceptibility, hazard, Săsăuș river basin, Mislea river basin.

Introduction

In the geomorphic literature the terms of susceptibility and landslide hazard are often used interchangeably, although they are different concepts (Guzzetti, 2005). Landslide susceptibility is the probability for a landslide to occur in an area characterized by certain environmental conditions (Brabb, 1984) referring to the degree to which a surface can be affected by slip processes. In contrast, the hazard is the probability that a landslide of a certain magnitude will occur in a particular time and in a certain area. In addition to prediction of where the sliding will occur, landslide hazard forecasts "when" or "how often" it will occur and "how much" will it be (Grecu, 2006). Thus, susceptibility is the spatial component to landslides hazard.

In Romania the field research was initially sporadic, and was based mostly on small relief units and approaching different methodologies. The necessity of creating hazard maps was first underlined by Petre Coteș (1978). In time, risk assessment maps were developed, especially in units studied in detail as doctorate thesis, without following a consistent methodology. Significant contributions to this domain were: Schreiber (1980), Bălțeanu (1983,1992), Bălțeanu and colab. (1989, 1994), Grecu (1994, 1996, 1997, 2001, 2002), Cioacă (2002), Sandu (1994, 1997), Constantin (1999), Grecu, Comănescu (1997, 1998), Branduș, Grozavu (2001), Armaș and colab. (2003), Sorocovschi (2002, 2003), etc. In recent decades

there is a wealth of information aimed at in-depth knowledge of the process of sliding, information based on interdisciplinary studies, used in the development of numerous policies relating to weather phenomenon and determining areas susceptible to landslides, large-scale studies justified by natural disasters around the globe, some of which are influenced in a growing share by the high human impact.

Latest trend since the 1990s, is to develop susceptibility maps for landslides, which are the synthesis of quantitative and qualitative analysis of the area studied, reclassification and interpretation of results (Carrara, 1983; Brabb, 1984; Varnes and IAEG Commission on Landslides and other Mass-Movements, 1984; Crozier, 1986; Carrara and colab., 1995; van Westen, 2008; Chung and Fabbri, 1999; Crozier and Glade, 2005; Glade and Crozier, 2005; Guzzetti and colab., 2005, etc.).

In Romanian geomorphic literature, assessment and methodological references on landslide susceptibility were made by Bălțeanu and colab. (1989), Rădoane and colab. (1993), Cioacă (1996), Grecu (1997, 2002), Armaș (2003, 2006), etc.

The sliding susceptibility zoning map was obtained by combining the successive stages of the spatial distribution maps of the factors responsible for landslide processes, namely the degree to which they contribute to the destabilization of the slope (Montgomery and colab., 1991; Pachauri and Pant, 1992; Rădoane and colab., 1993; Mejia-Navarro and colab., 1994; Grecu, 1997; 2002; Pachauri and colab., 1998; Moreiras, 2005, etc.).

Also, in recent years, numerous studies have emerged to evaluate susceptibility of landslide based on probabilistic computing models such as Bayes theory, known as the “Weight of Evidence” (Bonham-Carter, 1991; Lee and colab., 2002; Armaş and colab., 2003), likelihood ratio (Chung and Fabbri, 2003, 2005; Fabbri and colab., 2003; Lee, 2004), certainty factors (Chung and Fabbri, 1993, 1999; Binaghi and colab., 1998) etc.

Studied areas

This paper aims to evaluate the slope landslide susceptibility of two river basins (Mislea and Sasăuș) located in different landscape units: the Curvature Sub-Carpathians, a unit of Orogen with hilly terrain and an active neotectonic manifested by an accentuated morphodynamic and Transylvanian Depression, also an Orogen unit all but a with a plateau terrain. The catchments have many similarities in morphology, despite being located in different morpho-structural units. Săsăuș morpho-hydrographic basin is situated within the Romanian territory, in the southern part of Hârtibaciu Plateau, a subunit of the Transylvanian Depression, and it is framed by the geographical coordinates 24°49'23" and 24°32'14" Eastern longitude and 45°56'51" and 45°47'54" Northern latitude (Figure 1).

Săsăuș river basin is bordered in the North, Northwest and West by Hârtibaciu River basin, in the East by Cincu River basin and in the South by Olt River basin and it occupies a total surface of 232,21 km². The geology of the basin area is

relatively simple as it overlaps a Neogene sedimentary package belonging to Sarmatian and Badenian, uncemented rocks (sands and gravels) or weakly cemented rocks (friable sandstone, thin horizons of conglomerates, clays and marls).

Mislea morpho-hydrographic basin is located in the South-Eastern part of Romania, at the contact of the Curvature Sub-Carpathians with the Romanian Plain, framed by the geographical coordinates 45°11'25" and 45°03'12" Northern latitude, 25°46'19" and 25°59'48" Eastern longitude (Figure 1).

Mislea river basin is a tributary to Teleajen river basin and has a total surface of 175km². The basin is bordered in the North and East side by Vărbilău River basin, by Doftana basin in the East and Dâmbu basin in the South. The geology of Mislea River basin is more complex as it overlaps the following structural units: Carpathian Molasses, consisting of sandstones, marls, clays, marl-limestone of Mio-Pliocene age and Tarcău nappe consisting of Oligocene and Eocene age formations (sandstones, shales, marls, breccias).

Materials and methods

The landslide susceptibility map was developed in alignment with the 575/2001 Law, 124/1995 Law, HGR 382 and 4447/2003 and Ord. MLPAT/MAPL 62/N/1995/1998, following the “Guidelines for drafting slope sliding risk assessment maps for assuring construction stability” – Indicative GT-019-98.

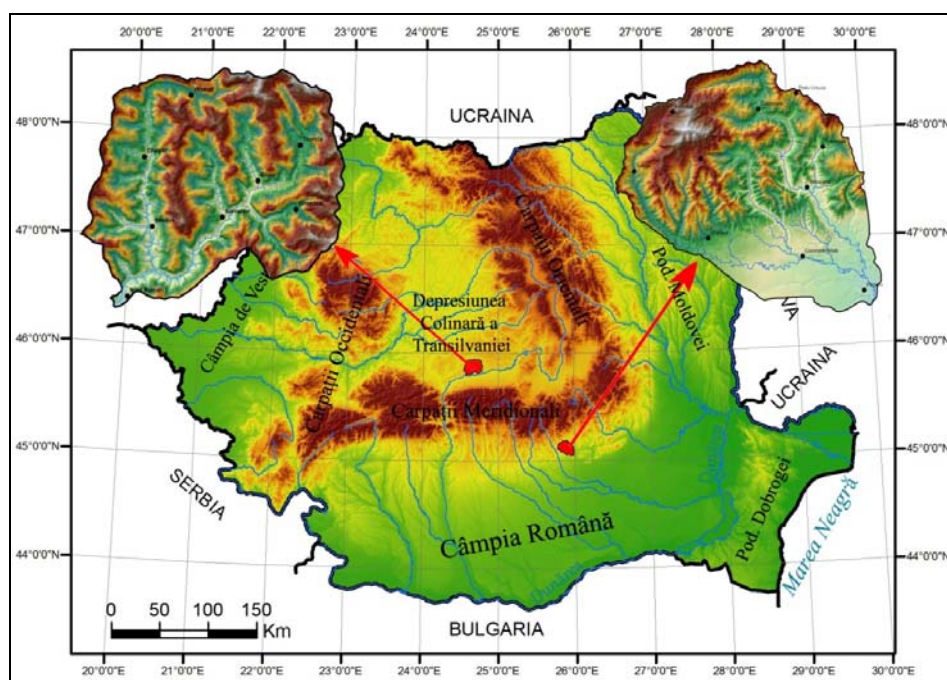


Figure 1. The location of Săsăuș and Mislea River catchments within Romania

The slopes susceptibility to landslides was evaluated by combining the following methods: the *HG 447/2003* methodology (semi-quantitative) and the „weight of evidence” method (quantitative method), (Agterberg, Cheng, 2002). The susceptibility map was obtained by weighting factors based on field observations and the frequency of landslides calculated for each class of each factor considered preliminary.

The hazard/susceptibility map according to *HG 447/2003* was developed by estimating the importance of each class of the eight factors involved and calculating average coefficient hazard (K_m), taking into account the specifications in Annex C.

Due to overestimation or underestimation of the importance of classes and many of the introduced errors by using factors whose mapping is difficult (hydro-climatic, hydrogeological, structural factors), the validation of the obtained map indicates a weak correlation between the susceptibility classes, respectively of the average coefficient hazard and active landslides.

Susceptibility map achieved by using the „weight of evidence” method consisted in probabilistic calculation of weights which are assigned to each class of each factor used. Based on positive and negative weights (computed for each class), resulting contrast values which were used, by summation, in the spatialization classes of of landslide susceptibility.

The validation of susceptibility map achieved through the weight of evidence method indicates a good correlation between susceptibility classes and active landslides. Although it has a good degree of correlation, this method has a tendency to overestimate or underestimate the importance of classes, but this can be limited by field observations.

In order to develop “the average coefficient susceptibility” maps for Săsăuș and Mislea basins, the following materials were considered and used: Topographic map of Romania, scale 1:25.000; Geological map of Romania, scale 1:200.000; Romania’s Soil map, scale 1:200.000; Seismicity zoning map scale MSK (SR-11100-93); orthophotos (A.N.C.P.I.) and Corine Land Cover data set (2006) which was the base for developing the vegetation and land usage Maps. For the study area these coefficients were calculated at pixel level, for the 20m resolution model. The calculation of the K_m coefficient was done with the Spatial Analyst and Map Calculator functions from ArcGIS 9.3. program.

The results were validated by correlating the K_m coefficient with the landslides mapped in the field using a GPS receiver. The following levels of the potential to cause landslides (low, medium, high) were established according to the K_m coefficient (*Table no. 1*).

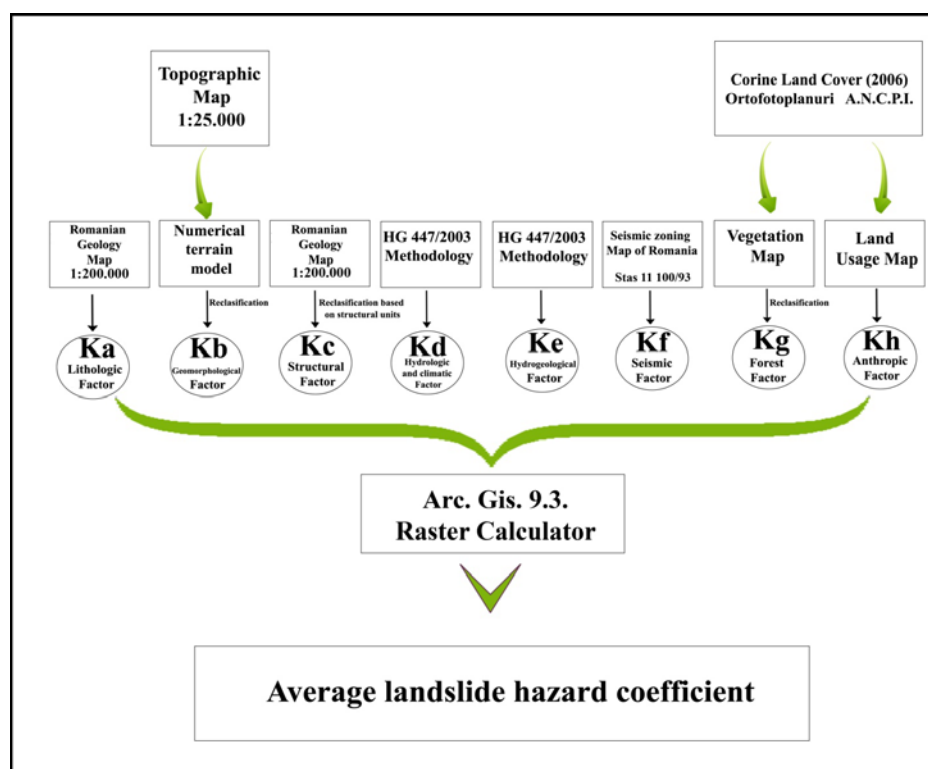


Figure 2. The elaboration scheme of the Average landslide hazard coefficient using GIS techniques (Alexandru, Cătescu, 2012)

Table 1. Landslide occurrence potential (Driga & al., 2007)

Landslide occurrence potential (Ding et al., 2007)					
Low		Medium		High	
Landslide occurrence probability (P%) and the corresponding risk potential (K _m)					
Zero	Low	Medium	Medium-High	High	Very high
0	<10	10-30	31-50	51-80	>80

In order to carry out the analysis of the *GT-019-98 Indicative*, the following formula was used (Driga & al., 2007):

$$K_m = (K_a * K_b) / 6 * (K_c + K_d + K_e + K_f + K_g + K_h),$$

where

K_a = lithologic criterion;

K_b = geomorphological criterion;

K_c = structural criterion;

K_d = hydrological and climatic criteria;

K_e = hydrogeologic criterion;

K_f = seismic criterion;

K_g = forest criterion;

K_h = anthropogenic criterion.

Aiming for the implementation of landslide susceptibility maps it is necessary that the above criteria and their association to be taken into consideration: K_a (lithologic criterion), K_b (geomorphological criterion), K_c (structural criterion), K_d (hydrological and climatic criteria), K_e (hydrogeologic criterion), K_f (seismic criterion), K_g (forest criterion), K_h (anthropogenic criterion).

The Lithologic criterion (K_a) is based on the classification of geological formations, starting from the average values of superficial formations (diluvium, colluvium, proluvium) or from the basic rocks (shale, marl, limestone) and reaching very high values for uncemented or poorly cemented sedimentary rocks (sands, breccia). Based on the Romanian geological map, the lithological factor from Săsăuș basin was classified as follows: $K_a = 0.5$ was assigned to Quaternary (Holocene), composed from gravel and sand; $K_a = 0.7$ is assigned to the Sarmatian which overlaps on marl, sand, gravel and tuff formations; $K_a = 0.9$ refers to the Pannonian with gravel, sand and clay-marls.

Taking into account the geographic position and the geological base, Mislea river basin presents more values of this criteria than Săsăuș river basin. Thus, the following classes are present: $K_a = 0.5$ is attributed to the Quaternary (Pleistocene and Holocene), consisted from gravel, sand and sandy-clay; $K_a = 0.6$ represents the Romanian and Dacian with clay, sand, marl, and charcoal formations; $K_a = 0.7$ is assigned to the Oligocene and Eocene with clay, marl, breccia, marl-clayish shale formations (Pucioasa Layer), sandstone (Fusaru and Kliwa Layers), flysch (Șotrișle), clay-flysch (Plopu); $K_a = 0.75$ represents the Pontian and Helvetian with

marl, clay, gravel, charcoal, sandstone, gypsum and conglomerate layers; $K_a = 0.8$ corresponds to the Meotian with gravel, sandstone, clay and marl formations; $K_a = 0.9$ refers to the Sarmatian with an under layer of marl, clay, sand and limestone formations; $K_a = 0.95$ is identified as being part of the Tortonian, Aquitanian and Burdigalian with marl, clay-shale, breccia, tuff, salt, gypsum and sandstone.

The Geomorphological criterion (K_b) refers to the classification of the study area in the macro-relief units (hills and mountains, plateaus, plains). According to this assignment (Săsăuș basin in the plateau unit and Mislea in the hill unit) a classification regarding slope values is emerging (interval values are directly proportional with slope values). Thus, for both basins, these intervals have been defined based on slope gradient: $K_b = 0.1$ is for slopes with an angle smaller than 3° ; $K_b = 0.3$ contains slope values between $3^\circ - 5^\circ$; $K_b = 0.4$ represents the slope values between $5^\circ - 10^\circ$; $K_b = 0.6$ refers to the slopes with $10^\circ - 15^\circ$ values; $K_b = 0.8$ goes to the slope values of $15^\circ - 25^\circ$. Due to steeper slopes found in Mislea basin, a new slope value class is added to the K_b criterion, respectively $K_b = 0.9$ with slopes that surpass 25° .

The Structural criterion (K_c) in Săsăuș river basin is represented by the class $K_c = 0.5$ which is totally assigned to the Transylvanian Depression, meanwhile within Mislea basin we encounter two classes as follows: $K_c = 0.8$ refers to Tarcău Nappe and $K_c = 0.9$ for the molasse formations.

The hydrological and climatic criteria (K_d) refers to the demarcation of areas depending on the amount of precipitation and erosion potential of the river, amid climate types in our country. Therefore, the $K_d = 0.7$ value is assigned for the hill climate found in both basins, the $K_d = 0.5$ value is assigned to plain transition climate, encountered only in Mislea basin at the contact of the Subcarpathians with the Romanian Plain.

The hydrogeologic criterion (K_e) is difficult to approach due to lack of hydrogeological maps, which would determine with greater precision the depth at which groundwater lies. Consequently, the criterion values were estimated using the *HG 447/2003 methodology*.

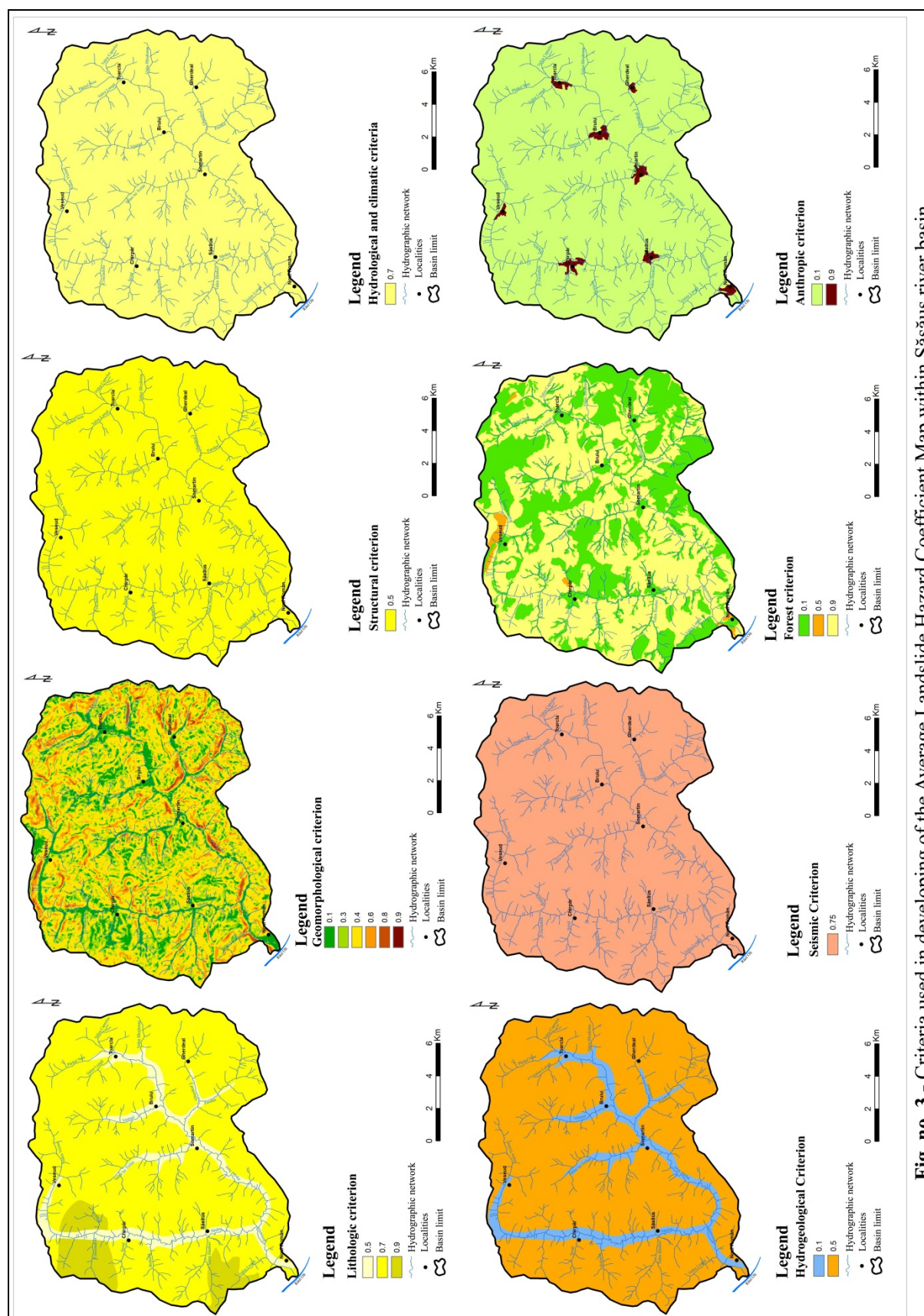


Fig. no. 3 - Criteria used in developing of the Average Landslide Hazard Coefficient Map within Săsăuș river basin

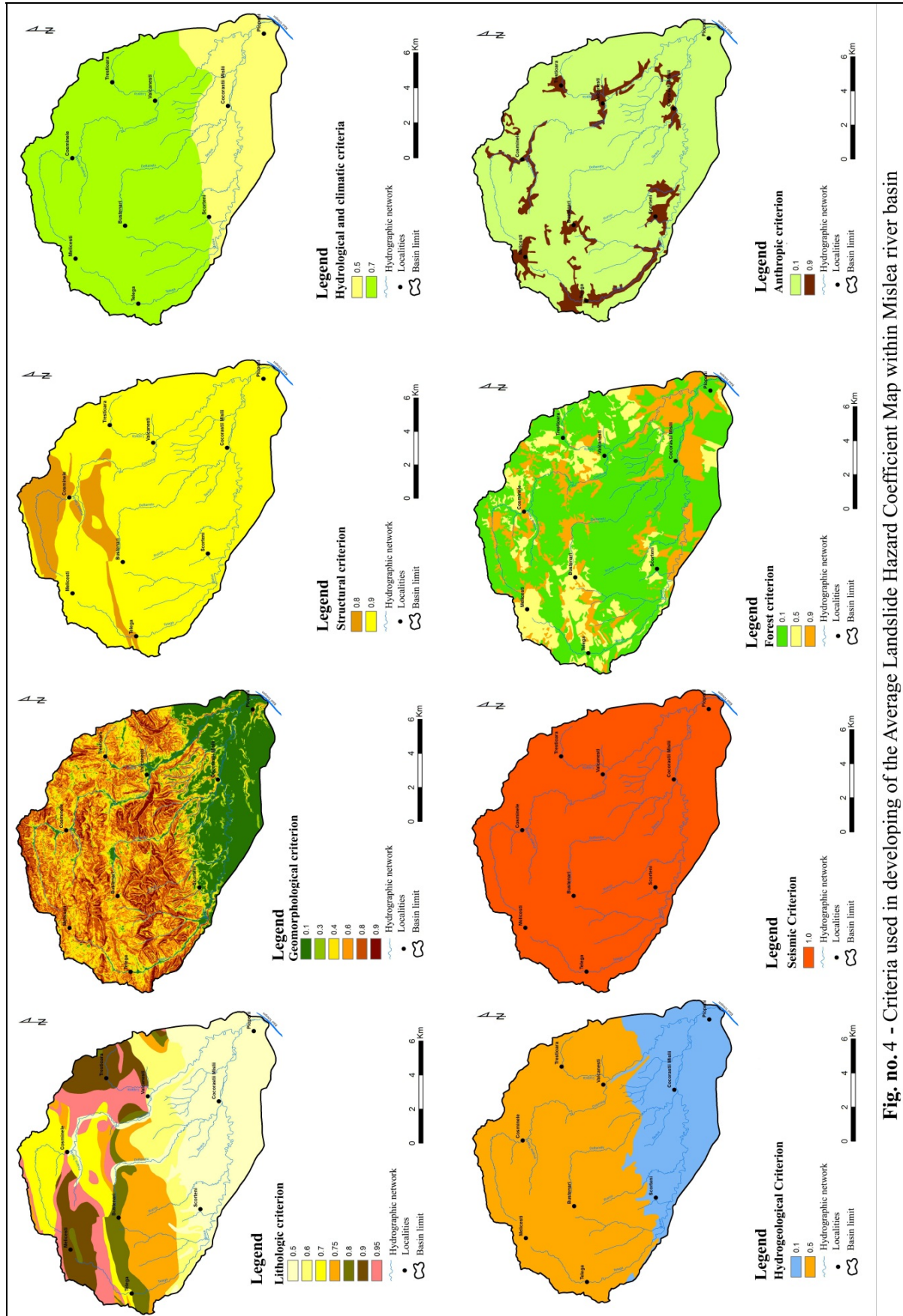


Fig. no. 4 - Criteria used in developing of the Average Landslide Hazard Coefficient Map within Mislea river basin

The medium-high values $K_e = 0.5$ were assigned to the areas where groundwater flow occurs at high values of the hydraulic gradients, causing pressure filtration. Very small values such as $K_e = 0.1$, were assigned to groundwater with a very low hydraulic gradient (filtration forces are reduced). The lowest values encountered within Săsăuș basin are concentrated along the main river valleys, while within Mislea basin these values are present in the Mislea Depression.

The seismic criterion (K_f) was determined by seismic zoning map of Romania, scale MSK (SR - 11100-93), which indicates the intensity of earthquakes. Săsăuș basin area falls within the values of seismic intensity of 7 (degrees MSK), with the coefficient $K_f = 0.75$, while Mislea basin corresponds to values of seismic intensity 9 (MSK degrees), with the coefficient $K_f = 0.9$.

The forest criterion (K_g) was developed from the Land usage Map, taking into account the vegetation coverage percentage. The values for this factor vary from $K_g = 0.1$ to $K_g = 0.9$ as follows: $K_g = 0.1$ for forests, $K_g = 0.5$ for orchards and $K_g = 0.9$ for pastures, hayfields and meadows. In Săsăuș river basin, the coefficient $K_g = 0.1$ is evenly distributed

over the entire basin, mainly in its Eastern half. The coefficient assigned to orchards occupies small areas, concentrating mainly in Northern basin, on Vizina Valley, near villages Chirpăr, Toarcia and Noul Român. The coefficient $K_g = 0.9$ is the most widespread within the basin, homogeneously distributed on the slopes of the main river valleys Săsăuș, Pârâul Nou, Valea lui Trifan, Gherdeal, Panda, Valea Lungă, Veseud. Regarding Mislea basin the forests ($K_g = 0.1$) show the highest widespread.

The orchards occupy a larger area compared to Săsăuș basin, being most common in the northern and southern parts of the basin, near the villages of Cosminele, Trestioara, Cocorăștii Mislui and Plopeni. The $K_g = 0.5$ coefficient which indicates the distribution of pastures, hayfields and meadows, has a smaller distribution compared to Săsăuș (encountered mostly on the valley slopes of Telega, Poiana Trestia, Lupăria and Runcu).

The anthropogenic criterion (K_h) shows very high values, namely $K_h = 0.9$, for both basins for settlements located valley slopes of Săsăuș, Pârâul Nou, Șomartin, Telega, Doftănet, Mislea and Cosmina.

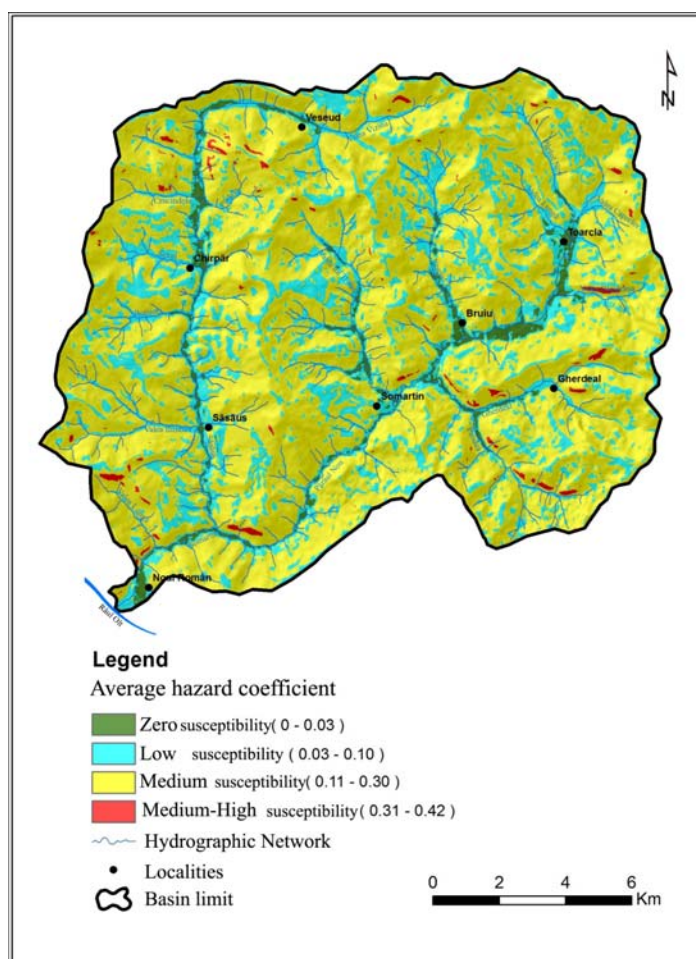


Figure 5. The Average landslide hazard coefficient map within Săsăuș river basin

Results and discussions

Following the completion of average coefficient landslide hazard map, four respectively five classes of values were obtained within the Săsăuș and Mislea river basins. The *zero susceptibility class* (0-0.03) corresponds to the surfaces with no sliding risk (Săsăuș, Valea lui Trifan, Pârâul Nou and Mislea Depression).

Class of reduced susceptibility (0.03-0.10) is mostly found in Săsăuș basin on the interfluvies of Săsăuș, Valea lui Trifan, Valea Vizina, Gherdeal, Veseud valleys, whereas within Mislea basin it is

present in Mislea depression along the main river valleys.

Medium susceptibility class (0.11- 0.30) has the largest expansion of Săsăuș basin (175 km² of the total of 232 km²) and corresponds to areas occupied by pastures, hayfields and meadows (with slopes ranging from 10°-15°, presenting an average inclination, most of this range overlapping Panonian and Sarmatian formations). However, regarding Mislea basin, this class is present in the central-southern on the valley slopes of Cosmina, Telega, Doftăneț, which mostly correspond to areas covered by forest with under layers of marl and sand Pliocene formations.

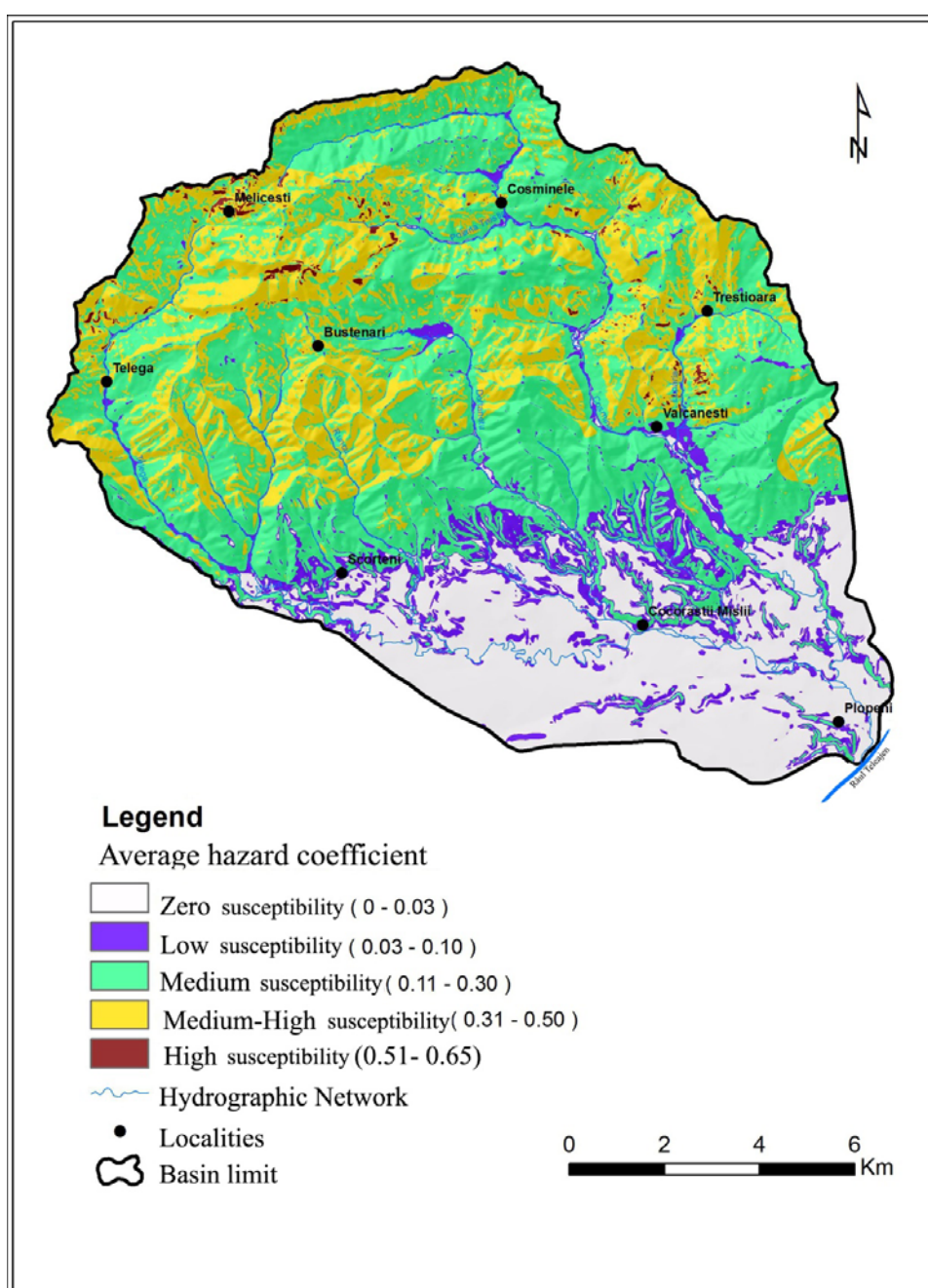


Figure 6. The Average landslide hazard coefficient map within Mislea river basin

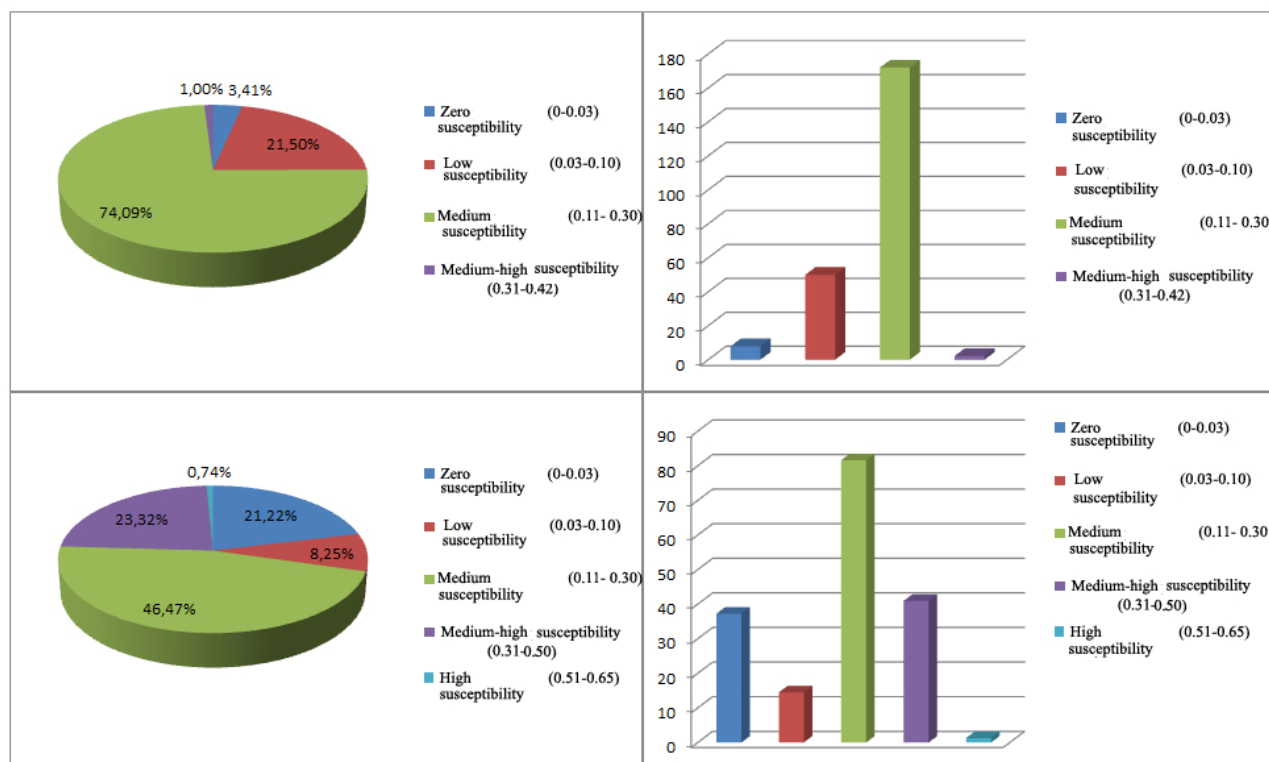


Figure 7. The cyclogram and hystogram of the Average lanslide hazard coefficient for Săsăuș (above) and Mislea (below) river basins

The *medium-high susceptibility class* (0.31-0.42) occupies the smallest area, unevenly distributed on the basin surface, in the Northern Sector of Vizina Valley, South-West on Săsăuș Valley and East on the left side of the Pârâului Nou, Gherdeal, Pandea, Valea Caprelor, Valea Bleșăraua and Valea Lungă valleys. This class is associated with grasslands areas, hayfields and meadows, with Sarmatian and Quaternary substrate deposits (gravel, sand and marls).

The *medium-high susceptibility class* (0.31-0.50) within Mislea basin corresponds to forest covered surfaces belonging to Vâlcănești, Cosminele, Telega and Buștenari depressions. The landslides framed in the *medium-high and high* classes overlap with areas occupied by orchards, pastures, hayfields and meadows. This class is superimposed on reactivated old slides encountered in torrential valley slopes in the upper Sector of the Cosmina, Poiana Trestia, Lupăria and Telega Rivers.

Most areas in the medium to high and high categories fall in the range of slopes between 15° – 20° (steep), represented by sandy-clay and marly-clay formations and salt deposits found especially in the north-west part of the basin (upper sectors of Telega, Mislea, Doftăneț and Poiana Trestia valleys). Regarding the high

susceptibility class (0.51- 0.65), it is only present in Mislea basin due to slopes with values higher than those in Săsăuș basin, which favors the probability of landslides to occur. The representative areas for this class are adjacent to Trestioara, Vâlcănești and Cosminele settlements.

Conclusions

Resulting maps cannot pinpoint when the landslide may occur because such estimates require continuous monitoring of the factors involved in producing landslides (lithological, geomorphological, structural, hydrologic and climatic, seismic, forestry and anthropic factors).

However, the maps may be viewed as an essential instrument for the development of landslide susceptibility maps. Such an analysis can capture the environmental influences on human activities and their intervention on the dynamics and destabilization of slopes by deforestation, inappropriate land usage and construction. A landslide hazard map can be used as a tool to help identify land areas best suited for development by examining the potential risk of landsliding. Though even with detailed investigation and monitoring, it is extremely difficult to predict landslide hazards in absolute terms.



Figure 8. The validation of the Average landslide susceptibility coefficient Maps with the help of spatial images for Săsaș (above) and Mîslău (below) river basins

REFERENCES

- ALEOTTI P., CHOWDHURY R.N., (1999), *Landslide Hazard Assessment: Summary Review and New Perspectives*, Bulletin of Engineering Geology and the Environment, Vol. 58, No. 1, 21 - 44, August;
- AGTERBERG, F. P. and Q. CHENG, (2002), *Conditional Independence Test for Weights-of-Evidence Modeling*. Natural Resources Research, 11(4), 249-255;
- ARMAȘ IULIANA, (2006), *Risc și vulnerabilitate, Metode de evaluare aplicate în geomorfologie*, Editura Universității din București;
- ARMAȘ IULIANA, DAMIAN R., ȘANDRIC I., OSACI-COSTACHE GABRIELA, (2003), *Vulnerabilitatea versanților la alunecări de teren în sectorul subcarpatic al văii Prahova*, Editura Fundației România de Măine, București;
- BALLY R. J., STĂNESCU P., (1977), *Alunecările și stabilitatea versanților agricoli*, Edit. Ceres, București;
- BĂLTEANU, D., TALOESCU, IULIANA, (1978), *Asupra evoluției ravenelor Exemplificări din dealurile și podișurile de la exteriorul Carpaților*, SCGGG – Geogr., XXV;
- BĂLTEANU, D., (1986), *The importance of mass movement in the Romanian Subcarpathians*, Z. Geomorph. N. F. Suppl. – Bd. 58;
- BĂLTEANU D., DINU MIHAELA, CIOACĂ A., (1989), *Hărțile de risc geomorfologic*, SCGGG - Geogr. XXXVI, București;
- BROMHEAD E. N., (1997), *The treatment of landslides*. Journal of Proc. Instn Civ. Engrs Geotechnical Engineering, 125, April, 85-96;
- CARRARA A., CARDINALI M., GUZZETTI F., REICHENBACH P., (1995), *GIS technology in mapping landslide hazard*, Kluwer Academic Publisher, Dordrecht, The Netherlands;
- CHIȚU ZENaida, (2010), *Predicția spațio-temporală a hazardului la alunecări de teren utilizând tehnici S.I.G. Studiu de caz arealul subcarpatic dintre Valea Prahovei și Valea Ialomiței*, Teza de Doctorat, București;
- CHANG-JO F. CHUNG C.J.F, FABBRI A.G., (2003), *Models for landslide mapping*, Natural Hazards, vol. 30, nr. 3, pg. 451-472, Springer;
- CIOACĂ A., (1996), *Evaluarea vulnerabilității terenurilor afectate de procese geomorfologice actuale*, AUȘMS - Geogr. - Geol., V, Suceava;
- DINU M., CIOACĂ A., (1987), *Morfotectonica Subcarpaților Vâlcei și Vrancei*, Lucr. Sem. Geogr. „D. Cantemir”, nr.7, Univ. „Al. I. Cuza”, Iași;
- DONALD I. B., CHEN Z. Y., (1997), *Slope stability analysis by the upper bound approach: fundamentals and methods*. Canadian Geotechnical Journal, vol. 34, pp. 853-862;
- DUMITRESCU I., SÂNDULESCU M., BANDRABUR T., SÂNDULESCU J., (1970), *Harta geologică a României, Scara 1:200,000*, Inst. Geol., București;
- DRIGA B.V., NICULESCU GHE., CIUPITU D., ȘERBAN MIHAELA, DĂRUȚ C., (2007), *Riscurile naturale din județul Satu Mare*, Edit. Arvin Press, București;
- FREDLUND D. G., KRAHN J., (1977), *Comparison of slope stability methods of analysis*. Canadian Geotechnical Journal, Vol. 16, pp.121-139;
- GEORGESCU E.S., (1993), *Zonarea seismică a teritoriului României - scara MSK conf. SR 11100 - 1:1993 Zonarea seismică. Macrozonarea teritoriului României, Evaluarea Riscului Seismic și Acțiuni în Construcții*;
- GLADE T., CROZIER M.J., (2005), *A review of scale dependency in landslide hazard and risk analysis*, in *Landslide hazard and risk*, edited by Thomas Glade, Malcolm Anderson, Michael Crozier, John Wiley, London;
- GRECU FLORINA, (1997), *Fenomene naturale de risc* (Natural Phenomena of Risk), Editura Universității din București;
- GRECU FLORINA, (2002), *Risk – prone Lands in Hilly Regions: Mapping Stages*, in *Applied Geomorphology*, edited by R.J. ALLISON, Ed. John Wiley & Sons, Ltd. Chichester, England, p.49 –64, 6 fig., 6 tabele;
- GRECU FLORINA, (2003), *Geomorfologie dinamică*, Editura Tehnică, București;
- GRECU FLORINA, (2009), *Hazarde și riscuri naturale geologice și geomorfologice*, Edit. Credis, București;
- GRECU FLORINA, (2009), *Hazarde și riscuri naturale*, Ediția a IV-a, Edit. Universitară, București;
- GUZZETTI F., (2005), *Landslide hazard and risk assessment*. PhD dissertation. Bonn, Germany;
- GUZZETTI F., CARRARA A., CARDINALI M., REICHENBACH P., (1999), *Landslide hazard evaluation: an aid to a sustainable development*, Geomorphology;
- GUZZETTI F., REICHENBACH P., CARDINALI M., GALLI M., ARDIZZONE F. (2005), *Landslide hazard assessment in the Staffora basin, northern Italian Apennines*, Geomorphology;
- LEE S., CHOI J., MIN K., (2002) *Landslide susceptibility analysis and verification using the Bayesian probability mode*, Environmental Geology;
- LEE S., (2004), *Application of Likelihood Ratio and Logistic Regression Models to Landslide Susceptibility Mapping Using GIS*, Environmental Management;
- MEJÍA-NAVARRO M., WOHL E.E., OAKS S.D., (1994), *Geological hazards, vulnerability and risk assessment using GIS: model for Glenwood Springs, Colorado*, Geomorphology, 10, 331-354;
- MONTGOMERY D.R., DIETRICH, W.E., (1994), *A physically based model for the topographic control of shallow landsliding*, Water Resources Research, 30, 4, 1153-1171;
- MOREIRAS M.S., (2005), *Landslide susceptibility zonation in the Rio Mendoza Valley, Argentina*, Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales-Consejo Nacional de Investigaciones Científicas y Tecnológicas, Argentina, Geomorphology nr. 66/2005, pg. 345-357;
- NOÛMÈNE F., (2007), *Les rapports entre les processus morphogéniques et les pratiques agro-pastorales dans la plaine oléicole de Sfax: Exemple du bassin versant de l'oued Chaâl – Tarfaoui (Tunisie centro –orientale)*, Faculté des Lettres, des Arts & Humanité, Manoubâ;
- PACHAURI, A.K., GUPTA, P.V., CHANDER, R., (1998), *Landslide zoning in a part of the Garhwal Himalayas*, Environmental Geology, 36, 3-4, 325-334;
- PACHAURI, A.K., PANT, M., (1992), *Landslide hazard mapping based on geological attributes*, Engineering Geology, 32, 81-100;

- RĂDOANE, MARIA, RĂDOANE, N., ICHIM, I., (1993), *Folosirea metodei cubului matricial în evaluarea susceptibilității la alunecări de teren. Caz de studiu: jud. Neamț*, SCGGG, București;
- van WESTEN C.J., CASTELLANOS A., SEKHAR L.K., (2008) *Spatial data for landslide susceptibility, hazards and vulnerability assessment : an overview*. In: *Engineering geology : an international journal*, 102 (2008)3-4, pp. 112-131;
- VARNES, D.J., IAEG Commission on Landslides and other Mass-Movements, (1984), *Landslide Hazard Zonation: A Review of Principles and Practice*, UNESCO Press, Paris, 63 p.
- *** *Harta Solurilor României, scara 1:200 000*, I.G.F.C.O.T., București.
- *** Hotărârea Nr. 447 (2003), *Aprobarea normelor metodologice privind modul de elaborare si continutul hartilor de risc natural la alunecari de teren si inundatii*, GUVERNUL ROMANIEI.
- *** (2000), *Ghidul de redactare a hărților de risc la alunecare a versanților pentru asigurarea stabilității construcțiilor (indicativ GT019 - 98)*, Anexa 2, Elaborator: I.S.P.I.F. București.

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Geomorphologic Considerations on the Dobrotfor Catchment

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Abstract. The Dobrotfor Creek is a right tributary of Zeletin River and its catchment of 87 km² is stretching within the central part of the High Tutova Rolling Hills.

The geologic layers brought to the surface by the erosion have been deposited in deltaic facies. They are predominantly sandy-clayey and showing a gentle dipping south-southeastwards of 7-8 m/km. Also, they are Upper Miocene and Pliocene in age and belong to the Chersonian, well outlined in the lower third of the valley sides, to the Meotian with a maximum vertical development and just a few to the Pontian in the south-western corner.

The Dobrotfor valley is, generally, a consequent one and on the background of an intense relief fragmentation, the valleys of some tributaries, however, emphasize the two types of structural asymmetries specific to the Moldavian Plateau.

The natural, geologic, pedo-geomorphologic, climatic, hydrologic circumstances, combined with the influence of the human activity, are in the favor of significant development of the present-day geomorphologic processes.

The analysis of some morphometrical indicators suggests that the susceptibility to the land degradation processes is higher in the northern half and more reduced in the southern part of the Dobrotfor catchment. Under these circumstances, soil erosion, gullyng, landslides and sedimentation are representing the major threat to the local environment.

Key-words: structural asymmetries, soil erosion, gullies, landslides.

Introduction

The Tutova Rolling Hills represents a major subunit of the Moldavian Plateau of eastern Romania covering around 3.400 km². This area is well-known for its elongated and narrow rolling hills (colinnes) that are southward stretching and separated by parallel valleys. The hydrological regime of the rivers is characterized by big pulses including either lack of streamflow or severe floods. Due to its natural conditions (friable layers, high relief amplitude, rain aggressiveness and wooden soils prone to erosion) and non-appropriate human impact, this area is at a high risk of land degradation.

The catchment of Dobrotfor Creek, a right tributary of the Zeletin River, is located in the central part of the Tutova Rolling. Of the total 423 km² of Zeletin catchment about 20.6% (87 km²) is drained by Dobrotfor network.

Presently, significant changes in land management practices resulted from the application of the Land Property Act no.18/1991, namely the marked shifting from contour to up and down hill farming. Thus, on the background of a sandy-clayey lithology, of steep slopes, of some changes on the climatic parameters, and the impact of human activities, a large range of land degradation processes are on the screen, among which the soil erosion and gullyng being one of the most important.

The Study Area and Methods

From an administrative point of view, the Dobrotfor catchment is situated in the eastern part of Bacau County and comprises a big part of the Stanișești community, in the northern area and Motoșeni community, in the South.

Spindle-like in shape, a classic type for the rivers within the south-western part of the Moldavian Plateau, the Dobrotfor catchment is 32 km long and only 4 km wide in the southern half.

From a geological point of view, the Dobrotfor catchment is superposed upon the Barlad Platform, which is surrounded by two main deep faults, in the North – Falciu-Plopana fault which divides the Moldavia Platform, and in the South – Sf. Gheorghe-Oancea-Adjud fault, where it reaches the Orogen North Ddrogea (Ionesi, L. 1989). Over the Precambrian or Paleozoic folded structure, rests a thick sedimentary layer, from which the erosion brought into relief layers belonging to the Chersonian, Meotian and Pontian, laid in deltaic facies (Figure 1). The sedimentary layers are set out in a generally monocline structure, showing a gentle dipping of 7-8 m/km to South-South-East (Jeanrenaud P., 1966, 1971, 1995).

The Upper Sarmatian (Chersonian) layers are well outlined in the lower third of the hill sides, and the Meotian ones have a maximum development on the vertical. At the beginning, Jeanrenaud P. (1966) has distinguished the following three layers in the

Meotian formation: the lower layer, an intermediary, cineritic layer and the upper sandy and clayey layer. Later on, in 1971, the author previously mentioned, reduces the Meotian layers at two horizons, the cineritic and the upper, respectively. The former lower horizon was included into the Upper Sarmatian (Chersonian).

The typical, cineritic layer of the Meotian formation has a thickness of 30 – 40 m, and it consists of three cineritic banks split by sand, clay and marl deposits. The volcanoes located on the western side of the Eastern Carpathians represented the source of the pyroclastic material, thus some authors as Filipescu M. don't exclude the likely occurrence of extra-Carpathian volcanism. Both types of structures, the Chersonian and the Meotian, are developed in deltaic facies.

Frequently, the outcrops of the Nuțasca-Ruseni andesitic cinerites or cineritic sandstones appear well outlined in the valley-side gullies of the Dobrotfor (Figure 2).

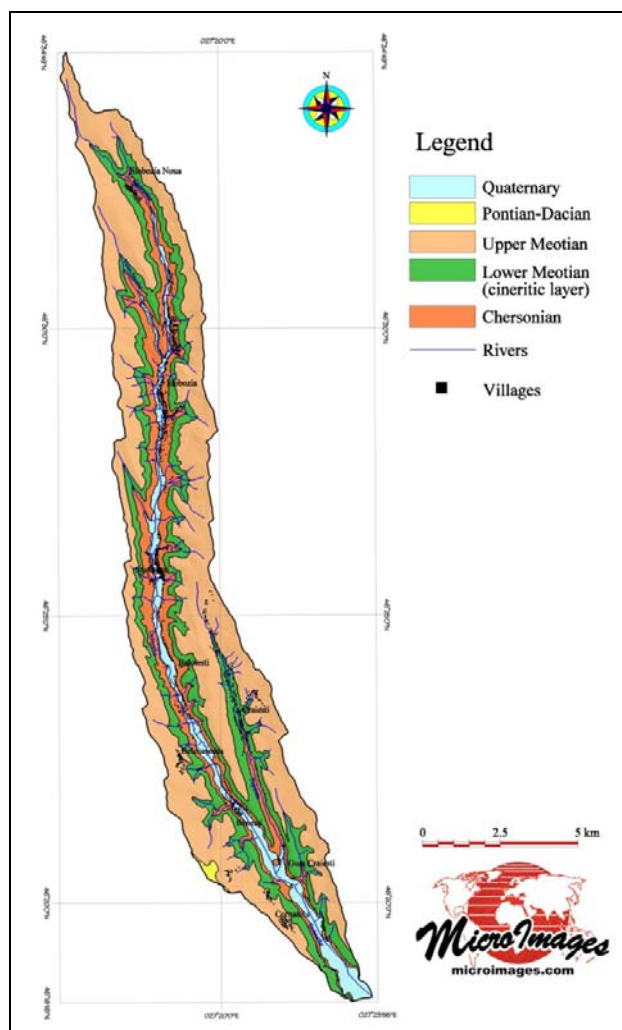


Figure 1 The geological map of the Dobrotfor catchment (processing after Jeanrenaud, 1971)



Figure 2. Cineritic sandstones in the Onofrei gully, north of Stanișești village, on the left valley-side of Dobrotfor

The Pontian layers have reduced incidence, covering only 0.30 km², in the south-western corner of Dobrotfor catchment, on the hilltop between Berheci and Zeletin. Initially, they were more extended, but they have been eroded as the hydrographic network and the relief developed.

Among the geologic units within the Dobrotfor catchment, the biggest share belongs to the Meotian, which averages 75.20% (66.3 km²) from the total area (Figure no.3). That formation is stretching in the middle and upper third of the hillslopes. Thus, the cineritic horizon occupies 22.17 % (19.47 km²) and the upper horizon has a share of 53.03 % (46.56 km²).

Beside these older deposits, there are also recent Quaternary formations, such as: eluvia, diluvia, colluvia, proluvia, and alluvia.

Under such conditions, between the Siret and Barlad rivers a typical area has been outlined, the Tutova Rolling Hills, whose main characteristic is depicted by narrow, prolonged interfluvies, southward oriented and separated by parallel valleys (*Hârjoabă I., 1968*). In addition, the cuesta relief was notified to have appeared and developed (*Ioniță I., 1985, 1998, 2000a*).

The climatic factor acts, first of all, through the thermal regime and rainfalls, secondly through the action of the wind. The annual average temperature at the Oncești Weather Station, located on the western side of the Dobrotfor catchment, varies around 9.0° C, with maximum in July and minimum in January. As to the thermal regime, an important role in the development of geomorphologic processes is played by the freezing regime. For the Tutova Rolling Hills area, the average annual number of *freezing days* oscillates between 112 and 127, values that are specific to the Moldavian Plateau.

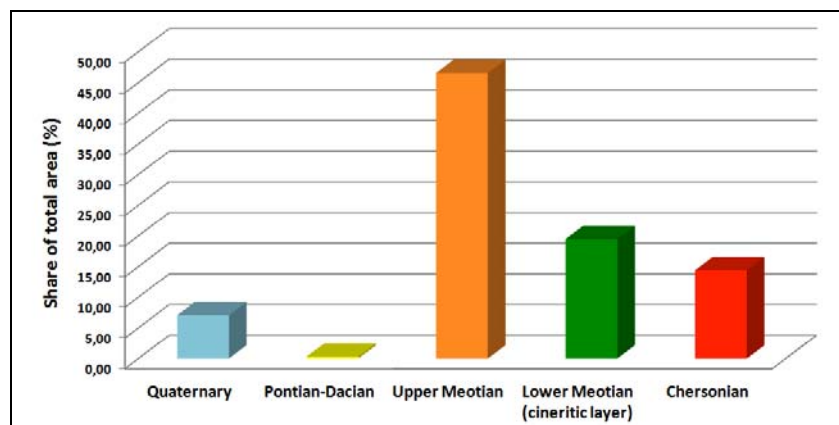


Figure 3. Histogram of the areas covered by different layers

The rainfalls may be considered the most important factor in the climatic control hierarchy of the geomorphologic processes. As to the rainfall distribution in the Tutova Rolling Hills area, we may note that the influence of the altitude is bigger than the influence of the latitude. The average annual precipitation is 529.4 mm at Motoșeni, 551.3 mm at Oncești and 531 mm at Plopana, with maximum in June for all the three locations and minimum in December for Motoșeni and January for Oncești and Plopana.

The main rivers don't have a regular flow regime during the year, the frequent drying up in summer contrasts with floods resulting from snow melting or heavy rainfalls, but the average water discharge of Dobrotfor river is 0.20 m³/s. The specific average streamflow is of 1 l/s/km², the spring streamflow being dominant due to the snow melting and the heavy rainfalls in May and June.

The natural vegetation, especially the forest vegetation, occupies much smaller areas at present than in the past, the ubiquitous presence of the forest soil in various stages of degradation being the proof of that. It occupies 12.92 km² (14.72 %) as discontinuous areas, especially in the upper part of the interfluvies.

The dominant soils belong to Luvisols (2018.39 ha, 29.32%), Antrisol (1768.89 ha, 25.70%), Protisol (1748.13 ha, 25.40%) și Cambisol (1176.91 ha, 17.10 %) and very little to Chernisol (102.37 ha, 1.49%), Pelisol (59.64 ha, 0.87%) și Hidrisol (9.23 ha, 0.13%).

The objective of this paper is to underline the main relief characteristics, through its geological structure and in close connection to the other physical-geographical factors, and to emphasize the impact of the land degradation processes.

In order to make the maps concerning the morphographic and morphometric analysis and all

the other thematic maps the TNTMips v. 6.9. programme has been used, achieved by Microimages Inc., Lincoln, NE, USA. The analysis of the morphometric factors and the morphographic aspects are based on achieving the Digital Elevation Model (DEM), obtained by the georeference and the vectorization of the topographic maps in 1:5,000 scale. In order to analyze the state of land degradation the orthophotoplans of the year 2006 and the field survey have been used.

Results and Discussion

The morphometric characteristics of the relief intervene in the rate of land degradation processes through the direct influence on soil erosion, gully, landslides and sedimentation.

Based on the Digital Elevation Model (DEM) several thematic maps have been delivered, such as those regarding the hypsometry, slope gradient, slope facing, the relief fragmentation map etc.

1. The Hypsometry

Within the study area, the altitudes are decreasing as we're heading towards South, likewise in the entire Tutova Rolling Hills area (Figure 4).

The highest altitude of 555 m is encountered at the Doroșanu Hill, in the northern tip of the Dobrotfor catchment. A close value, of 532 m, occurs at the Panu Hill, west of Panu Village, now called Slobozia Nouă. The lowest altitude of 137 m appears in the Dobrotfor floodplain at the confluence with Zeletin River and, therefore, the maximum relief amplitude is 418 m. Almost 80% from the study area has the altitude between 150-400 m and the medium altitude is 302 m (Figure 5).

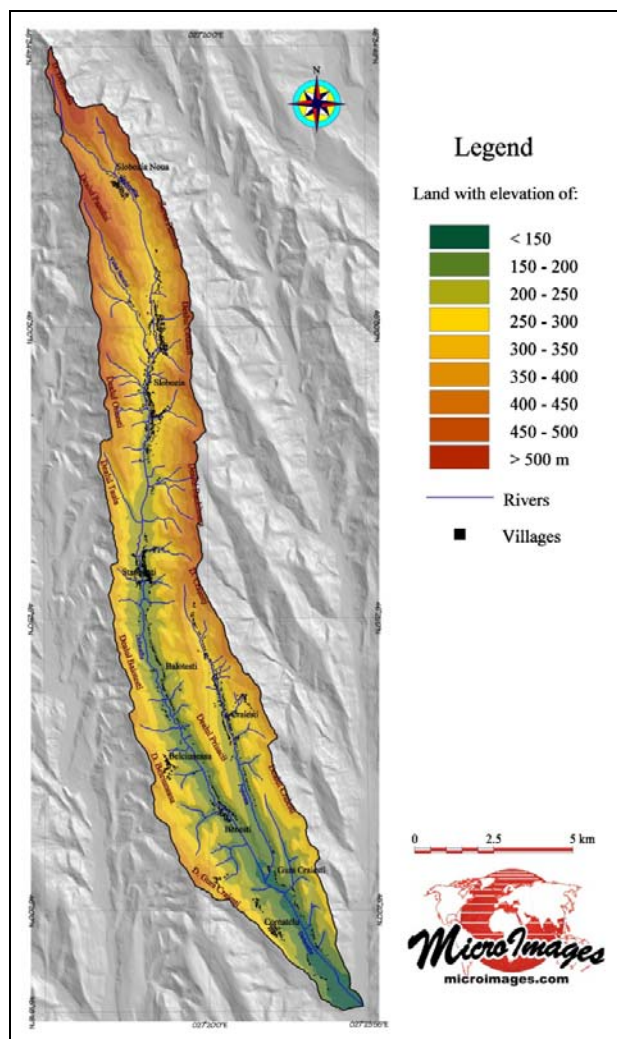


Figure 4. Hypsometric map of the Dobrotfor catchment

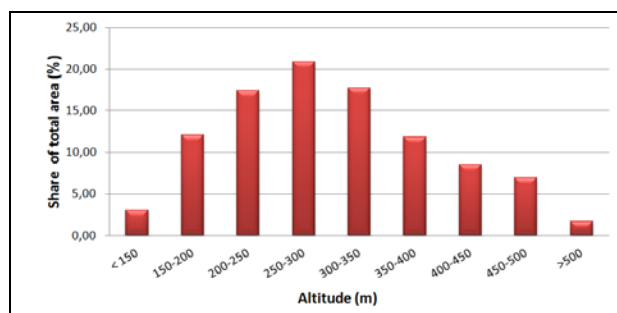


Figure 5. Histogram of the areas by altitudinal classes

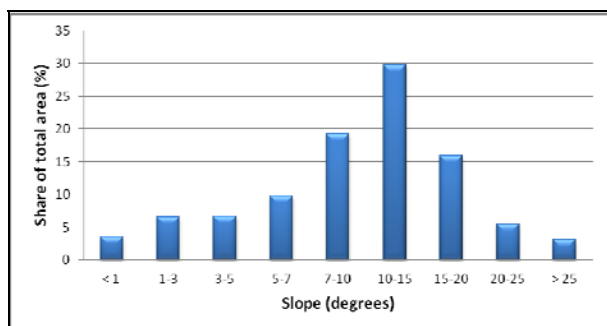


Figure 6. Histogram of the areas by slope classes

2. The geodeclivity

This feature is very important as the soil and water conservation is concerned because it influences the distribution, intensity and specific of the present-day geomorphologic processes. The average value of slopes is 11.2° and the peak value reaches 50° . Two thirds of the Dobrotfor catchment are covered by field with the slopes between $7-20^\circ$ (Figure 6).

The slopes with smaller values than 3° are found especially in the Dobrotfor floodplain, but also on some hilltops in the North, as at Panului Hill, Dorosanu Hill or on the hilltop between Dobrotfor and Pojorâta.

The slopes between 3° and 5° are found especially on the glacises located at the contact between the floodplains and the hill slopes. The poorly-moderate sloping field of $5^\circ-10^\circ$ usually occupies the back-slope of cuestas. The field with slope over 15° is found on the cuesta escarpments which are facing to the west or to the north (e. g., the left hillside of Dobrotfor valley near Benești village). Other deluvial very steep slopes appear also on the front of cuestas being associated to cornices or in the drainage basin of tributaries.

3. Slope orientation

Figure 7 shows us on one hand the weak presence of the northern and north-western facing slopes, with direct implication on the classic Moldavian cuestas whose escarpment is always looking to the north, north-west and on the other hand, the development of the cuestas with the western front and eastern back-slope.

Northern facing cuesta escarpments are linked to the valleys of the tributaries by first or second order as in the south-western part of the Dobrotfor catchment and very rarely on the valley associated to the upper river orders.

For the consequent/re-consistent valleys, which have the main drain direction on NNW-SSE, we can notice the high percentage of E and NE orientation, well outlined on their right slope. Thus, the eastern facing slopes, the back-slopes of cuesta, represent the most typical example being the right side of the Pojorâta Valley. Instead, the left side of these valleys has a predominantly SW orientation as in Sacului Valley and Darie's Valley.

Generally, the *eastern looking slopes* (23.85 %) have the greatest development, and they are followed by the western facing ones (20.21 %), this fact being mainly due to the southward flow direction of Dobrotfor river (Figure 7). The slopes with eastern orientation dominate the right side of

the northern half of the Dobrotfor catchment or Pojorâta Valley, and the western slopes are prevailing in the central part of the study area.

The distribution of north-western slopes depends upon the orientation of the valleys, and they are more present in the SSW and NW of the Dobrotfor catchment, where the valleys have NW - SE orientation.

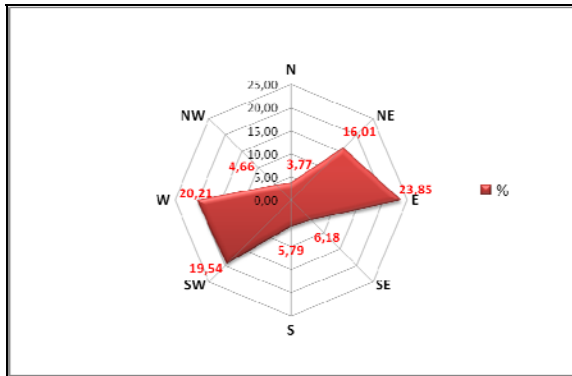


Figure 7. Orientation of the slopes in the Dobrotfor catchment

4. The main genetic landforms

4.1. Structural lithologic topography

Since the main geologic check-layer in the Barlad Plateau, the Repedea oolitic limestone of Middle Sarmatian in age, is under the floodplain level within the Tutova Rolling Hills, this type of relief is very poorly represented. It appears, however, in the restricted areas, as small *structural plateaus* depending on the outcropping of Nuțasca-Ruseni andesitic cinerites/cineritic sandstones. These rocks are more resistant at erosion than the sandy-clayey prevailing layers, but they are crumbly, and they rarely appear as erosion remnants in the local landscape. Thus, some small plateaus of local importance are mentioned, such as those at Mosia Panului Hill, westward of Slobozia Nouă village, at Sacului Hill situated between Dobrotfor and Pârâul Sec, at Crăiești Hill, Curtea Veche Hill west of Stănișești village (Figure 8).

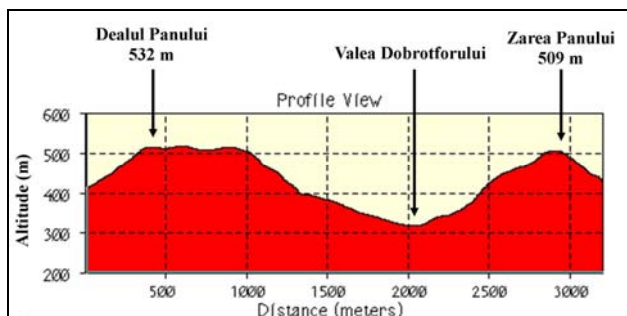


Figure 8. Cross-section through the upper Dobrotfor valley, south of Slobozia Nouă (Panu) village

On the other hand, other types of valleys developed within the geological monoclinical structure, specific to the Moldavian Plateau, are of interest.

Consequent valleys are those whose direction corresponds to the dipping of the layers, so that they comprise all the valleys with north-south orientation. Here are typical almost the entire Dobrotfor Valley and the reconsequent valleys as well, which are younger and located on a derived lower surface.

The cross-section of these valleys is slightly asymmetrical, due to the influence of the secondary digging eastwards of layers by 3 m/km. It is dependent upon the neo-tectonic uplifting of the Moldavian Platform/Plateau at the contact with the Carpathian Orogen. Such valleys, as Pojorata, Gura Crăiești, Darie Valley are typical to the second order structural asymmetry reported by Ioniță I. (1985, 1998, 2000a).

Subsequent valleys are displayed approximately transversely to the general tilt of the layers, so they are west-east or east-west oriented and they are characterized by a classic asymmetrical cross-section. They are slightly outlined within the Dobrotfor catchment, appear mainly as torrential small valleys, and this actually underlines the youth relief in the Tutova Rolling Hills (*Hârjoabă I., 1968*).

Obsequent valleys are oriented in a direction opposite to the dip of the local strata and they are depicted by a low incidence in the Dobrotfor catchment as Râpa Analagelor, south-east of the Slobozia village.

4.2. Sculptural (fluvio-denudational) landforms in monoclinical general structure

This type of relief is prevailing in the study area and it is represented by both the hilltops and the deluvial slopes.

The main *top of hills* impose themselves as relief, first of all by their parallelism, a characteristic due to the predominance of the consequent valleys in the Tutova Rolling Hills (*Hârjoabă I., 1968*). They are very elongated, have the longitudinal profile lines slightly wavy and the flanks are sometimes steep, and the local people call them "*horizons*" like for Panului Horizon, Slobozia Horizon, Crăiești Horizon etc.

At the first sight we can distinguish two major interfluvial hilltops, namely those which form at the same time the eastern and western watersheds of the Dobrotfor catchment. They are parallel on the north-south direction in the north part and north-west - south-east in the south.

The main hilltop Dobrotfor - Berheci has a length of 37.9 km and it is stretching southwards from Dorosanu Hill until the Gura Crăiești Hill, and further is changing the direction to south-east (Figure 9). Due to the geologic specific features, and especially due to the faster and more pronounced relief evolution in the northern and higher part of the Tutova Rolling Hills, the interfluvial hilltops are more dissected and they often show some saddles which separate „hillocks” like the one in Gura Crăiești Hill (428 m).

The hilltop Dobrotfor – Zeletin, of 36.9 km length, is smoother than previous and its altitude decreases gradually southwards, with few exceptions.

The average altitude of the first interfluvial hilltop is of 390 m, while Dobrotfor – Zeletin hilltop is higher and showing an average altitude of 422m.

Inside the Dobrotfor catchment, a series of secondary hilltops are outlined, and the Dobrotfor – Pojorâta hilltop is imposing itself. This hilltop is 11.53 km long, smooth, with altitude that decreases gradually from the north (455 m) to the south (146 m), but the average height is 290 m.

Deluvial slopes represent the most representative landform in the Dobrotfor catchment and it has the greatest share among the existing relief forms. Slopes frequently play role of either the cuesta escarpment or cuesta back-slope within the Bârladului Plateau. For a better understanding of the cuesta relief in the Moldavian Plateau Ioniță I. (1985, 1992, 1998, 2000) recommends to be taken into account two dipping planes of the outcropping layers, namely: a major one North-South of 6-7 m/km, who is responsible for the first order structural asymmetry and a secondary one, West-East of 3 m/km, which is specific to the second order structural asymmetry. By combining the two dipping planes of the strata, a general monocline structure of de 7 – 8 m/km southwards is resulting.

The most obvious example in this respect is represented by the consequent Pojorata , which is described by its typical asymmetric cross-section and thus emphasizes the second order structural asymmetry. Its right valley-side is a cuesta back-slope eastern facing, whilst the left hill-side is a western looking cuesta escarpment.

The lack of typical subsequent valleys explains the weak development of the first order asymmetry. We can mention only a series of small torrential valleys, orientated West- East or East-West, which show cuesta escarpments (small apophyses) northern looking. The Alunis Valley near Stănișesti village or Bărbălău Valley near Benesti village are few examples of this valley type. Due to the intensity of the degradation processes, the cuesta back-slope in these valleys is severe deraded too, and it doesn't play the role of classic cuesta reverse.

Generally, the cuesta back-slopes are subjected to soil erosion, usually of moderately-strong intensity, to gullyng or landslides. In many cases, cuesta back-slopes present a narrow basal border, usually with 10 to 20 m amplitude increasing upstream, and the geomorphologic processes are often similar to those on the cuesta escarpment. Often, based on the petrographical facies, some morphological discontinuities coincide with local cineritic sandstones. That is why it is estimated that the border at the basis of the cuesta reverse is firstly due to the Würmian deepening of the rivers, which was moderate in the middle courses and stronger in the upper courses of the valleys (Ioniță I., 1985, 1998, 2000a). A typical example for the differential evolution of the cross-section is illustrated by Pojorâta Valley.

It is important to learn that, due to the very high values of the relief fragmentation and the intensity of the present-day geomorphologic processes, the second order structural asymmetry is much more blurred. Initially, the consistent valley of Dobrotfor was installed on the Berheci cuesta backslope, and at least the middle and upper catchment exposed an asymmetric cross-section: the right valley-side as cuesta back-slope eastern facing and the left one with as western looking cuestă escarpment. Subsequently, the reverse was heavily degraded and, therefore, its actual cross-section is a symmetric one. So that, the second order asymmetry is encountered on the younger valleys of the tributaries, like Pojotâta Valley. Usually, the cuesta escarpments are subjected to severe gullyng, landslides and soil erosion.

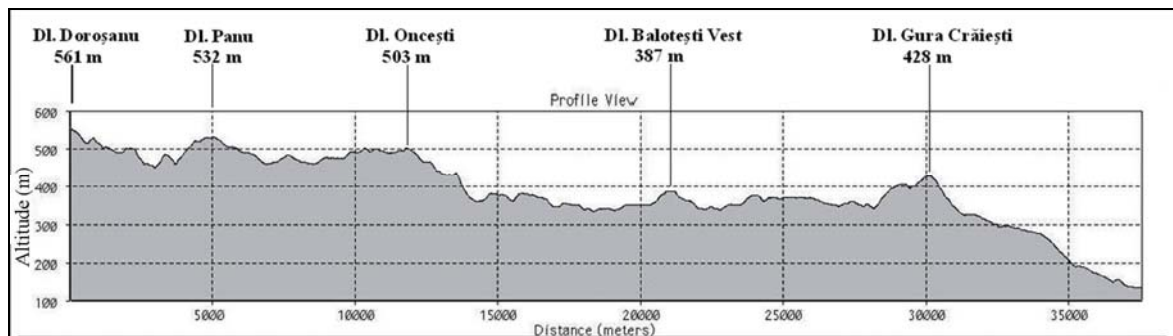


Figure 9. Topographic longitudinal profile, on the N-S direction, through the top of Dobrotfor – Berheci hill

In general, the soil erosion is ubiquitous and according to Ioniță I. (2000c, 2007) the critical season of this process covers two months from mid-May to mid-July. On the slightly eroded cambic chernozems, the annual soil loss averaged 7.74 t/ha for corn and 33.10 t/ha for continuous fallow. Moreover, under the forestry soils, strongly-excessive eroded, with small cohesion, slightly structured, the soil loss doubles (Ioniță I., 2000c). Since wooden soils (luvosols) are dominant in the Dobrotfor catchment, it is estimated that the average annual soil loss 15-16 t/ha under row growing crops.

Gullying represents the most typical process in the study area, which Hârjoabă I. (1968) summarizes as “one of the most important geomorphologic phenomena in the Tutova Rolling Hills, assuming the most important role the current development of this region.” Moreover, successive long term measurements allowed Ioniță I. (1998, 2000b, 2007) to get a series of findings, namely:

- The annual gullying regime has pulses, with large variations;
- The critical gullying season covers four months, between mid-March to mid- July;
- Cold season, especially freeze- thaw cycles at the end of winter, plays an important role in the gully development been responsible for 57% of the changes occurring in the gully;
- The average gully-head retreat was about 1.0 m/yr for the discontinuous gullies and increased to 12.5 m/yr for continuous gullies during 1960-1990.

The discontinuous gullies are more frequent in the Dobrotfor catchment and they have moderate dimensions when are situated on slopes, while the bigger gullies were subjected to land reclamations, like dam structures or forestry plantations, deployed before 1990 (Figures 10).

By using topographic maps in the 1:5000 scale, the orthophotoplans done in 2006 and the field surveying it was possible to identify a number of 285 gullies and to estimate that the area covered by gullies is 3,76 km², which represents 4.28 % of the total (Figure 11).

The slopes subjected to landslides have a considerable spreading of 45.32 km² (51.61 %). At present, most landslides have a high degree of stability, mainly due to forest plantations but also due to the drier period of time after 1982. As Hârjoabă I. (1968) stated that the incision through gullying is an important factor in triggering landslides and the majority of landslides in the basin are “almost exclusively connected with the development of the gullying”. The slopes strongly

affected by this process are located mainly in the northern half of the catchment and in the south-western part as well (Figure 12).



Figure 10. Dam structure built in the Gura Poacei gully (April 21, 2011)

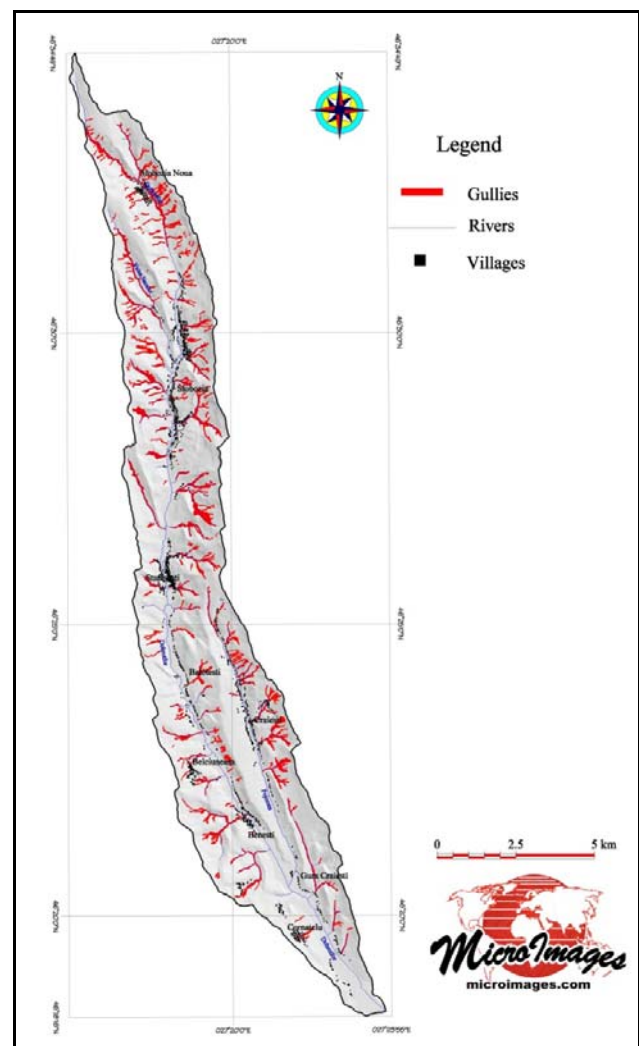


Figure 11. Map showing the distribution of the gullies within the Dobrotfor catchment

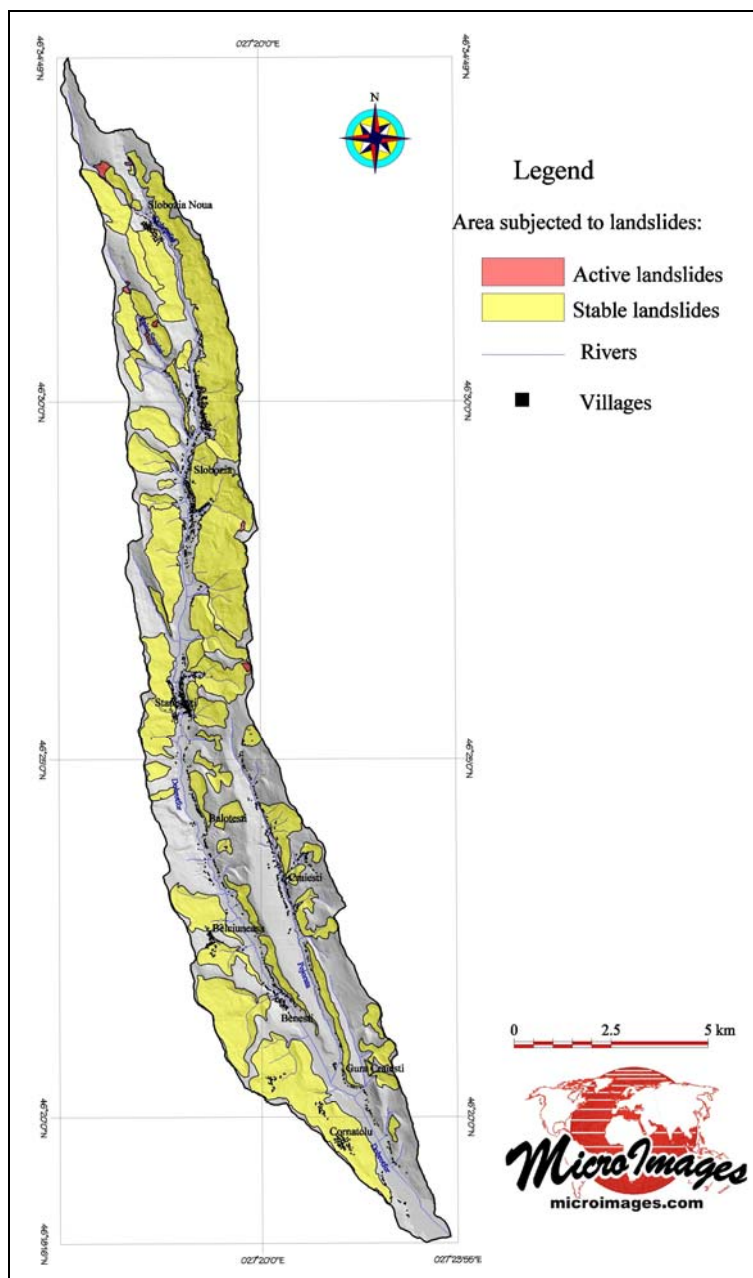


Figure 12. Distribution of the landslides in the Dobrotfor catchment

The active landslides have a reduced incidence of only 1.24 km² (0.27 %), most of them being actually reactivations of the old landslides.

In certain sectors, following heavy rainfalls, it is obvious a significant aggradation in the floodplains, phenomenon reported since 1950 by Filipescu M. as “*premature aging of the hydrographic network*”. Besides rainfall pattern, the main causes of this process are related to the steepness of slopes, the poor development of the vegetation cover, the non-adequate land use, especially the up and down hill farming, and the low longitudinal slope of the floodplains.

Glacises have a noticeable spreading, forming connection areas between the hillslopes and the floodplains of the Dobrotfor or Pojorâta rivers. Colluvial or colluvio-proluvial in nature, their presence is given by the predominantly sandy strata, by the steep slopes etc.

The fluvial terraces have a very limited distribution, under the form of small fragments towards the confluence of Dobrotfor with Zeletin, and this is due to the petrographic composition, predominantly sandy, but also due to the current intense geomorphologic processes (Hârjoabă I., 1968). The left side terrace of Dobrotfor near Gura Crăiești village with a relative altitude of 2.5 to 3 m is more clearly outlined.

Conclusion

The Dobrotfor Basin can be integrated in the typical morphology of the Tutova Rolling Hills. Due to the relatively fast evolution of the rivers and the pronounced fragmentation of the relief, the second order structural asymmetry is much more blurred.

The land degradation by the present-day geomorphologic processes are ubiquitous, noting that the most characteristic processes are soil erosion, gully erosion and landslides. The area covered by gullies is 3.76 km², which represents 4.28 % of the total. Landslides are especially

triggered by previous gullying and half of the entire Dobrotfor catchment is subjected to landslides. Most of them are old landslides and now they show almost stable because of both the drier period of time since 1982 and the impact of the conservation practices deployed by 1990.

Acknowledgements

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REFERENCES

- FILIPESCU M., (1950), *Îmbătrânirea prematură a rețelei hidrografice din partea sudică a Moldovei dintre Siret și Prut și consecințele acestui fenomen*. Natura, nr.5, București.
- HÂRJOABĂ I., (1968), *Relieful Colinelor Tutovei*, Ed. Academiei Române, București;
- IONESI L., (1989), *Geologia României (vol. I)*, Ed. Univ. „Al. I. Cuza”, Iași.
- IONIȚĂ I., (1985), *Considerații privind simetria și asimetria unor văi din partea sudică a Podișului Moldovei*. Lucr. Sem. Geogr. D. Cantemir, nr.5, pp. 71-78, Iași.
- IONIȚĂ I., (1998), *Studiul geomorfologic al degradărilor de teren din bazinul mijlociu al Bârladului*, Teză de doctorat, Univ. „Al. I. Cuza” Iași.
- IONIȚĂ I., (2000a), *Relieful de cueste din Podișul Moldovei*, Ed. Corson, Iași.
- IONIȚĂ I., (2000b), *Formarea și evoluția ravenelor din Podișul Bârladului*, Ed. Corson, Iași.
- IONIȚĂ I., (2000c), *Geomorfologie aplicată. Procese de degradare a regiunilor deluroase*, Ed. Univ. „Al. I. Cuza”, Iași.
- IONIȚĂ I., (2007), *Sezonul critic de eroziune în Podișul Bârladului*, în Workshopul „Impactul riscurilor hidro-climatice și pedo-geomorfologice asupra mediului în bazinul Bârladului”, Ed. Univ. „Al. I. Cuza” Iași, ISBN 978- 973-703-294-2, 147-160 pp.
- JEANRENAUD, P., (1966), *Contribuții la cunoașterea geologiei regiunii dintre valea Siretului și valea Bârladului*, An. ^{at} Univ. „Al. I. Cuza” Iași, t. XII.
- JEANRENAUD, P., (1971), *Harta geologică a Moldovei Centrale dintre Siret și Prut*, Teză de doctorat, Univ. „Al. I. Cuza” Iași.
- JEANRENAUD, P., SARAIMAN, A., (1995), *Geologia Moldovei centrale dintre Siret și Prut*, Ed. Univ. „Al. I. Cuza”, Iași.

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Using Gis Tools in Niraj River Fluvial Morphodynamics

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Abstract. Lately, the role of computerization has increased thus to the existence of software and its use has become indispensable as a result of its applicability to all Earth sciences. The Niraj minor and major riverbeds present a varied morphology and instability in some sections; due to rainfall intensity and flashfloods growing frequency the potential erosion of the river has increased, 28 settlements being situated in proximity of the river. Thus, we have used GIS technologies to identify the relations of interconnection and interdependency between causative factors, relying upon measurements of changes; in this way we want to emphasize the advantages and disadvantages of using the tools provided by GIS technologies.

Keywords: fluvial morphodynamics, meander, vulnerability, G.I.S., Niraj river

1. Introduction

The analytical, quantitative and qualitative approach of this paper, based on available data and information wants to serve to a better understanding of the possibility of using GIS technologies in the study of fluvial morphodynamics as a geographic phenomenon which induces a potential risk. Thus we have studied the genetic factors, qualitative and quantitative characteristics and also its consequences in the geographic environment. From the category of morphodynamics effects of the Niraj River we concentrated our attention to lateral migration of the riverbeds.

By GIS (Geographic Information System) technology we understand the ensemble of calculus equipment (hardware), software, information, persons and design, update and exploitations of the maps' rules which contain both the territorial repartition and the descriptions of identified elements and phenomena. Because of this I consider that GIS technology is a viable method to analyze and identify the phenomena reviewed in this study.

This working method allows the user to store maps, whose entities can be represented as vector form (point, line, polygon), but also as raster; it also allows to create a descriptive and/or numeric database, the main advantage being given by analyzing facilities based on spatial criteria or alphanumerical querying. (Băduț, 2007)

As a result of the erosion interchangeability, transport and accumulation processes in the drainage basin, the minor and major riverbeds of the Niraj river show a varied morphology and in some places unstable, and for this reason time evolution required a special analyzing method, one that would

allow not only cartographic representation of the phenomena, but also one that achieves interconnection and interdependence between causal factors based on actual measurements of the riverbed changes.

Due to its positioning at the contact area of the main morphostructural units, mountains and Carpathian foothills, the area is characterized by break of slopes, changes in the river flow and important contribution of solid flow. The alluvium of the floodplain is intense. The resulting morphology will have a dynamic aspect, comprising in the interior sector numerous changes of the watercourse, abandoned channels, river and floodplain deposits in various stages of development, all this indicating that the action of the river is to achieve a dynamic balance in accordance with the system changes. The geographic components mentioned above give unity to the analyzed territorial ensemble, but some differentiations allow us to individualize two sectors: the mountain and the Sub-Carpathian sectors, represented by alternation of the hilly and depression areas differentiated by geological structure, terrain morphology, climatic and hydrological characteristics.

Thus, we processed the GIS database structured as thematic line layers for hydrography, polygon type layers for hydrographic basin characteristics (soil types, lithology etc.), grid type layers for DEM and also for the database derived from its spatial analysis (Slope, Hill shade, Aspect).

The advantage of layer type data is given by the possibility of data overlapping and by the combination made to obtain new maps. Taking advantage of the fact that the database can be

updated for different intervals of time we can get layers for the same category of spatial entities for different periods. Using ArcGIS functions we obtained numerical information of different characteristics such as: catchment basin, length of the hydrographic network and average flow coefficients. Because the digital map represents a model of the geographic reality, from the informatics point of view it is made from a collection of files, so of a spatial database.

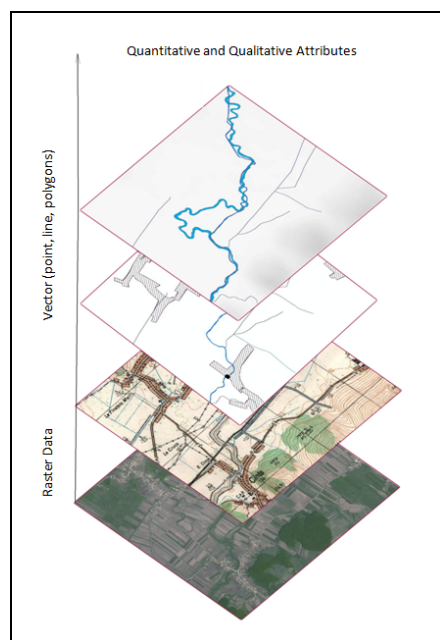


Figure 1. The database structures

2. Data Use and Methodology

The cartographic database realized for this paper can be separated into three big parts: the basic database, which consists of watershed, hydrographic network, lakes, channel systems, the built up area limits, vector information on land use, soil types, geological structure, the geographic database, which contains information such as terrain geo-declivity, land digital model, fragmentation depth, fragmentation density and the third part of the geographic database which is modeled after all other data that are reclassified in order to determine vulnerable areas to riverbed changes. Geographic Information Systems (G.I.S) offers us the possibility to identify the quantitative and qualitative characteristics of the studied geographic system now by analyzing land data, previous to the studied period using information obtained from cartographic data, but it also offers us the possibility to define areas that might have a great potential risk of recurrence and occurrence of the identified

processes. So that the obtained data to be compared they were georeferenced in Stereografic 70 projection system, with the related coordinates, the specific projection system for our country. By georeferenced data (geographic referenced) we understand a data that can be linked with a position well-determined on the Earth's surface (Haidu, I., &all, 1998).

The Austrian maps, made after the third surveying campaign (NeueAufnahme), carried out since 1869, were based on St. Anne's 1840 datum, which is a reference point to Bessel's 1841 ellipsoid (adopted by the Habsburgic Empire beginning with 1869); those maps had a scale of 1: 200 000. The temporary and permanent streams, the built-up area, the river deposits, the parallel streams and neck cut-offs were digitized as well. It can be noted the impressive quantity and quality of the content, taking into consideration the technical means of that period. Landforms are represented by hatches, which in addition have contour lines for the used map sheets. The difficulty of extracting data from those sources is given by the lack of contour lines, the low resolution and the use of Hungarian language for settlements, streams and landforms.

Chronologically, the next data source is represented by the Topographic maps, with a scale of 1:25 000 edited between 1961-1964. From this cartographic source we also have mapped the watershed, which represents the natural boundary used in this analysis. In order to achieve this limit it was followed both the maximum inflection of the contour lines and also the streams' source area.

SPOT satellite images from 2008, with a resolution of 2.5 m were used for mapping the streams and the built-up area limits, out of the desire to obtain the actual position of the minor riverbed and that of the urban and rural area exposed to risk. Thus it was realised a morphometric database based on major and minor riverbeds characteristics. The database was obtained by making transverse profiles and by direct measurement of the meanders from cartographic materials from different periods.

The analysis was realized in the drainage basin unit due to applied features of the hydrological and geomorphodynamic studies. In the current morphodynamics analysis, the accent was put on phenomenon and variability dimension in time and space.

3. Study Area

The studied territory represented by the Niraj drainage basin is located in the central-east part of

the Transylvanian Depression, between the hydrological basin of River Mures in the North and Tarnava Mica's basin in the South. The territory has a 658 km² area. (figure 1)

With a length of 82 km, the Niraj River crosses a succession of landforms: mountain in the upper area, high hill relief in the middle basin and low hills to the confluence. That's the reason why the drainage basin has a steep slope, the floods have a higher torrentially and the river is influenced by the water volume which it receives from its tributaries.

The high density of the settlements situated in river's proximity, predominantly in the major riverbed proves the applied character of this analysis, necessary when it comes to make the inhabitants aware about the danger to which they are exposed, and it also helps to assess the most appropriate measures to protect them against these phenomena.

4. Results and Discussions

In the case of Niraj drainage basin the morphological differences are obvious between the

superior and lower basin, both transverse and longitudinal profiles.

The longitudinal profile made by joining the lowest points of the minor riverbed is basically a curve with irregularities, with a downward slope from the source to shedding which sometimes has breaks of slope. The general trend is that of reducing the slope and diminishing the irregularities (Zăvoianu, 1978). In reality this rarely happens, our case showing that the differences are large across the three sectors. The upper sector, which corresponds to Gurghiu Mountains, is characterized by pronounced slope and evident structural and petrographic changes; the middle sector, that corresponds to the Sub-Carpathian area is characterized by a lower slope, with smaller and rarer slope breaks (depth erosion is diminished, the river's energy being channeled to side erosion); in the lower sector, the slope gets even smaller, thus leading to an alluvial and a pronounced lateral erosion. Slope reduction in concordance with geological and soil conditions leads to a horizontally growth of riverbed mobility making meanders and floodplains to appear.

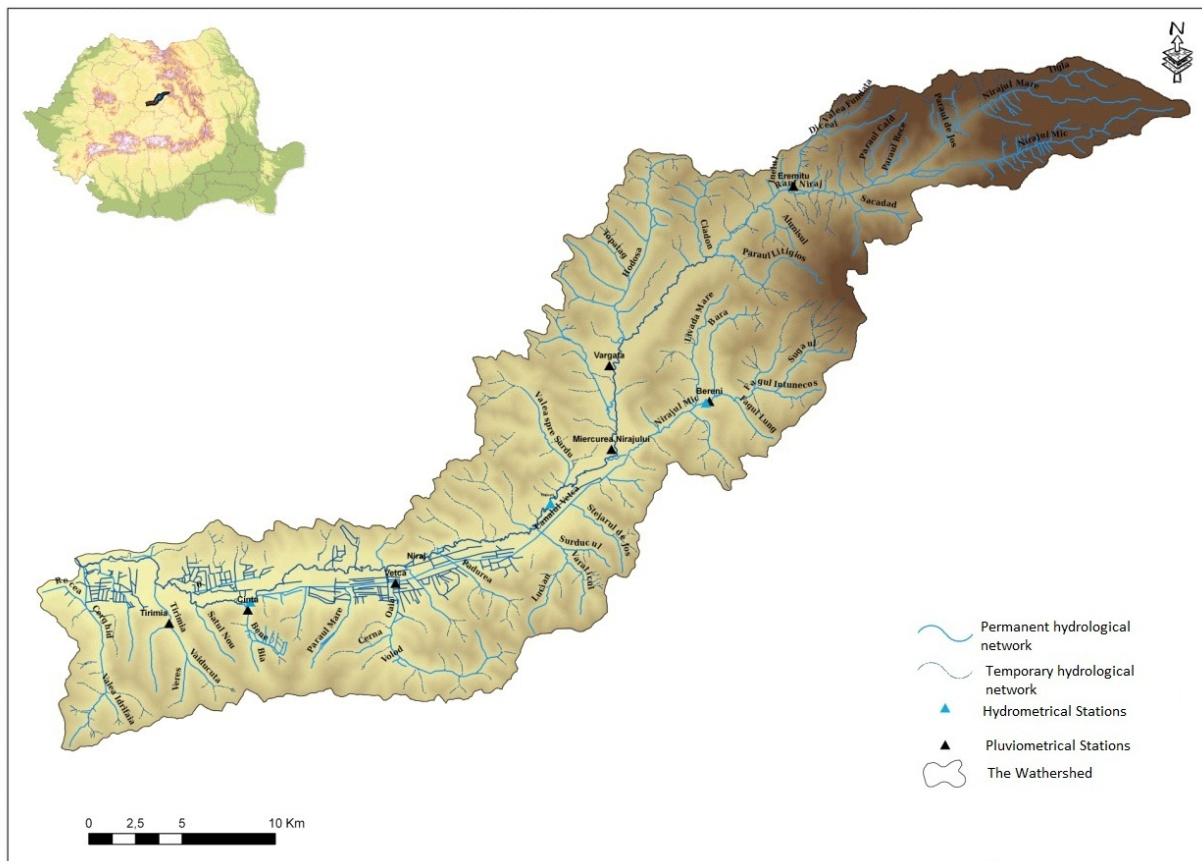


Figure 2. The geographic position of the Niraj drainage basin

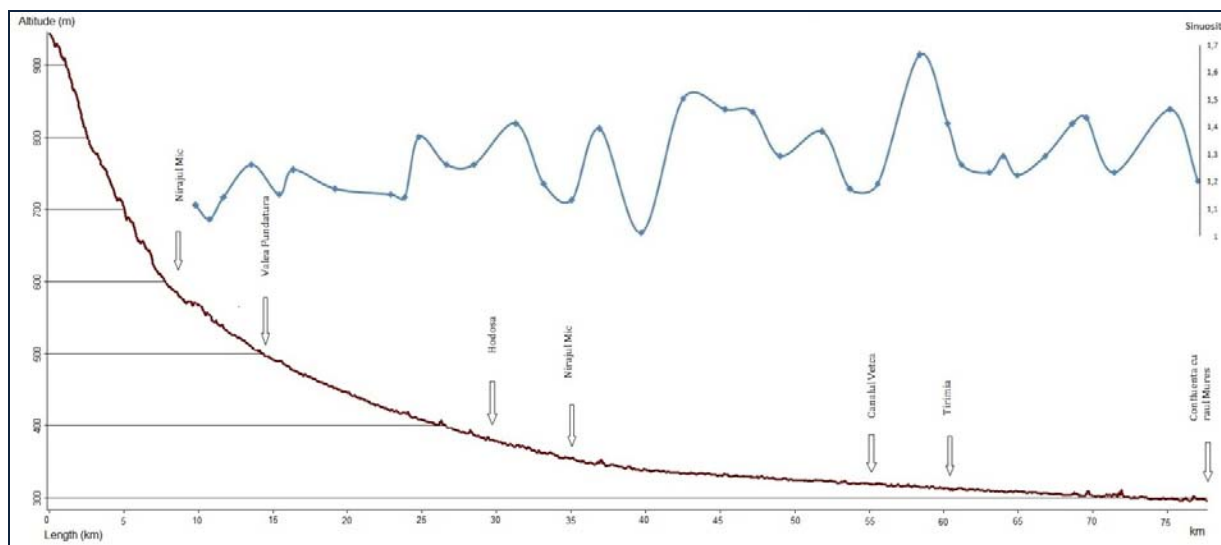


Figure 3. Longitudinal profile of the Niraj River highlighting the sinuosity variation index

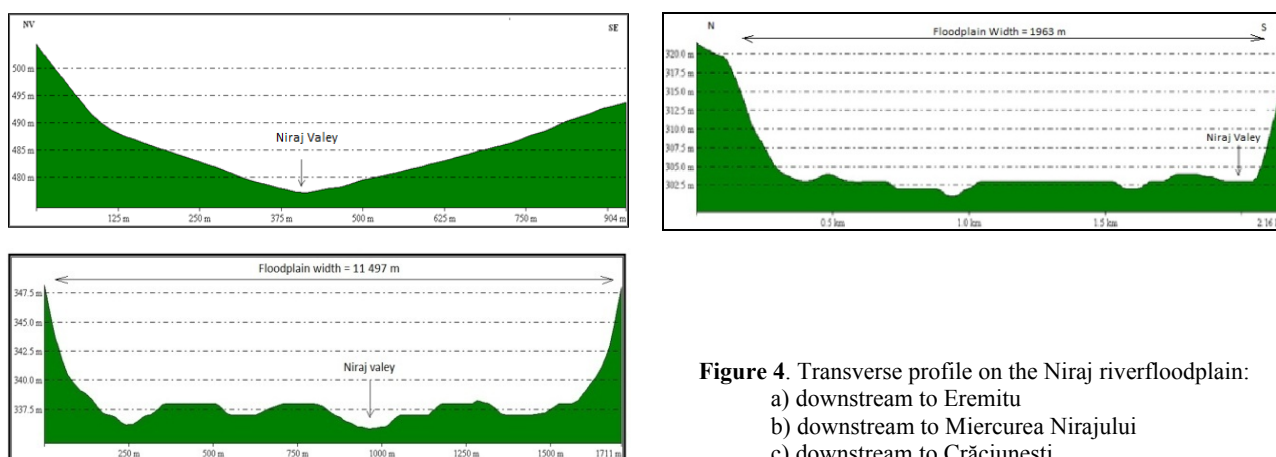


Figure 4. Transverse profile on the Niraj riverfloodplain:

- a) downstream to Eremitu
- b) downstream to Miercurea Nirajului
- c) downstream to Crăciunești

The possibility of transforming transverse profiles using GIS software has a wide applicability due to large amount of information obtained through time and energy economy.

Thus it can be observed the mountain profiles with deeper areas, with steep slope and major riverbed widths reduced, sometimes with areas of expansion in the depression areas.

In the Sub-Carpathian hill area, profiles become wider from upstream to downstream, have different terrace levels on which were developed human settlements. However, due to changes in geology, the slopes have a high geomorphologic risk being susceptible to landslides, and flood activity. In the

lower basin, due to slope decreasing and geological changes, rivers' energy is channeled towards lateral erosion and sediment transport, thus resulting channel deposits and alluvial fans. Based on these profiles we can identify morphological elements of scientific interest: floodplain terraces, handcuffed meanders etc.

All this aspects raise practical problems: valleys are densely populated because in this area are developed railways and roads. Facilities are subject of riverbed spatial planning, protection against settlements flood, protection of the infrastructure, agricultural land and also for exploitation of water resources from the area.

Table 1: The morphometrical parameters based on transverse profiles

Nr.	The floodplain width (m)	Left Floodplain width (m)	Right Floodplain width (m)	The river length (m)	Straight length	Sinuosity Index	Distance to the built up area (m)
1	404	358	148	1340	1215	1,10	-
2	540	20	520	2667	2513	1,06	-
3	445	189	256	1675	1495	1,12	45,24
4	1028	465	563	1776	1417	1,25	20
5	883	598	285	1278	1129	1,13	Eremitu

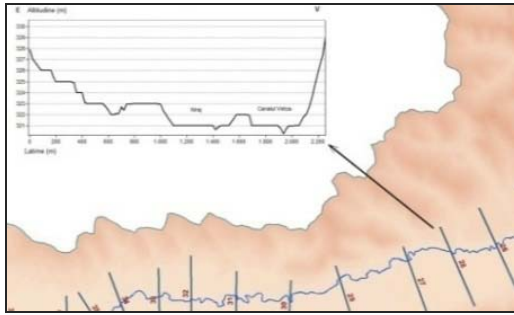


Figure 5: Location of transverse profiles

The minor and major riverbed morphometric variability was studied with the help of longitudinal and transverse profiles. In order to observe the dynamic of transverse sections along the river, morphometric measures can be used based on the principle of transverse section (Rădoane, 2008).

For analyzing the minor riverbed dynamic we have studied its basic element: the meander loop. Data mining method is to realize measurements along river's course, in relation to minor riverbed axis, over the meander loops and meanders. The resulting parameters are radius of curvature, wavelength, amplitude, the width of the minor riverbed and the length of the stream between the meander loops.

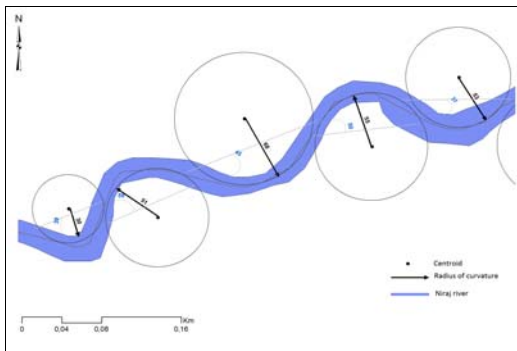


Figure 6: Meander morphometric indices

Table 2: Morphometric indices measured to the level of meander loops

Nr. of meander	Wavelength (m)	Amplitude (m)	Radius of curvature	Length of the river (km)
1	801	290	252	80,6
2	564	120	107	80,4
3	247	94	49	80,1
4	284	93	76	79,9
5	440	145	156	79,8
6	548	198	204	79,6
7	446	169	101	79,2

Overlay analysis of the temporal spatial dataset reveals the vulnerable segments of the river to the process of cut-off and down-valley migration. GIS

technology allows statistical analysis of the measured indices, their graphical representation and correlations with altitude, catchment area or river length.

Meandering is the common process of the riverbed morphodynamics and is considered an expression of achieving dynamic balance between the factors that shaped the riverbed (Mac I. 1986). After we analyze the sinuosity index variation for the entire reviewed period, it can be observed its downward trend from 1.7 (specific to meander river) to 1.17 (specific to sinuosity river).

By having this database available we can identify areas with pronounced meanders along the analyzed period and those sectors that are exposed to dynamics, in conditions of extreme anthropogenic and hydrological events.

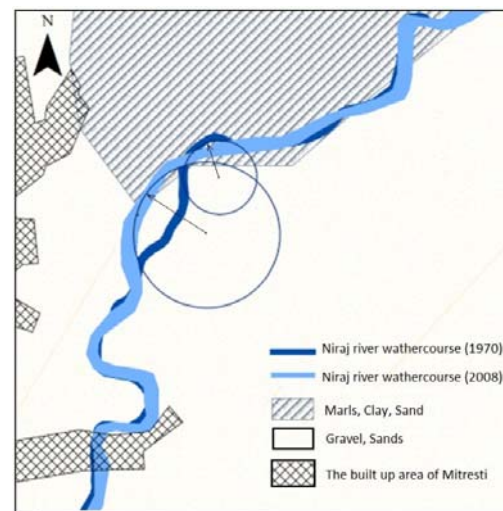


Figure 7: Meander migration in Mitresti area

In the nearby example it can be seen a complex change of the meandering (according to Hooke's classification, cited by Ichim & collaborators, 1989) next to Mitresti village. Seeking the cause of this change in the existing database it was revealed the lithology's role. The meander is positioned at the crossing zone of an area dominated by a marls clay lithology and an area dominated by a sand and gravel lithology. For a clear picture of the factors that influence riverbed dynamics it was analyzed the trend of rainfall and flow that is in a constant growth, contrary to forestation index which places the analyzed region in the weak ecological balance category, affected by human pressure.

The effects of human action in this region are felt especially in the marginal zones of the river dammed sectors. Designed to reduce the negative effects of the lateral erosion, these dams lead to minor bed handcuffing, which at high flows cause an increased erosion in the downstream sectors.

Table 3: Sinuosity coefficient variation between 1806-2008

1806 sinuosity index	1869 sinuosity index	1970 sinuosity index	2008 sinuosity index
1,7	1,67	1,59	1,17

Table 4: The evolution of the sinuosity index and that of the factors involved

Rainfall trend (1950-2008)	↗
Niraj River flow trend (1970-2008)	↗
Afforestation trend index (1970-2010)	↗
Sinuosity trend index (1806-2008)	↘

Where: ↗ represent an increasing trend and ↘ a decreasing trend

5. Conclusions

Although the river provides preliminary information necessary to its planning in order to mitigate negative side erosion, GIS is a valuable tool. This study shows that the processes involved in fluvial morphodynamics are: meander migration, meander growth with the channel cut-off being predominant. A special attention has to characterize the user of this technology because overestimation or

underestimation of an indicator may decrease the accuracy of assessment.

By correlating the spatial numerical characteristics of the control factors and having the advantage of obtaining accurate spatio-temporal data, comparable with the possibility of 3D visualization, we consider the advantages of this method for morphodynamic identification and analysis as being a viable one.

BIBLIOGRAPHY

- BĂDUȚ, M., GIS. (2007), *Fundamente practice*, Ed. Albastră, Cluj Napoca.
- BĂTUCĂ, DAN, DUMA, DIDI, ICHIM, IONIȚĂ, RĂDOANE, MARIA, (1989), *Morfologia și dinamica albiilor de râuri*, Ed. Tehnică, București.
- FLORINA, GRECU, (2008), *Geomorfologie Dinamică*, Ed. Tehnică, București.
- HAIDU, I, HAIDU, C., (1998), *S.I.G. Analiza spațială*, Ed. *H*G*A*, București.
- MAC, I., (1986), *Elemente de geomorfologie dinamică*, Ed. Tehnică, București.
- RĂDOANE, MARIA. RĂDOANE, N., (2007), *Geomorfologie aplicată*, Ed. Universității din Suceava, Suceava.
- RĂDOANE, MARIA, RĂDOANE N., CRISTEA I., (2008), *Evaluarea modificărilor contemporane ale albiei râului Prut pe granița românească*, Revista de Geomorfologie, Vol. I.
- MATIAS, KONDOLF, HERVE PIEGAY, (2003), *Tools in Fluvial Geomorphology*, Ed. Wuley, Anglia.
- SIDDAN ANBAZHAGAN, S. K. SUBRAMANIAN, XIAOJUN YANG, (2011), *Geoinformatics in Applied Geomorphology*, CRC Press, Florida.
- ZĂVOIANU, I, (1978), *Morfometria bazinelor hidrografice*, Ed. Academiei, București.

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Altitudinal Zonation of the Morphodynamic Processes in the Piatra Craiului Mountains (The Carpathians, Romania).

Case Study: Cheii de sub Grind and Șpirlea Valleys

Anca MUNTEANU, Laura COMĂNESCU, Alexandru NEDELEA

Abstract: This paper focuses on the altitudinal zonation of the morphodynamic processes in two small watersheds, namely the Șpirlea and the Cheile de sub Grind, which lie in the central part of the Piatra Craiului Massif, being almost perpendicular to the main ridge. Because of some differences imposed by lithology, morphology, gradient, aspect, climatic conditions and vegetation, the morphodynamic altitudinal zones have a distinct appearance. The vertical zonation and the conditioning relationships will be further discussed in detail in order to establish the differences that exist among the morphodynamic zones lying on the two major slopes (eastern and western) of the Piatra Craiului ridge.

Keywords: morphodynamic processes, morphodynamic factors, altitudinal zonation, Șpirlea Valley, Cheile de sub Grind Valley, Piatra Craiului Mountains

1. Introduction

The Piatra Craiului Massif has a particular morphology, which is explained by its long evolution. The shaping systems that have existed here over the time are therefore responsible for the present appearance of topography. Thus, their long action has resulted in the creation of a narrow calcareous ridge, looking like a hog back, lifted to 2000 m altitude and showing steep slopes (to the east and west) dissected by numerous valleys. However, this striking feature of the landscape is mainly the result of geology, orography and climatic conditions, which explains why this study has focused in particular on these factors in order to

identify and explain the morphodynamic elements and their altitudinal zonation.

In order to analyze the altitudinal zonation of the morphodynamic processes two valleys lying on both sides of the main ridge were chosen, i.e. the Cheia de sub Grind, on the east, and the Șpirlea, on the west. Both of them originate near the highest peak of the massif, the Piscul Baciului (2238 m), lying in the central part of the ridge (Figure 1, 2 and 3).

On these valleys, five zones and one sub-zone exhibiting various shaping processes and landforms imposed by geological structure, gradient, aspect, fragmentation and climate have been identified. The shaping factors, as well as the shaping systems and the morphodynamic altitudinal zones will be further analyzed in detail.

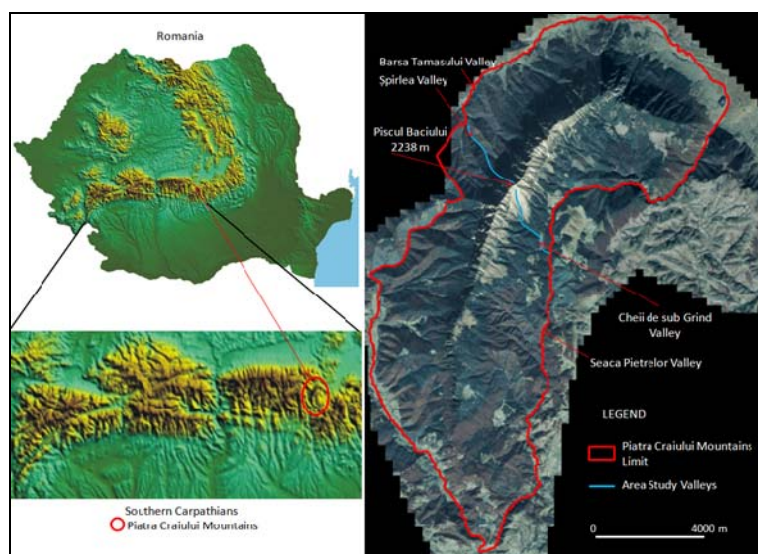


Figure 1. The study area in the Romania, Carpathians and Piatra Craiului Massif shown on an Ykonos 2004 image (provided by the Administration of the Piatra Craiului Natural Park)



Figure 2. The geographical position of Șpirlea Valley within western slope of Piatra Craiului Massif (photo Spencer Coca)

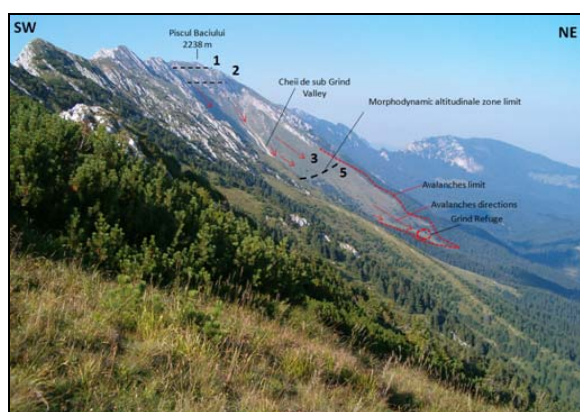


Figure 3. The geographical position of Cheii de sub Grind Valley within eastern slope of Piatra Craiului Massif and upper morphodynamic zone (figures indicates : 1. cryonival zone, 2. upper sub-alpine cryonival zone, 3. lower sub-alpine cryonival zone, 5. forest zone)

2. Methodology

In order to study the vertical zonation of the morphodynamic processes on the two valleys in the Piatra Craiului Massif, we accomplished schematic profiles along each of them. At the same time, we analyzed the morphodynamic controls represented on the one hand by the geological, lithological, structural and tectonic conditions (Constantinescu 2009), and on the other hand by aspect, gradient, hypsometry, relief dissection, morphology, contemporary processes (Constantinescu 1994, 2006, 2009; Constantinescu and Pițigoi, 2003; Munteanu and Constantinescu 2003; Moțoiu and Munteanu 2006; Munteanu 2008, 2009; Munteanu et al. 2011), vegetation and soils (Geanana 1994; Mihăilescu 2001). Likewise, we made observations in the field, mapped the processes and landforms, and when necessary we took analytical pictures in order to support the investigation. Data processing was accomplished using the ArcView 3.2 software.

The resulted altitudinal zones were analyzed according to the existing literature (Ancey et al. 2003; Castelltort and Simpson, 2006; De Scally et al. 2001; Grecu and Comănescu, 2000; Guiot et al., 2008; Jentsch and Beierkuhnlein, 2008; Johnson

and Smith 2010; Kotarba 1987; Kotarba and Dlugosz 2010; Luckman 1992; McClung 2001; Mihai 2005; Mihai and Nedelea, 1999; Nedelea and Oprea 2008; Stanley et al. 1973; Posea 2002; Posea et al. 1974; Rapp 1959; Urdea 2000; Voiculescu 2002; Tufescu 1966; Young 1969).

3. Discussion and results

3.1. Morphodynamic controls

The vertical zonation and the way the morphodynamic processes act themselves out are influenced by an array of morphodynamic factors (Fig. 4 and 5), which explain the different features displayed by the two valleys and implicitly by the two slopes to which they belong.

The geological factor is responsible through lithology and structure for the basic features. This means the limestones of the western flank of the Piatra Craiului synclinorium, which resembles a hog back with steep slopes (65 to 70°), are prevalent. Apart from these, conglomerates occur in the Grind watershed and as far as the synclinorium axis. The Grind Saddle (2178 m) is the only place in the Piatra Craiului Massif where conglomerates advance to the ridge top, more exactly to a lower section of it, 150 m long, stretching between the Piscul Baciului peak (2238 m) on the south and the Grind summit (2210 m) on the north (Figure 6).

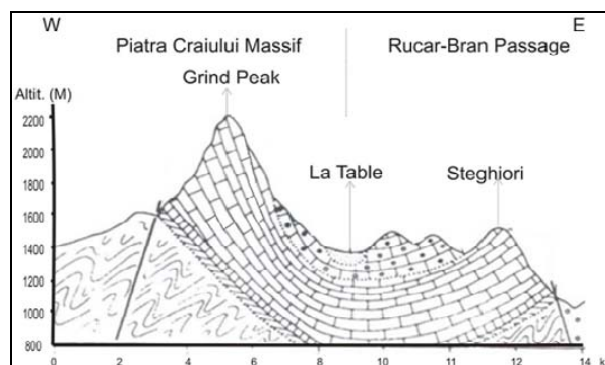


Figure 4. Cross geological profile through the Piatra Craiului Massif and synclinorium, accomplished south of the Șpirlea and Grind valleys (according to Constantinescu, 1994)

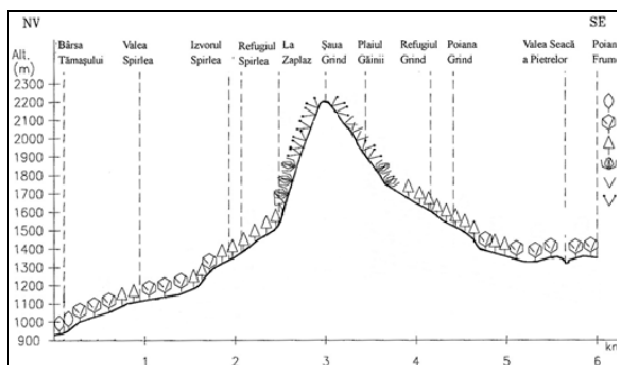


Figure 5. Cross morphological profile through the Piatra Craiului ridge showing the zonation of vegetal elements (according to Mihăilescu, 2001, simplified)

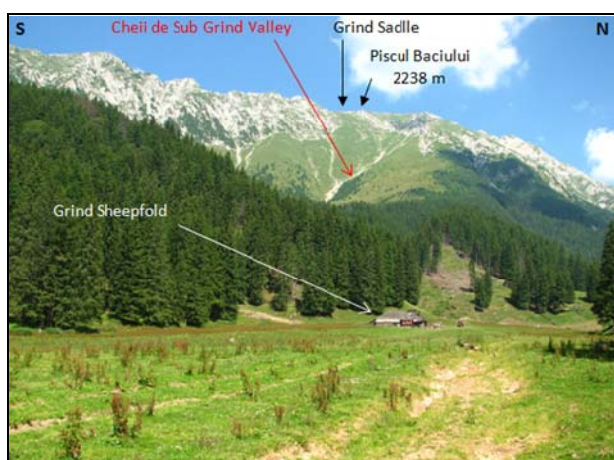


Figure 6. The Cheia de sub Grind Valley – overview from the glades sub-zone, where the Grind sheepfold lies. The ridge section with the Grind Saddle and the Piscul Baciului peak is also visible

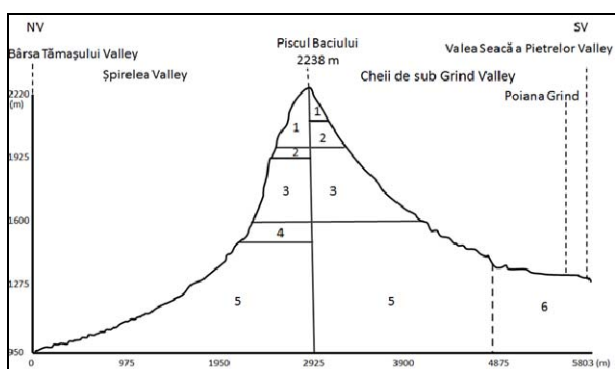


Figure 7. The morphodynamic altitudinal zones on the Spirlea and Cheia de sub Grind valleys: 1. The alpine cryonival zone; 2. The upper sub-alpine cryonival zone; 3. The lower sub-alpine cryonival zone; 4. The colluvial-alluvial deposits zone; 5. The forest zone; 6. The glades sub-zone

These features are responsible for the conglomerate elements that are found on the rock stream overlapping the thalweg of the Cheia de sub Grind Valley, a characteristic that is missing on the opposite slope. To the west, on the Șpirelea Valley, crystalline and Dogger formations are capped by scree. The limestones occur as layer ends on the west and as bedding planes in the east. From the

very beginning, the geological features lend the morphology some specific features. The two valleys are tectonically conditioned, inasmuch as they have developed along some fault lines (Constantinescu 1994). This fact is highlighted by the appearance of the profiles, which shows differences between the two major slopes: the valley on the west is subsequent and steeper on the layer ends, whereas that on the east is consequent, follows the gradient of the strata and is less steep.

The altitude and hypsometric steps depend on local conditions. Above 2000 m on the east and 1900 m on the west is the upper alpine and sub-alpine cryonival step; between these elevations and 1600 m is the lower cryonival step; below 1600 m are the colluvial deposits and the forest step on the west, whereas at 1300-1400 m on the east follows the glades step. These altitudinal steps are at the origin of the functional zones of the avalanches. Thus, higher than 2000 m, i.e. on the upper part of the ridge, are the headwaters of the two valleys, as well as the avalanche starting zones; on the eastern slope, between 1800 and 2000 m lies the calcareous cliff that flanks the valley carved in conglomerates (Figure 4). On the western slope, the cliff goes down as low as 1600 m altitude and still below follows the deposition zone (Figure 7 and 8). On the eastern slope, the avalanche track overlapping the valley is carved in conglomerates and the runout zone goes as low as 1550 m (Moțoiu and Munteanu 2006) (Figure 3 and 9). Also on the Cheia de sub Grind Valley, at elevations of 1500-1450 m, below the deposition zone, one can see a stretch of narrow gorge (less than 1 m wide) cut into the conglomerates, which lent the valley its actual name. Generally, avalanches end above this stretch (Munteanu and Constantinescu 2003) (Figure 9).



Figure 8. Spirlea Valley – connection between lower sub-alpine cryonival zone (3) and colluvial-alluvial deposits zone (4) (the figures indicates that zone)



Figure 9. The morphodynamic altitudinal zones on the Cheia de sub Grind valley:

1. The alpine cryonival zone; 2. The upper sub-alpine cryonival zone;
3. The lower sub-alpine cryonival zone; 4. The colluvial-alluvial deposits zone;
5. The forest zone; 6. The glades sub-zone

The different aspect of the slopes (Fig. 2 and 3), sunny on the east and shadowed on the west, is responsible for the way the processes act themselves out. Thus, avalanches are frequent on the eastern slope, because in wintertime the snow melts out and slides down. On the west-facing slopes, however, such phenomena occur especially in spring, when the shadowed areas begin to get warmer (Munteanu 2009). Likewise, cryonival processes, weathering and aeolization are more significant on the west.

The vertical dissection is higher on the west-facing slopes, reaching 600 – 800 m in the central part of the declivities, whereas on the east-facing slopes the highest values are between 400 and 600 m and are specific for the high calcareous ridge. Along the entire Grind Valley, the average values range from 200 to 400 m, while on the Șpirlea Valley such values are encountered only on the runout zone (Constantinescu 2009).

Gradients are controlled by the geological structure. In the upper part, slope angles generally range from 45 to 75°, but on the limestones occurring on the west, and especially on the layer ends, they can reach 65-70° or even more. To the base of the declivities, gradients are lower, between 30 and 45° on the avalanche deposits or the talus slopes, but on the structural cliffs with low vertical difference (10-15 m), the values can reach 60°. In-between these landscape features there are areas with mean gradients of 30°, which gradually become lower to the axis of the synclorium.

Climatic elements vary according to the altitude and slope aspect (Fig. 2 and 3). Thus, the western

slope is more humid and windy (which explains the aeolization processes and the formation of snow cornices) in comparison with the eastern one, which is more sheltered. The 5°C isotherm is found at 1000 m, while the 4°C one climbs to 1400 m (Teodoreanu 2006). The 0°C isotherm, which lies at 2000 m, corresponds to the avalanche-starting zone (Voiculescu 2002). On the main ridge, precipitation amounts to 1200 mm. More often than not, it has a torrential character and consequently encourages the vertical erosion of the streams. In wintertime, the snow fallen to the ground may last more than 160 days per year and sometimes even until the month of June (Teodoreanu 2006).

Vegetation is zoned by altitude, but it displays different features on the two valleys (Fig. 2, 3 and 5). On the Grind Valley the mixed forests (interspersed with secondary grasslands used as pastures) lie at 1400 m, while on the west-facing slopes they develop below 1300 m. As far as the coniferous forests are concerned, they reach 1700 m on the east and 1600 m on the west. The sub-alpine bushes with mugo pines are better developed on the west, reaching 1850 m altitude on both slopes, while alpine elements are common on both valleys near the headwaters (Mihailescu 2001). This distribution of vegetal elements may enhance or diminish the effects of contemporary geomorphological processes.

In their turn, the soils mirror the different conditions existing on the two macro-slopes. Thus, the soil blanket is better developed on the east, while on the west the bare areas prevail. Consequently, on the west-facing slope, the rocks

are exposed to weathering and surface erosion, while on the east they are better protected, but solifluction is active.

3.2. Contemporary relief shaping processes

The complex processes associated with the erosion and accumulation represent the present-day shaping system (Nedelea and Oprea 2008). The contemporary shaping of the topography of the two valleys is accomplished especially through torrential and cryonival processes (Constantinescu 2006). These act periodically, inasmuch as the two watersheds lack a permanent flow, because the water from precipitation percolates rapidly the limestones and the sedimentary deposits, thus increasing the dissolution transport. Consequently, water flows on the ground only when precipitation has a torrential character. This happens especially during the summer rainfalls, when the water flowing swiftly along the thalwegs, due to the high gradients, exerts a high vertical erosion force. In their turn, the avalanches unleash complex erosion, transport and accumulation processes and create rugged deposits in which torrential water disappears (Constantinescu 2009). It is worth mentioning that these avalanche chutes are among the most significant in the entire massif. The destructive force of the avalanches is tremendous. On the Grind Valley, they destroyed the Radu Negru chalet in 1953, whereas in 2005, the present tourist shelter was hit by a huge avalanche (Moțoiu and Munteanu 2006) (Fig. 3 and 9). Where the rocks are directly exposed to the elements, as it often happens on the

west, gravitational processes are active and consequently they complete the picture of the contemporary morphodynamics.

3.3 Morphodynamic potential of altitudinal zones

In order to analyze the morphodynamic potential of the two valleys, we accomplished a ridge cross-sectional profile on which we identified the existing morphodynamic altitudinal zones. The profile had a northwest to southeast orientation. It started on the western slope, from the junction with the Barsa Tamasului Valley and then followed the Șpirlea Valley as far as the Piscul Baciului peak, from where it passed on the eastern slope. From there, it followed the Cheia de sub Grind Valley, crossed the Grind Glade lying on the synclorium axis and ended at the junction with the Valea Seaca a Pietrelor Valley (Fig. 1 and 7). The profile was conceived in accordance with the characteristics and the way of manifestation of the morphodynamics controls. Based on it, five altitudinal zones and one sub-zone were identified, which differ in terms of structure, aspect, slope angles, climatic elements and vegetation cover. For each zone, we analyzed the elevations, the contemporary processes and the vegetation (Table 1), paying attention to their specific features and the way they fit in the general context of the entire slope system (Constantinescu 2009; De Scally et. al. 2001; Kotarba and Dęugosz 2010; Luckman 1992; Mihai 2005; Mihăilescu, 2001; Nedelea and Oprea, 2008).

Tab. 1 The inventory of contemporary geomorphological processes affecting the morphodynamic zones

CARPATHIAN ZONE	ALTITUDE (m)	FEATURES	
		Contemporary processes	Vegetation
1. The alpine cryonival zone	E 2100 m W 2000 m	Cryonival, mechanical weathering, solifluction, chemical weathering, dissolution, karstification, surface and vertical erosion, collapses, small eluvial blocks, aeolization, avalanches;	Alpine and sub-alpine;
2. The upper sub-alpine cryonival zone	E 2000-2100 m W 1900- 2000 m	Cryonival, mechanical weathering, solifluction, chemical weathering, dissolution, karstification, surface and vertical erosion, collapses, accumulation of deluvial scree;	Alpine and sub-alpine;
3. The lower sub-alpine cryonival zone	E 1600-2000 m W 1600- 1900 m	Cryonival, mechanical weathering, chemical weathering, karstification, dissolution, collapses, avalanches, surface and vertical erosion, scree accumulation, solifluction (enhanced by overgrazing);	Sub-alpine
4. The colluvial-alluvial deposits zone	At the base of the western calcareous slope, at elevations of 1600 – 1500 m	Accumulation, surface and vertical erosion;	Sub-alpine at the upper part and forest to the base
5. The forest zone	At elevations less than 1600 m on the east and 1500 m on the west	Surface and vertical erosion, chemical weathering, solifluction, deposition;	Coniferous forests and mixed coniferous-broadleaf forests
6. The glades sub-zone	On the eastern slope, between 1300 and 1400 m altitude	Surface and vertical erosion, chemical weathering, solifluction, anthropogenic processes (sheep tracks and deforestations)	Pastures, coniferous forests, broadleaf forests, mixed forests, swampy areas

3.3.1. *The cryonival zone* corresponds to the altitudes above 2100 m on the east-facing slope and 2000 m on the west-facing one (Figure 3, 9 and 10). It is characterized by cryonival processes, weathering, karstification, solifluction, dissolution, surface and vertical erosion, collapses on residual landforms, and small-size eluvial blocks, which evolve through freeze-thaw action and aeolization (especially on the west-facing slope). This is the place where snow accumulates during the cold season, where cornices come into existence and where avalanches begin their journey to the lower altitudes. Here, alpine and sub-alpine vegetation finds proper development conditions.

3.3.2. *The upper sub-alpine cryonival zone*, lying at altitudes of 2000 – 2100 m on the east and 1900 – 2000 m on the west (Figure 3, 9 and 10), is dominated by cryonival processes, weathering, solifluction, dissolution, karstification, surface and vertical erosion and avalanches. The collapses and the scree accumulations in the thalwegs and at the base of the secondary cliffs affect, as we have seen previously, the residual landforms that evolve through freeze-thaw action. Alpine and sub-alpine elements are still present.

3.3.3. *The lower sub-alpine cryonival zone*, develops between 1600 and 2000 m on the eastern slope and between 1600 and 1900 m on the western slope (Figure 3, 8, 9 and 10), where the bare rocks mark the contact with the underlying crystalline formations. Here, cryonival, weathering, dissolution and karstification processes are extremely common. The collapses are more active to the west, while to the east the prevailing processes are solifluction (intensified by overgrazing), surface and vertical erosion, as well as the accumulation of deluvial blocks and screes on the valley bottoms. Avalanche tracks that usually overlap the valley alignments are found everywhere. The alpine and sub-alpine vegetation hinders the natural tendency of the forest to advance to higher altitudes, as it happens on the adjacent interfluvies.

3.3.4. *The colluvial-alluvial deposits zone* is found at the base of the western calcareous slope (Figure 8), at elevations less than 1600 m, but above 1500 m, where accumulation processes, as well as surface and linear erosion prevail. On the upper part, the deposits overlying the crystalline formations are made up of colluvial blocks and scree formations, while at the junction with the Barsa Tamasului they have an alluvial origin.

3.3.5. *The forest zone*, where surface erosion, vertical erosion and chemical weathering are

prevalent, develops at lower altitudes: 1600 m on the east and 1500 m on the west (Figure 3, 6, 9 and 10). As the name suggests, this area is covered by coniferous forests on the upper part and mixed coniferous – broadleaf forests to the base. This altitudinal zone is better developed on the eastern side of the mountains, where solifluction is active because of the overgrazing. The forest elements bring their contribution to the stabilization of the mobile colluvial deposits and in addition, they show a tendency to advance to higher altitudes.

3.3.6. *The glades sub-zone*, which is affected by surface and vertical erosion and weathering, is found only on the eastern slope, in the axis of the synclorium, between 1300 and 1400 m. It corresponds to an alignment of glades, namely the Vlădușca – Grind – Lespezi, where sheepfolds have found good development conditions (Figure 6 and 9). Here, one can also see swampy areas and peat bogs. Because this lands are utilized for grazing, anthropogenic processes are present, too, which explains the existence of sheep tracks and the intense solifluction. During the last years, the forests that used to cover this area have been cleared off, which has increased the surface and vertical erosion.

The differences in morphology between the altitudinal zones mentioned so far mirror the features imposed by structure, gradient, aspect, contemporary processes and vegetation zonation. This morphodynamic zones are similar to those identified and described in other Carpathian massifs or in the Tatra Mountains (Kotarba 1987; Kotarba and Dlugosz 2010; Mihai 2005; Nedelea and Oprea, 2008; Posea 2002; Posea et. al. 1974; Urdea 2000; Voiculescu 2002).



Figure 10. The morphodynamic altitudinal zones on the Spîrlea valley: 1. The alpine cryonival zone; 2. The upper sub-alpine cryonival zone; 3. The lower sub-alpine cryonival zone; 5. The forest zone; 6. The glades sub-zone

4. Conclusions

This study shows the relationships between the altitude and the morphodynamic processes on the Șpirlea and Cheia de sub Grind valleys. At the same time, it highlights the role played by the morphodynamic factors in the zonation of contemporary geomorphological processes. The differences in lithology, morphology, gradient, aspect, vegetation and soils impose particular features on the morphodynamic altitudinal zones. These zones have a temporary dynamics, because the present-day geomorphological processes are controlled by the cyclicity of seasons. All these influences explain the differences that exist between the two investigated valleys and implicitly between the two macro-slopes of the Piatra Craiului Mountains.

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REFERENCES

- ANCEY, C., MEUNIER, M., RICHARD, D., (2003), *Inverse problem in avalanche dynamics models*. Water Resour. Res. 39(4), 1099, 13.
- CASTELLTORT, S., SIMPSON, G., (2006), *Growing mountain ranges and quenched river networks*. C. R. Geoscience 338, 1184–1193.
- CONSTANTINESCU T., (1994), *Masivul Piatra Craiului. Studiu geomorfologic*, Teză de doctorat, Facultatea de Geografie, Universitatea București, 210 p.
- CONSTANTINESCU, T., (2006), *Torrentiality and avalanches, the main present day geomorphological processes in Piatra Craiului Ridge*, Reserch in Piatra Craiului National Park, 2. Ed. Universității Transilvania, Brașov, pp. 38-46.
- CONSTANTINESCU, T., (2009), *Piatra Craiului – Studiu geomorfologic*. Ed. Universitară București, 163 p.
- CONSTANTINESCU, T., PIȚIGOI R., (2003), *The main types of relief of Piatra Craiului Ridge. Research in Piatra Craiului National Park I*, Ed. Phoenix, Brașov, pp. 13-34.
- DE SCALLY, F., SLAYMAKER, O., OWENS, I., (2001), *Morphometric control and basin response in the Cascade Mountains*. Geografiska Annnnder 83A(3), 117-130.
- GRECU, F., COMĂNESCU, L., (2000), *Surface formations on the Bucegi Mountains. Valea Cerbului Case-Study*. Geomorphology of the Carpatho-Balkan Region, Ed. Corint, București, pp. 89-99.
- GEANANA, M., (1994), *Influența condițiilor geomorfologice asupra limitei superioare a pădurii în Munții Retezat*. AUB-Geogr. 4, 12-22.
- GUIOT, J., HÉLY-ALLEAUME, C., WU, H., GAUCHEREL, C., (2008), *Interactions between vegetation and climate variability: what are the lessons of models and paleovegetation data*. C. R. Geoscience 340, 595–601.
- JENTSCH, A., BEIERKUHNLEIN, C., (2008), *Research frontiers in climate change: Effects of extreme meteorological events on ecosystems*. C. R. Geoscience 340, 621–628.
- JOHNSON, A.L., SMITH, D.J., (2010), *Geomorphology of snow avalanche impact landforms in the southern Canadian Cordillera*. The Canadian Geographer 54, 1, 87–103.
- KOTARBA, A. (ed.), (1987), *High Mountains denudation sistem of Polish Tatra Mountais*. Ossolineum, Wroclaw, 106 p.
- KOTARBA, A., DLUGOSZ, M., (2010), *Alpine cliff evolution and debris flow activity in the high Tatra Mountains*. Studia Geomorphologica Carpatho-Balcanica 44, Krakow, pp. 35–47.
- LUCKMAN, B.,H., (1992), *Debris Flows and Snow Avalanche Landforms in the Lairig Ghru*, Cairngorm Mountains, Scotland, Geografiska Annnnder, SQA, 74 2/3, 109-121.
- McCLUNG, D.M., (2001), *Characteristics of terrain, snow supply and forest cover for avalanche initiation caused by logging*. Annals of Glaciology, International Glaciological Society, 32, 223-229.
- MIHAI, B., (2005), *Munții din Bazinul Timișului. Potențialul reliefului și amenajarea spațiului*. Ed. Universității București, 430 p.
- MIHAI, B., NEDELEA, A., (1999), *Câteva comparații geomorfologice între masivele înalte din Carpați. Studiu de caz: Munții Făgăraș-Tatra Înalță*, Com. de geografie, București, 3, pp. 159-167.
- MIHĂILESCU, S., (2001), *Flora și vegetația Masivului Piatra Craiului*. Ed. Vergiliu, București, 400 p.
- MOȚOIU, M. D., MUNTEANU, A., (2006), *Large Avalanches on The Eastern Slope of the Piatra Craiului Massif in March 2005*, Reserch in Piatra Craiului National Park 3, Ed. Universității Transilvania, Brașov, pp. 44-66.

- MUNTEANU, A., (2008), *The Impact Of Avalanches Upon The Anthropic Activities, On The Western Slope Of Piatra Craiului Massif*. Revista de Geomorfologie 9, Ed. Universității din București, pp. 95-102.
- MUNTEANU, A., (2009), *Morfodinamica actuală, riscuri și hazarde naturale în Masivul Piatra Craiului*. Teză de doctorat, Universitatea București, 282 p.
- MUNTEANU, A., CONSTANTINESCU, T., (2003), *Geomorphological researches in the hydrographic basin of Valea Cheii de sub Grind*, Research in Piatra Craiului National Park 1, Ed. Phoenix, Brașov, pp. 43-49.
- MUNTEANU, A., NEDELEA, A., COMĂNESCU, L., GHEORGHE, C., (2011), *The dynamics of slopes affected by avalanches in Piatra Craiului Massif – Southern Carpathians*. International Journal of the Physical Sciences, 6 (7), 1720-1731.
- MUNTEANU, A., NEDELEA, A., COMĂNESCU, L., (2011), *The dynamics of the snow avalanche affected areas in Piatra Mica mountains (Romania)*. C. R. Geoscience 343, 691–700.
- NEDELEA, A., OPREA, R., (2008), *Etajarea altitudinală a proceselor morfodinamice pe văile Capra și Buda (Munții Făgăraș)*. Geographical Forum – Geographical studies and environment protection research 7, 14 – 22.
- POSEA, G., (2002), *Geomorfologia României*. Ed. Fundației România de Măine, București, 444 p.
- POSEA, G., POPESCU, N., IELENICZ, M., (1974), *Relieful României*, Ed. Științifică, București, 483 p.
- RAPP, A., (1959), *Avalanche boulder tongues in Lappland, descriptions of little known forms of periglacial debris accumulations*, Geografiska Annaler 41, 34-48.
- STANLEY, A., SHUMM, S.A., MOSLEY, P.M., (ed.), (1973), *Slope morphology*. Dowden, Hutchinson & Ross. Inc., Stroudsburg, Pennsylvania, 454 p.
- TEODOREANU, E., (2006), *The climate of Piatra Craiului National Park. Research*, în *Piatra Craiului National Park 2*, Ed. Universității Transilvania, Brașov, pp. 57-69.
- TUFESCU, V., (1966), *Modelarea naturală a reliefului și eroziunea accelerată*. Ed. Academiei, București, 618 p.
- URDEA, P., (2000), *Munții Retezat*. Ed. Academiei Române, București, 272 p.
- VOICULESCU, M., (2002), *Fenomene geografice de risc în Masivul Făgăraș*. Ed. Brumar, Timișoara, 231 p.
- YOUNG, A., (1969), *Slopes*. Oliver & Boyd, Edimburgh, 280 p.

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The Promotion of Geomorphosites on Salt from Sovata–Praid and Turda using Cultural – Scientific Tourism

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Abstract. The Promotion of Geomorphosites on Salt from Sovata – Praid and Turda using Cultural – Scientific Tourism. The paper highlights the role of geomorphosites on salt, in experts and specialists training, in geography of tourism and planning, namely, the involvement of educational factor in defining managerial and marketing skills of future specialists in training. Geographical area of investigation belongs to the Transylvanian tectonic basin, overlapped to saliferous tectonic area from eastern Transylvania, represented by Praid – Sovata – Corund anticline and Sic – Cojocna – Turda anticline, analysis is focused on the Praid – Sovata and Turda diapirs.

Saliferous area Praid – Sovata – Corund is situated on the contact area of the Transylvanian Basin with neo-eruptiv mountain chain of Eastern Carpathians, Calimani – Gurghiu – Harghita, and at the contact of Târnavelor Plateau with the orogen alignment of Gurghiu – Harghita Mountains. The salt body, in the horizontal plane, has a quasi-circular shape, slightly ellipsoidal, with diameters of 1.2 and 1.4 km, and is estimated to have a burial depth of 2.6 to 2.8 km. The salt massif from Praid, pierce the Mio-Pliocene blanket around and appears at the surface as diapir, flanked by sedimentary rocks that are partially covered by extrusive post-Pliocene volcanic formations and Quaternary deposits. Evaporitic deposits presents a varied lithology represented by gypsum, anhydrite, salt rock, potassium salt and celestine.

The salt massif from Turda develops on the anticline Sic–Cojocna – Turda, oriented NE – SW, 2 km NE of Turda's downtown. It has an elongated shape, about 4 km, with widths ranging from 700 m to 200 m and also with a thickness ranging from 750 m to over 1000 m. In terms of stratigraphy, the salt massif is surrounded by deposits belonging to Badenian, Sarmatian and Quaternary.

Due to salt dissolution by meteoric waters, carsto-saline lakes were formed, and due to ceiling collapse, because of an intensive exploitation, and infiltrations of rainwater and rivers, antropo-salted lakes were formed. The water and mud of these lakes are used for external treatment. The holes resulting from exploitation were arranged and turned into treatment rooms for those affected by respiratory diseases.

Localities Praid and Sovata from rural settlements, have become balneary resorts, that use these salt resources by multiple forms of tourism: spas, climatic, cultural, recreational and scientific.

In Turda has developed both health, climacteric and recreational tourism, as well as cultural and historical tourism, given the historical relics that are housed here.

The design of applicative segment of geomorphological sites on salt recovery, through tourism activities is the objective of our work. Methodological argumentation is supported by the objective motivation, of geomorphosites on salt capitalization, by the content of syllabus and specialization of geography of tourism and territorial planning, from the Faculty of Geography, Babes-Bolyai University from Cluj-Napoca. The syllabus content argues the need for knowledge of geomorphosites genesis, their morphology, touristic valences, urbanistic valences, and the possibility of recovery, through forms and types of tourism, namely, urban, agricultural, industrial forms and types of exploitation.

Key words: salt, geomorphosites, Praid, Turda, tourism

1. Geomorphosites Location: Praid, Sovata, Turda

Saliferous structures Praid, Sovata, Turda are part of the Transylvanian Basin Neogene molassic areas (Figure 1). Salt tectonic in Transylvanian space is materialized in diapiric anticlines and synclines who are disposed in Transylvanian Basin circumscribed relays. Praid-Sovata structure belongs to eastern diapiric region and Turda belongs to western diapiric region, both being strong tectonized structures, diapir presenting the shape of a solid pillar of salt.

Sovata Basin is a depression developed on the axis of a diapir anticline and results from the epigenetic deepening process of Târnavă Mică Valley and its tributaries in anticline fold. Sovata resort has a spectacular hilly relief and is bordered to the west of Bichiș hill (1080 m), which along with Firtuș and Șiclod hills are part of a line of hanging synclines. To the north is bordered by Cherry Hill (912 m) and to the east by Elah Hill (649 m). These hills are dominated by Saca Mountain (1777 m) which belongs to Gurghiu Mountains.

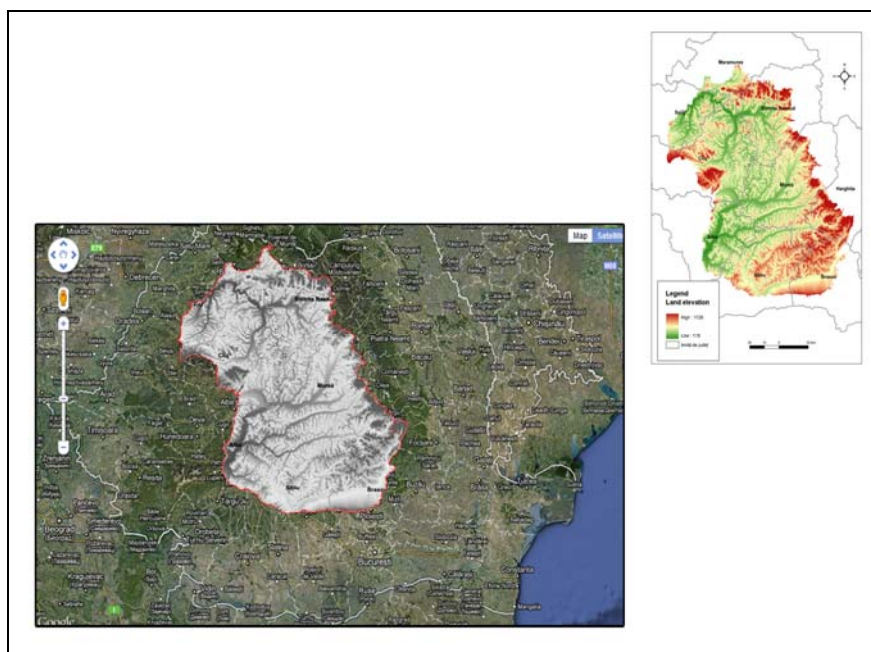


Figure 1 Transilvanyan Basin

Praid Basin is around Salt Hill. Basin has a triangular shape whose top, in the south, is oriented to Corund village, and in north and west merges with Sovata basin. Praid Basin is separated from the rest of the Transylvanian Basin by the peaks line Sălaș-Firtuș (1062 m), Fiasmăl (983 m), Stone Cușmedului (991 m) and Stone Șiclodului (1025 m). Salt Hill, in local name "Salt Back" (576 m), covers the largest salt deposit in the country, whose "roots" are buried up to 2.7 to 3 km deep. Altitudes in the Praid village area are between 460 m, Târnava Mică thalweg, and 681 m, Raspberry Peak, south of Salt Hill.

Turda Salt Massif - on the back of which are salt lakes - is placed in the western point of the Transylvanian Depression. It is in the area immediate neighbor of the Apuseni Mountains block, contact with the sedimentation basin. Investigated area, belongs, from the tectonic point of view to the strip of symmetrical anticlines and synclines, oriented north-south, which correspond to mobile-area Turda Depression (M. Bleahu, M. Lupu, 1963) located in contact with Trascau Mountains. Two arching more significant marks the Turda salt massifs: the salt massif from "Salt Baths" is incorporated to the anticline which passes through Turda's town center, in the direction of Ploscoș locality, and "Ocna's" salt massif belongs to Mihai Viteazul – Salt Stram anticline structure.

2. Genesis and salt tectonics

Salt, according to the lagoon model proposed by Mircea Paucă (1967), is Badenian – Wielician age

and comes from the seas lying to the external curvature of the Carpathians (Figure 2), from where it entered inside the Transylvanian Basin. A circular current, more or less continuously, has been made. Extra - Carpathians sea waters entered in the Transylvanian Basin over the curve (Figure 1), and the return current has been made through the Turnu Roșu - Cozia region, creating a zone of discharge in Govora, in north of Getic Platform. Separation of salt from other evaporites, is explained by the presence of intermediate lagoons (small dimensions) from the curve (Figure 3). These "fulfill the role to retain from the sea waters, at concentrations still low, but high temperatures (which could reach shallow waters), calcium and magnesium carbonates" less soluble and thermophilic "and deposited them in the form of dolomites" (Paucă, 1967).

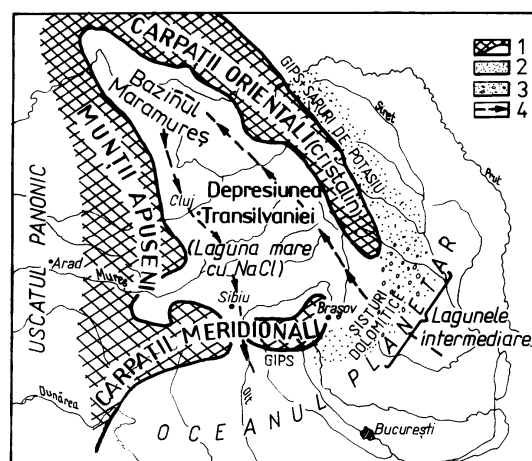


Figure 2. Circular current diagram, carrier of potassium and magnesium salts (after D. Ciupagea et al., 1970)

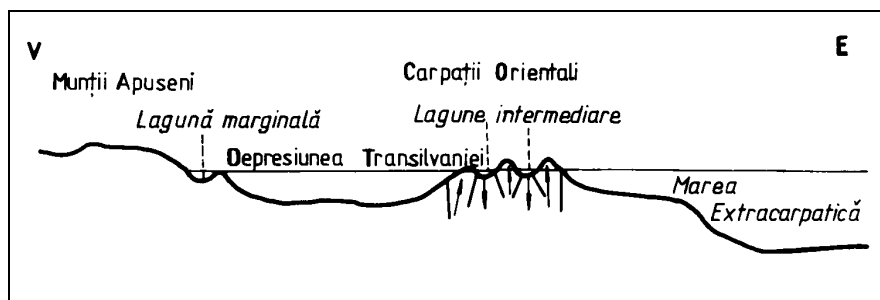


Figure 3. Intermediate lagoons configuration (after M. Paucă, 1967)

Therefore, in Transylvanian lagoon, reached waters loaded with sodium chloride and complex potassium and magnesium salts. These waters, which in intermediate lagoons reached temperatures of 70 °C, as they entered in the Transylvanian lagoon has cooled and deposited only rock salt, which is a cryophil mineral.

The deposition of salt went unevenly, across the Transylvanian Basin, depending on the variations of the salts saturation degree of the water, on the input of terrigenous material and seasonal variation of climatic conditions, aspect showed by the alternation rhythm of the pure white salt strips and gray salt strips. Pure white salt, corresponds to a sedimentation made due to a warm climate, arid, and gray impure salt, corresponds to seasons of heavy rainfall and intense input of terrigenous material.

Rock salt, describes the full range of shapes, from weak lens and embryonic folds (central and north-western basin) to the "violent" ones, with the breakdown seeds in diapir peripheral areas (figure 4). Between primary stage not tectonised (horizontal), and proximal stage (diapiric) the salt

packages elevation, distinguish a wide range of morphological types (large folds, lens, blades, apophyses, arches, columns, mushrooms, domes, etc.). Salt horizon thickness varies between 1300 m at Brâncovenești and 1480 m at Praid.

Salt movement is explained by the fact that it (specific gravity 2.15) is lighter than rocks (clays, sandstone, tuff, sand, limestone) that covers the layers of salt (specific gravity 2.3 to 2.4). It possesses plastic properties and it's moving in sectors less loaded with sediment, causing thickening of salt layers (anticlines, brahianticlines). Continuous accumulation of salt in these sectors leads to massif and columns salt formation or salt pillars (vertical cylindrical bodies) which penetrates the sedimentary complex of rocks above.

The diapirism due to the high plasticity of salt, depends on the amount of salt massif and on the thickness of deposits above. The diapirism involves a slow decompression phase, which accuses a stage of proximal diapirism, with significant elevation of millimeters. Decompression stages are associated to isostatic decompression phenomena.

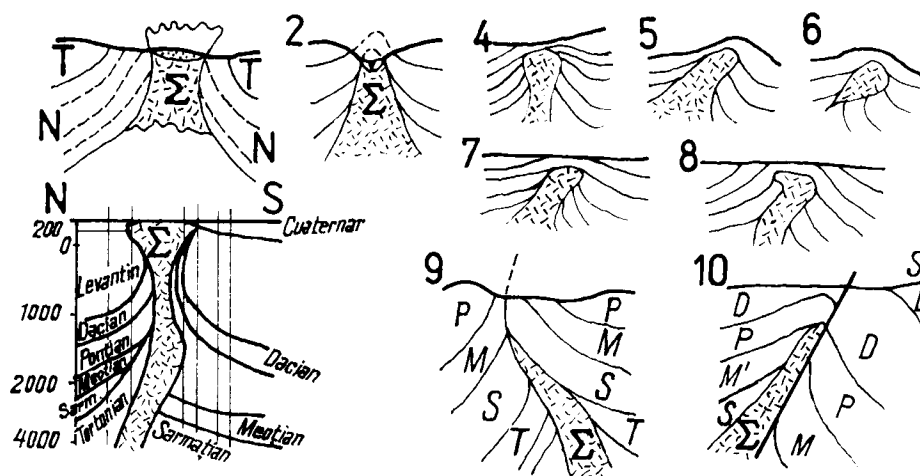


Figure 4. Diapir types (after V. Dragoș, 1982)

1-3. open diapir massif or stock type; 4, 5, 7, 8. embryonic anticline folds; 6. Salt lens; 9, 10. Crypto-diapir (faulted 10).

Differentiated manifestation of the tectonic diapirism in the Transylvanian diapir folds is reflected in their regional tectonic types: *salt massifs, anticlines and synclines elongated diapirs, short isolated anticlines and synclines, salt lenses*.

Salt massifs are localized in the east and west of the basin, in an intense fold areas. The diapir anticlines vault, placed in the wings or in the relay and rebuilt, presents the character of the open and pierced diapir folds. The emergence of these salt massifs or stocks is linked to a higher mobility of the foundation along regional faults (figure 5), which marks the connection between the cuvette and the monoclin area border: Praid, Sovata, Sărățeni, Sic, Cojocna Turda, Ocna Mures, Ocnișoara, Ocna Sibiu.

Elongated anticlines and synclines, have a great asymmetry of the flanks and slopes between

23° and 90°; they have broad representation in virgația Someș Mare, in Eastern, southeast, southwest and northwest fascicle.

Isolated short anticlines and synclines with the tendency to shift to the brahistructures are present both between the main anticlines and synclines lines and outside the relay or diapir fascicle, usually presented as isolated folds: Unguraș – Fizeș, Strugureni, Beclean – Apatiu, Sînmiclăuș, Sîncel, Feldioara, Șomîrtin, etc.

Salt lenses, present in Ocna Dej and Jibert shows the characters of salt lithogenesis period.

Diapirs folds from Sovata, Praid, Turda are presented as salt massifs pushed to the surface by rolling and by piercing the couverture to the Pontian deposits.

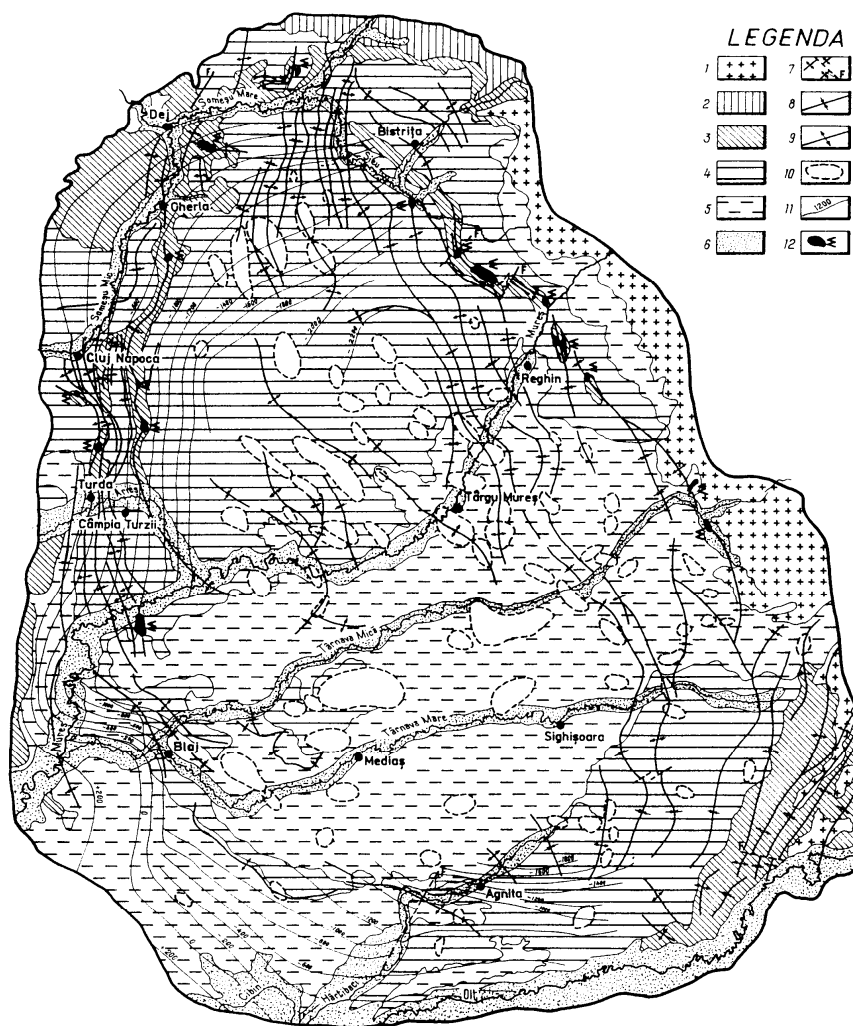


Figure 5. Transylvanian Basin. Geological map:

1. volcanic agglomerate plateaus; 2. Helvetian deposits; 3. Badenian deposits; 4. Sarmatian deposits (vh+bs₁); 5. Pannonian deposits; 6. Cuaternary deposits; 7. faulted anticline and synclinals; 8. diapire synclinales; 9. diapire anticlines; 10. Dom structures perimeter and brahianticline; 11. Dej tuff bathymetric; 12. salt massifs

3. Saliferous areas morphology

The occurrence of salt to the surface, condition the appearance of salt microrelief: clints and dissolution micro- sinkholes. Subsidence phenomena associated with the dissolution, generates a typical karst landscape on salt (clints field and sinkholes from Salt Bath - Turda, clints fields on salt massifs from Praid and Sovata).

Sliding formation meets, in diapirs folds area, processes and forms resulting from derosion, soil flow, mud flows and landslides (furrows and lens).

Layers alternation of marl and clay, with sand (in thick layers) and intercalation of layers more resistant to erosion (sandstone, andesite and dacite volcanic tuffs, limestones), have resulted in highly differentiated morphology, and a “fragile” balance of the slopes, showed since the Pleistocene, through the deep landslides, glimee type (Subatlantic). These landslides are part of Transylvania geomorphologic landscape by the frequency of affected areas (cca. 750) and by association of the landslides type glimee with Sarmatian, Pannonian sedimentary formations, or on the lithological contacts of Sarmatian-Pannonian, Sarmatian-Badenian.

Specificity and prevalence of sliding processes in Transylvanian depression, have led to the identification of the process with the type of slope: Saschiz type (Gârbacea, 1964), slope type Măgherani (Tövissi, 1970) and slope type Goagiu (Mac, 1970).

Landslides from Pleistocene-Holocene, have created the development premises of the current morphodynamic processes by creating a wide range of forms that have changed the slope (slip valleys, magnifiers, fake-solifluction and glimee) and its profile (convex and concave alternating sectors). Most areas with landslides, confirms the deposits structure convergence, neotectonics (including diapirism) and climate.

Contemporary morphodynamic is printed by the surface erosion, mass movements and riverbed erosion. Pluvio-denudation, gullyng, suffosion, compaction, subsidence, slumps and landslides, river erosion, shapes the salt massifs and the diapirs folds. Torrential, attacks regressive the structure (Figure 6, Salt Hill, Praid), developing small torrential basins, and the control is accomplished from local erosion bases (v. Corundului, v. Târnava Mică). This action is combined with landslides, runoff, suffosion and compaction on the salt massif which appears on the surface. The dome shape under which appears today, reveals the tectonic dominance on the exogen.

Longitudinal profiles of rivers crossing the diapir region Sovata-Praid appears as a slightly concave curve which is marked from place to place by the break of slopes (I. Mac, 1972), that are attributed to lithological differentiation (Figure 7) respectively the transition from volcanic agglomerates deposits to Pannonian (sands, clays, marls) and Sarmatian deposits (marls, clays, sandstones, sands).

Figure 6 . Geomorphologic profile across the Salt Hill (Praid)
1. Volcanic agglomerates; 2. Pannonian deposits; 3. glacis; 4. salt

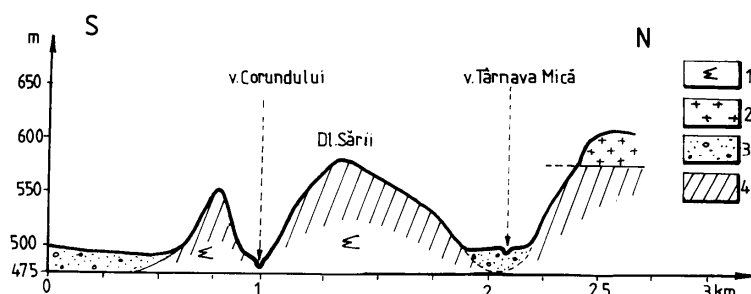
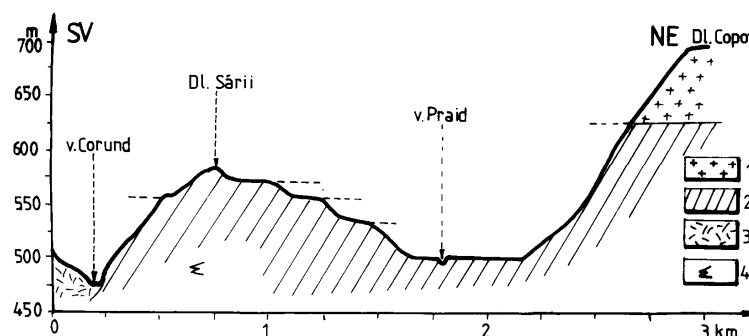


Figure 7. Geomorphologic profile across the Corund Valley and Târnava Mică Valley 1. salt; 2. volcanic agglomerate; 3. Cuaternary deposits; 4. Pannonian deposits

Current modeling process outlines the mechanisms and the work manner in relation to the "inherent" periglacial features, drawing morphodynamic complexes. On this "inherited" matter of the periglacial slope, in a state of relative morphodynamic equilibrium, is still evolving or outlines: derosion "beds", soil-flow magnifiers or shallow landslides, channels, ravines, torrential. Slopes evolve under the incidence of sliding configurations action, runoff, gullying and torrents. Action rate varies according to the morphogenetic potential of the salt massif. Landscapes that are frequently associated in the salt massif are landscapes of lenticular landslides, soil flows, mud flows (Turda, Praid, Sovata) and compaction. On the "day" diapir is modeled erosion clints or small sinkholes (Fig. 8 and 9). Washing of salt by precipitation accelerates flysch deposits mobility.



Figure 8 and 9. Clints and sinkholes on salt

Salt massif from Sovata presents a diversity of morphological shapes among which it is noted lacustrine depressions caused by tectonic-anthropogenic causes (now occupied by the large salt lakes: Bear, Black Ariniș); sinkholes on salt (partially occupied with water coming from precipitation) or torrential bodies (Snake Lake, Green Dolina). A similar morphology has the salt massif from Turda. The fall in levels after local

fractures of old mines ceiling (Turda, Sovata) has facilitated the development of large depressions "paved" with thick clay horizons, which facilitates the meteoric water accumulation, conditioning the occurrence of ponds in the area of sinkhole dissolution micro-sinkholes (Salt Bath - Turda), or even freshwater lakes: Green Lake, Aluniș Lake. Formation of lake complexes, on torrential valleys tributary Sovata Valley, involves a complex genetic mechanism: tectonic diapirism accompanied by local fractures, dissolution, anthropogenic impact as salt exploitation. Salt massifs from Sovata and Praid are affected by natural dissolution, which leads to the appearance of a carsto-saline relief: sinkholes, clints, potholes, natural bridges, winding valleys and caves.

River morphology, express areas differences in relation to salt massifs position and diapir folds orientation, antecedent or epigenetic character of the valleys. Corund Valley upstream of Salt Hill (Praid) has a slope of the riverbed of 2.5 m/km and meanders coefficient is 2.06. Downstream, the riverbed slope of Corund river, increases to 20 m/km and meanders coefficient is reduced by half, 1.1. These morphometric indices, are reflected in the morphology of the valley by the genetic characters of terraces, their numbers and natural setting. Upstream are carried out two steps of terraces poorly differentiated altitude (0.40 to 0.80 m), and downstream of Salt Hill with the confluence of Târnava Mica Valley are recorded four steps (t1, t2, t3, t4) of successive terraces. Upstream terraces, are presented as incorporated terraces, the latest (from the two levels) enrolling in the oldest, as the reduction of neotectonic movements amplitude (diapirs lifting). They were formed due to the diapir pushup movements, simultaneous with the raising of the alluvial bed of Corund Valley and alluvial accelerating.

Valleys (Sovata Corund and Praid) alluvial strongly behind salt massifs, widen, developing enlarged depression basins (Sacadat, Praid, Ocna de Jos). Large width of the valleys is also emphasized by transverse profiles. Thus Ocna de Jos, Corund Valley, records 4 km wide, and in the cross section of diapir, takes an aspect of a "canyon" valley, of a few meters (10 to 15 m).

Toponyms (Sarățeni, Sărata), oronyms (Salt Hill) or hidronyms (Salt Valley, Salt Lake, Salt Pond) are common in saliferous areas, beeing arguments of cultural sustainability and salt civilization in this region.

4. Geomorphosites on salt

Name		Corund Gorges (Salt Hill)	
Indicative	S1		
Location	Corund Valley, Gurghiu Mountains		
UAT	Praid Town, Harghita District		
Tipology	System – Gorge Geomorphosite		
Extension	Linear		
Total Value	24.25		
Structural Value	10.75		
Functional Value	12.75		
Restrictive Attributes	0.75		
STRUCTURAL VALUE			
TYPE	POINTS	JUSTIFICATION	
Geomorphologic	6	- In the geomorphosite genesis were involved at least four factors: tectonic, lithologic, climatic and hydrological, in the three phases of its evolution (salt deposit, increasing salt and formation of keys) (1 p) - Moderate dynamic, noticeable (0.75) - Brings together more than 5 elements of geomorphological interest: clints, sinkholes, dissolution valleys, salt lakes, caves and mud lakes (1 p) - Standard geomorphosite for the region, due to physiognomy and size (has a depth of burial of 2.8 km) (1 p) - Geomorphosite strongly affected by natural processes and anthropogenic intervention (0.75) - Geomorphosite, unique regional (0.75) - Interesting structure (0.75)	
Aesthetics	2.25	- Has a unique physiognomy due to the formation, geomorphological processes and the surface exploitation (1 p) - Has a special chromatic by mixing colors of rocks, vegetation and water (0.75) - Can be perceived panoramic (0.5)	
Ecological	2.5	- Presence of halophyte plants: Limonium Gmelin, "flower of salt", purple, Salicornia herbacea (purple or green salt grass), Aster tripolium (Autumn Rose), Spergularia salina, Salsola soda (salt grass), Artemisia saline (salif wormwood), Plantago maritime and Static Gmelin (salt flower) (0.75) - Presence of fauna biotopes, rare on a regional scale (0.75) - Is a fully protected area - Reserve "Land of Salt" (1 pct)	
FUNCTIONAL VALUE			
TYPE	POINTS	JUSTIFICATION	
Cultural	2	- Representation in art, most in photos and photo albums (0.5) - In areas of the perimeter, are held at least two annual cultural events (1 p) - Traditional architecture, specific Szekler land (0.5)	
Scientific	4.5	- There are at least two scientific theories about the genesis and evolution of form through epigenesis (1 p) - Has disclosure potential recognized by bibliographic citations in reference works dedicated to salt resources in the Transylvanian Basin and genesis of Transylvania Depression (1 p) - With polyvalent addressability in the field of Geography and Geology (1 p) - National representation (0.75) - Model with an indicative value (0.75)	
Economic	6.25	- It can practice at least four tourist activities: hiking, spas activities, geotourism, ecotourism (1 p) - Is a top tourist attraction at the regional level, because of its attractiveness potential (1 p) - Car access is possible close to 300 m (0.75) - Has many accommodation bases in the area, especially in Praid and Sovata (1 p) - Distance of 2 km from Praid, 8 km from Sovata and 25 km from Odorheiu Secuiesc (1 pct) - Distance of 25 km from the center with urban services (Odorheiu Secuiesc) (0.5) - Complex promoting, sustained at national level, but also international dedicated especially to Hungarian tourists (1 p)	
RESTRICTIVE ATTRIBUTES			
POINTS	JUSTIFICATION		
0.75	- Uncontrollable risks such as subsidence, extensive dissolution (0.5) - Site is vulnerable without being affected overall (0.25)		

5. Touristic recovery of geomorphosites on salt

Scientif-cultural tourism associate in diapir regions an acculturated landscape, where the traditions, habits and Catholic monastic attitudes, Roman Catholic, Greek Catholic, Orthodox, Calvinist, Protestant, Evangelical, etc., converging deterministic to meet the local community interest and welfare. Salt exploitation and marketing, have their beginnings in the Daco-Roman period. Along with the exploitation of salt deposits the salt spring water is also harnessed in cooking (cooking and food preservation).

Cultural landscape highlights the cultural values of this area, values that are closely related to economic development and social maturity of diapiric Transylvanian geographical area. Monastic habits and attitudes (annual and seasonal: religious or events related to nature, familyal and behavioral: receiving guests, inclusion in the adults community or local community), architecture and architectural landscape, cultural events (music festivals, film, sculpture, painting, congresses and meetings of science and art), confirms the close link between natural resources of salt geomorphosites, salt culture and civilization, as existential forms.

Among these customs and religious traditions are "Advent" is a kind of lent of the Christmas and marks "coming of the Lord", then on December 13 is celebrated "Saint Lucia" which has several meanings: weather prediction for next year, casting evil spirits, and finding Fates for unmarried girls. Another tradition is "Farșangul" which is celebrated before Lent entrance, and which drives away the winter, is a celebration of masks and a practice that allows excess before entering the Lent.

In the second day of Easter, is in this region the "watering" habit when the boys go to girls of their age and their relatives and wet with perfume, saying before a poem, then are rewarded with painted eggs. Other customs and traditions of these areas, not necessarily religious, are vintage, which is a big celebration each fall, the International Festival of stuffed cabbage (Figure 10), which is celebrated every year between 23-25 September in Praid and Snow festival in Sovata that is held annually in February.

Sovata's treatments have become famous all over. The resort is indicated for gynecological diseases treatment (ovarian insufficiency, chronic cervicitis, chronic metrosalpingitis, impotence) and for degenerative, inflammatory and rheumatic diseases (cervical, dorsal and lumbar osteoarthritis, poliartrosis, joint pain, tendinitis, tendimiosits, scapulohumeral arthritis) post-traumatic conditions

(after healed operations on joints, muscles, bones, dislocations and sprains), diseases of the peripheral nervous system (slight paralysis, sequelae of poliomyelitis, polyneuritis), endocrine disorders (hypothyroidism, after endocrinological treatment), cardiovascular disease (ulcers, acrocyanosis).



Figure 10. Festival of stuffed cabbage

The resort has multiple facilities, for warm baths in a tub or pool with salt water taken from lakes, for gynecological treatments and mud hot pools for physiotherapy, electrotherapy and hydrotherapy facilities, saunas, medical gyms, beaches on the Bear Lake and Aluniș Lake.

Methods of treatment:

1. Salt-water baths done in the tub, in the pool, in Bear Lake and sitz baths.
2. With mud and vaginal swabs
3. All forms of physiotherapy, electrotherapy, thermotherapy, water treatment and phototherapy, massage, medical gymnastics, outdoor walks.

The Bear Lake schedule is between 10 AM - 18 PM, with breaks between 13 PM -15 PM. In this pause, bathing is forbidden, because the lake takes several hours of rest to avoid losing property.

In Praid, salt baths are done in the basin, built near the salt mine, which is fed with salt water from the mine, which is an infiltration meteoric water and who acquired salinity by crossing the mountain of salt, and stationing in the underground sump. Treatment with warm baths in the tub, is done also in Praid and it consists of 10 to 30 min of bath and obligatory 30 min of rest in the rest room properly equipped with beds. The objective of salty baths spa operates seasonally, during the June 1st to October 15th, annually, and is open daily from 10.00 - 20.00, seven days / week.

Praid resort is famous for the climacteric treatment with aerosols in the Praid Saline, which is

open all year. Treatment is for people who suffer from respiratory diseases (asthma, bronchitis and allergic).

Treatments that are made in Turda are: the climacteric treatment with aerosols in the Turda salt mine, which is open all year and the spa in salt lakes from the salt mountain, which are accessible only in summer.

Field applications (figure 11) are scheduled in the curricula of geographer students, at license degree level, for all lines of study (Romanian, German, Hungarian) and specializations: Geography, Tourism Geography, Territorial Planning, Cartography, Cadastre and Land Measurements. Field application take place in 1st and 2nd year, in two stages differentiated as problematic, and is credited each stage with 3 credits respectively 6 credits per year, from a total of 60 credits.



Figure 11. Field applications

The first stage is identified with a field application of 5 days on a route determined in advance by the Professor and his collaborators (lecturers, assistants, PhD), based on the topics covered in geomorphology (dynamic geomorphology, climatic geomorphology, applied geomorphology, engineering geomorphology), tutorials, workshops, laboratories. The second stage is carried out of a period of 10 days, in the practice base of the university or college and seeks validation of theoretical knowledge of an academic year in one or two major themes: dynamic of the geomorphosites on salt, riverbeds morphodynamic in saliferous areas, slopes morphodynamic in Saliferous areas, tourist recovery of the geomorphosites on salt, tourist recovery of the salt lakes, tourist recovery of the karsts geomorphosites, recovery of the mountain landscape resources, etc. Preparation of field applications, involves research orientation to the demand or supply of local or regional beneficiaries, solving problems of seminars, laboratory, but also an offer of services to third party beneficiaries: local or regional

administrations, ministries (transport, tourism, culture, etc.).

6. Conclusions

Recovery of geomorphosite on salt by scientific – cultural tourism, requires geomorphosites identification, morphological analysis of the sites, identifying the valorisation and exploitation opportunities in touristic and scientific interest. The local customs include Knitting Hats (Figure 12) from Crișan, Pottery of Corund (Figure 13) and regional habit is Carved Gates (Figure 14).



Figure 11. Knitting Hats



Figure 12. Pottery of Corund



Figure 13. Carved Gates

Scientific tourism is not perceived as a form or type of tourism, since it does not assume rest, relaxation, pilgrimages, etc., instead, according to WTO (1978), the tourist is any person "who is outside his current residence for at least 24 hours (or overnight) and for maximum four months, because of the following reasons: entertainment (vacations and week-ends), health (termalism,

thalasso therapy) missions or meetings (congresses, seminars, pilgrimages, sporting events, etc.), business travel, educational travel, etc". Applying these explanations we consider that scientific meetings (congresses, symposia, seminars, workshops), business travel and school travel, particularly academic field applications are specific cultural tourism and scientific activities.

REFERENCES

- BALINTONI, I., PETRESCU, I., (2002), *A hypothesis on the transylvanian halite genesis*. Studia Univ. Babeș-Bolyai, Geologia, Special issue 1, pp. 51-61, Cluj-Napoca.
- BLEAHU, M., LUPU, M., (1963), *Dinamica scoarței terestre*. Ed. științifică și Pedagogică, București.
- CIUPAGEA, D., PAUCĂ M., ICHIM, TR., (1970), *Geologia Depresiunii Transilvaniei*. Ed. Academiei, București.
- DRAGOȘ, V., (1982), *Geologie stratigrafică*. Editura tehnică, București.
- GÂRBACEA, V., (1964), *Alunecările de teren de la Saschiz (Podișul Hârtibaciului)*, Studia Univ. "Babeș-Bolyai", Cluj, Ser. geol.-geogr., tom. VIII, fasc. 1.
- HORVATH, I., (2009), *Descrierea geologică a zăcămantului de sare gemă Praid*, Ed. De Salina Praid, Praid.
- HORVATH, I., (2001), *Scurt istoric al exploatării sării de la Praid*, Ed. De Salina Praid, Praid.
- ILIE, M., (1975), *Synthesis of the geology of the Neogene Transylvanian Basin (Romania)*, N. Jb. Geol. Paläont. Mh., pp. 91-101, Stuttgart.
- IRIMUS, I. A., (1998), *Relieful pe domuri și cute diapire în Depresiunea Transilvaniei*, Ed. Presa Universitară Clujeană, ISBN 973-9354-55-6.
- IRIMUS, I. A., (2006), *Hazarde și riscuri asociate proceselor geomorfologice în aria cutelor diapire din Depresiunea Transilvaniei*, Ed. Casa Cărții de Știință, Cluj-Napoca.
- MAC, I., (1970), *Massive landslides induced by excessive moistening conditions of the year 1970*. Abhandl. der Akademie, Goettingen.
- MAC, I., (1972), *Subcarpații transilvăneni dintre Mureș și Olt*, Ed. Academiei R.S.R., București.
- MAC, I., (1972), *Suprafețele de nivelare din Subcarpații transilvăneni dintre Mureș și Olt*, St. Univ. "Babeș-Bolyai", ser. geogr., an XVI, fasc. 2.
- MERA, O., STEFANIE, T., VIȘINESCU, V., (2010), *Cetatea din muntele de sare*, Ed. Delroti, Turda.
- PAUCĂ, M., (1967), *Zăcămintele de evaporite din România*, Ed. Academiei, București.
- TÖVISSI, I., (1970), *Contribuții la problema analizei dinamicii versanților*, Studia Univ. "Babeș-Bolyai", ser. geogr., fasc. 1, p. 23.

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Les aléas naturels en zones urbaines semi-arides – Étude de cas de Bou Saâda (Algérie)

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Abstract. Diagnosis of Geomorphological Hazard in Semiarid Urban Areas. Case Study of Bou-Saada (Algerie). The study aims to emphasize the hazard diversity in the warm semi-arid climate areas, beginning from the concrete analyze of the Bou-Saada city (Algeria).

Bou-Saada is situated at the contact of the Hodna shot with the Presaharian Atlas in the proximity of a corridor, which allows the orientation of the air masses. The extinction of the city has lead to the partial destruction of the oasis, as well as the exposition to the different risk phenomena, being frequent the following:

- The exposition to the sand accumulation, especially of the district developed on the Southern-Western corridor, in the wind direction;
- The exposition to the rock falls from the mountain side, in the conditions of a powerful desegregation;
- The exposition to the inundations during the rare torrential rains, being also facilitated by the city development in a narrow depression, which allows quick running of water from the mountain side.

The main factors determining the quality of the geomorphological vulnerability to the hazards (geological, geomorphological, climatic, anthropogenetic, biopedogeographical) highlight the favourability of the position of the first nucleus of the settlement compared to its area of current expansion.

The research was made in many campaigns between the years of 2006-2008, within an agreement of cooperation, being in progress.

Key words: vulnerability; geomorphological hazard, semiarid, urban, Bou-Saâda, Algeria

1. Introduction

1.1 Conception

Les aléas naturels dans les aires urbaines font partie en générale dans ceux qui caractérisent la région géographique. Il n'y a pas d'aléas naturels particuliers seulement urbains. Mais ce qui personnalise l'aire urbaine, c'est la présence active du facteur anthropique, qui par ses activités, par la densité, par les constructions, etc., expose aux risques de différents éléments de risque, comprise la population. Par conséquent, le passage de l'état d'aléas à celui du risque se fait beaucoup plus rapide en temps et espace. Une autre particularité, c'est le caractère multi- et interdisciplinaire du type génétique des aléas, souvent les aléas que l'on appelle naturels ont aussi une cause anthropique (Grecu, 2009 a, b).

Dans la littérature le risque urbain est défini, tout simplement, comme le risque qui est lié au

territoire de la ville, étant classifié en (J. Dubois-Maury, C. Chaline, 2002): risques naturels, risques industriels et technogènes, risques diffus. En effet, c'est la classification générale des risques (Grecu, 2009a).

En raison de la forte composante humaine, le caractère social du risque naturel s'y développe (Pigeon, 2002), voire les risques sociaux ont dans l'environnement urbain une intensité et fréquence plus grandes que dans l'environnement rural, par exemple.

Plusieurs aléas, lorsqu'ils dépassent les seuils de certaines valeurs, deviennent critiques pour le bon déroulement des activités humaines. Dans ce contexte, l'analyse des aléas dans les aires urbaines sémiarides, telles comme Bou-Saada, est nécessaire due à la dynamique des aléas, de la vulnérabilité et l'exposition aux risques de la population urbaine en développement.

1.2. Objectifs et matériaux

Le présent travail a pour objectif d'analyser, à partir d'un point de vue interdisciplinaire et en utilisant des méthodes spécifiques du chercheur de l'environnement, la dynamique globale urbaine de la ville de Bou-Saâda et les facteurs de vulnérabilité afin d'élaborer la carte de la vulnérabilité ; celles-ci visent deux étapes - niveaux :

1. Un premier niveau global de l'ensemble des vulnérabilités à une échelle de 1/50000^{ème}, interprétation des cartes et observation terrain ; traitement des données géomorphologiques, climatiques, statistiques (démographiques, économiques)

2. Un second niveau plus ciblé à la fois sur la thématique et sur l'espace.

Traitement de l'imagerie satellitaire multi date pour appréhender la dynamique du paysage urbain (qui n'est pas le sujet de la présente étude) ;

Les principaux matériaux utilisés sont : carte topographique 1/50000, carte géologique, plan cadastral, données climatiques (2000-2009), socio-démographiques (1954-2009), observations et cartographie du terrain (2006-2009), élévations GPS, interprétations des cartes analytique élaborées SIG...

2. Position géographique – facteur de conditionnement du type d'aléas

La ville de Bou Saâda, avec une surface de 36 900 ha, est située à la limite du Sud de la Dépression du Hodna (entre l'Atlas Tellien et l'Atlas Saharien) un « golfe » de la Plaine Hodna. L'ancien centre de la ville est apparu dans l'oasis situé dans un couloir dépressionnaire, à 461-550 m d'altitude. La position mathématique situe la ville dans la zone aride et semi-aride (fig. 1a) :

$\lambda = 4^{\circ} 12'$ Long. Est ; $\varphi = 35^{\circ} 25'$ Lat. Nord.

La ville de Bou Saâda est située à proximité du cordon dunaire et, comme de nombreuses oasis de la zone présaharienne, à flanc de montagne (rempart naturel de protection). Elle a par ailleurs connu cette dernière période une phase de croissance particulièrement soutenue. Ceci a induit une extension importante de la surface urbaine sur des espaces exposés à divers aléas : inondation, ensablement, voire glissement de terrain, ruissellement. En particulier, la ville nouvelle est située à l'exutoire du cordon dunaire au sud des Zahrez Gharbi et Chergui et à proximité de l'oued Maiter (fig. 1b).



Fig. 1a. Position géographique



Fig. 1b. L'oued Maiter

3. Facteurs de vulnérabilité aux aléas géomorphologiques

3.1. Conditions géologiques et tectoniques

Bou Saâda se situe dans la zone de contact de l'étage supérieur des régions de plissement alpin et les dépressions (les bassins) internes molassiques d'âge alpin sur l'ancien socle. Du point de vue tectonique, il se superpose à un synclinal suspendu. La dépression de Hodna de la part du Nord de la ville (Rmel) représente un bassin de sédimentation de Néogène - Quaternaire avec des dépôts de calcaire et gypses couverts des couches épaisses d'argile et des sables argileuses de Quaternaire (Hadjab Makhoulfi, Ouali Dehimi, 2007).

Les roches à grande favorabilité à la désagrégation et l'altération – dolomites et marnes de Jurassique – liasiques, grès, marnes et marnocalcaires flischoïdes Crétacées-, sont exposées directement aux facteurs exogènes dans les conditions de l'absence totale de la végétation. Les roches sont très fort diaclasées, faillées et altérées, en favorisant les processus gravitationnels (détachement des blocs, croulement et chutes de masses sur des versants) et la formation d'un réseau relativement épais de ravines, torrents de pierres, cônes et bas de détrit (fig. 2).

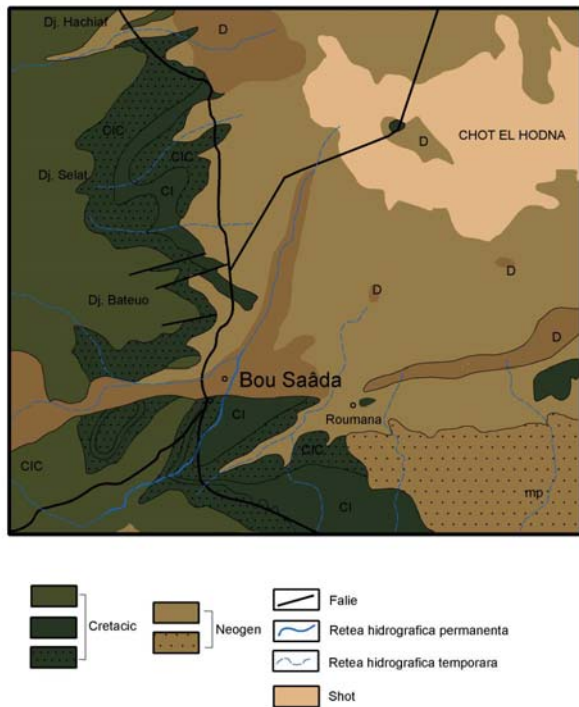


Fig. 2. La carte géologique

3.2. Conditions climatiques

L'analyse des éléments climatiques indique un climat sémi-aride, et leurs caractéristiques sont favorables aux différents types de processus (aléas) climato - géomorphologiques.

Direction, fréquence et intensité du vent sont influencées par les mouvements généraux des masses d'air de l'Ouest et se reflètent dans la direction et l'orientation des dunes (Benazzouz M. T. 1994), et aussi la grande vulnérabilité d'ensablement des constructions.

Le plus grand pourcentage est détenu par vents du Nord-Ouest (25%), suivi par les vents du Nord (23%) (fig. 3). Les accumulations de sable de la partie du Sud de la Dépression de Hodna (au Nord et Nord-Ouest de la ville), et l'orientation des dunes de Nord-Ouest vers le Sud-Est sont due au vent de ces directions. Les masses d'air de côté de l'Ouest (20%), sont canalisées sur le couloir de l'Oued Maiter entre Djebel Gorehor et Djebel Moubakhera, les accumulations de sable de la zone d'expansion de la ville couvrant pratiquement les bâtiments construits illégalement (fig. 4).

Le caractère torrentiel et irrégulier des précipitations conduit à l'entraînement des matériaux sur des versants, mais aussi à l'apparition des inondations dans le périmètre construit, où l'infiltration est diminuée par le pavage. L'analyse des données des dans l'intervalle Janvier 2000 - Décembre 2009 à l'aéroport situé près de la ville (www.weatheronline.co.uk) sont significatives en ce sens.

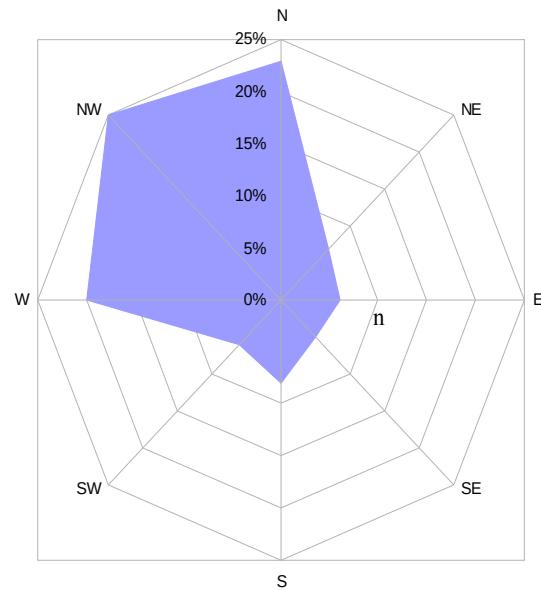


Fig. 3. Rose des vents à Bou Saâda



Fig. 4. Les accumulations de sable de la zone d'expansion de la ville

La quantité moyenne annuelle des précipitations a des valeurs réduites (338 mm), mais la distribution saisonnière et mensuelle montre de grands écarts. La plus grande quantité de précipitation est enregistrée le printemps (222 mm) dont environ 196 mm au mois d'avril, plus précisément en 4.1 jours (avec des précipitations plus grandes de 0.1mm), c'est à dire environ 50 mm /jour. En outre, les orages d'avril sont après le mois de Mars, le mois qui détient le record de sécheresse (6,2 mm), après le mois de Juin (5.0mm). Les précipitations sont associées avec les vents les plus intenses pendant tout le temps de l'année (16.6 km/h en avril).

Les grandes variations de température (fig.5), compris la présence des journées de gelée (environ 9.4 jours/an) contribuent à la désagréations des roches. La durée le long de l'année et la grande intensité du vent (tablette) amplifient la vulnérabilité des terrains à la désagréation. L'amplitude thermique moyenne annuelle est de 24,5° C, et celle

journalière absolue dépasse 35° C, pendant qu la température maximale atteint augmente à plus 40° C à l'ombre. Le degré élevé d'insolation (9-10 heures ensoleillée à partir d'avril jusqu'au Juillet), plus

l'humidité absolue (26-31% pendant les mois d'été) et, aussi, l'absence de la végétation sont les facteurs qui intensifient le processus de désertification.

Tableau 1 Nombre des heures ensoleillées à Bou Saâda (2000-2012)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Ann.	Hiver	Print.	Été	Autom.
6	8	8	9	9	9	10	9	8	8	7	6	97	20	26	28	23

Tableau 2 Humidité relative (%) à Bou Saâda (2000-2012)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Ann.	Hiver	Print.	Été	Autom.
68	52	42	38	38	30	26	31	43	50	58	67	45	62	39	29	50

Tableau 3 L'intensité du vent km/h à Bou Saâda (2000-2012)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Ann.	Hiver	Print.	Été	Autom.
10.5	11.4	14.1	16.6	13.5	11.6	9.8	8.9	8.8	7.2	9.8	10.6	11.1	10.8	14.7	10.1	8.6

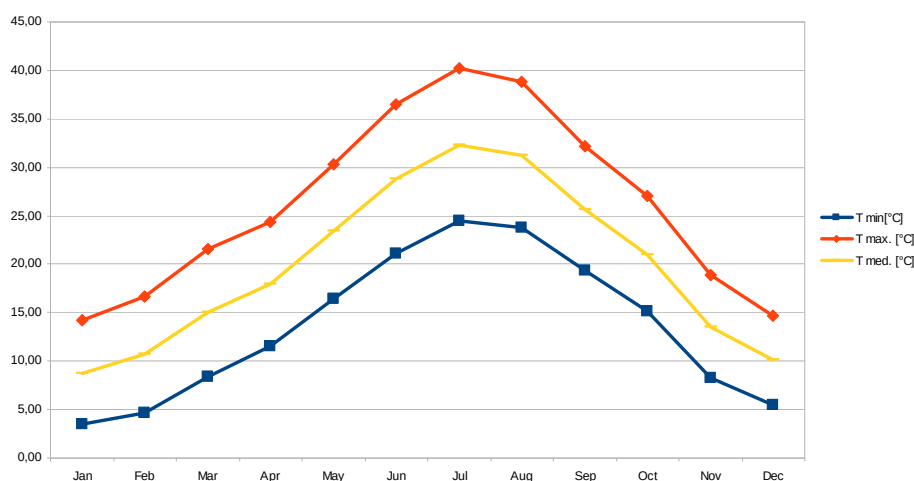


Fig. 5. Variation des températures moyennes mensuelles à Bou Saâda (2000 – 2009)

Tableau 4 Jours de gel moins 0° C Bou Saâda (2000 – 2009)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Ann.	Hiver	Print.	Été	Autom.
5.1	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.5	9.4	8.8	0.3	0.0	0.2

L'action de déflation du vent contribue par la dégradation – corrasion (abrasion éolienne) – au processus de désertification. La mauvaise gestion de ressources d'eau, de l'utilisation des terrains et des sols qui constitue le facteur qu'on doit tenir compte dans la définition du risque de désertification (Mostephaoui et al, 2009).

3.3. Conditions anthropiques

La ville est fondée au VIème siècle, sur un chemin utilisé par les nomades, dans la plus proche oasis du littorale de la Mer Méditerranée, à 245 km Sud d'Alger et à 70 km Sud de M'Sila (ville située approximativement dans le centre de la Dépression de Hodna). Il semble que d'ici son nom est dérivé, son étymologie signifie « la ville du bonheur » (Bou = père; Saâda = paix, bonheur).

L'ancien centre (le centre-ville, le noyau) est entouré par des murs – Ksar – village fortifié, et il a constitué une ancienne foire où les nomades faisaient du commerce (bijoux, tapis, produits de l'artisanat, produits en fer) (fig. 6).



Fig. 6. Le centre ville

Le centre-ville – Ksar – s'est développé autour de la Mosquée construite par Sidi Thameur au XI^{ème} siècle. Il a 7 départements habités en général par des familles faisant partie de la même tribu, ensuite il s'est étendu aussi dans les zones limitrophes. Les bâtiments sont construits très proches les uns des autres, en créant un microclimat de protection des habitants, la surface ombragée étant assez grande pendant la journée. L'accès est en général à pied. Après l'exode rural d'après 1980, les constructions de béton ont remplacés les anciennes maisons traditionnelles. De la population totale, 78% provient des zones rurales.

La ville de Bou Saâda a par ailleurs connu cette dernière période une phase de croissance particulièrement soutenue. Le nombre des habitants a augmenté d'environ quatre fois en 50 années (26 300 habitants en 1966 et 106 100 habitants en 2009) (fig. 7). Ainsi, il est apparu le besoin d'avoir des bâtiments et, bien entendu, des constructions non autorisée dans des régions vulnérables.

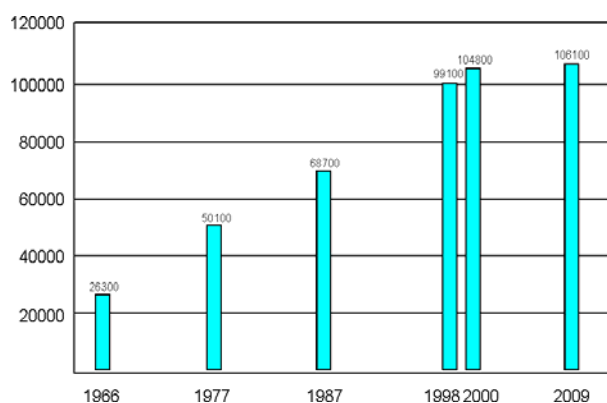


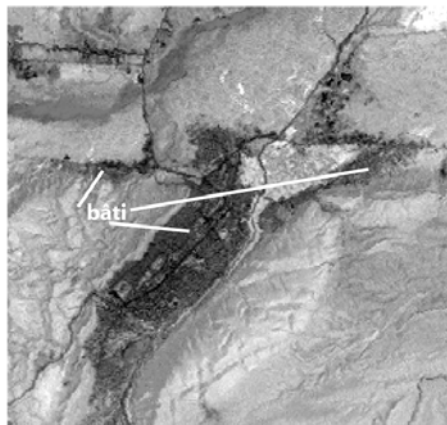
Fig. 7. L'évolution de la population de la ville de Bou Saâda 1966-2009

3.4 Analyse de l'évolution de l'étalement urbain

Nous avons analysé l'évolution de l'étalement urbain sur la période 1972-2006 à partir de l'imagerie satellitale. Pour cela nous avons utilisé quatre images Landsat respectivement de 1972 (de résolution ≈ 80 m), de 1987 (de résolution 30 m), de 2001 et 2006 (de résolution 28.5 m). Après extraction des fenêtres, nous avons procédé à un rééchantillonnage de tous les canaux à 15m afin de profiter des canaux panchromatiques (2001 et 2006). Une analyse en composante principale nous a permis de constater que certains nouveaux canaux rehaussent des thèmes particuliers ; ainsi le néo-canal ACP2 met en évidence le construit alors que le canal ACP3 rehausse la couverture végétale ; cela est montré, à titre d'exemple par la figure 8 correspondant à l'analyse en composantes principales de la scène Landsat de 2001 ; ceci est un résultat particulier qu'il n'est pas prudent de généraliser de façon automatique ; ce qu'il faut retenir par contre est que des néo-canaux avec une contribution faible (parfois jusqu'à l'ACP4) peuvent apporter une information spécifique importante qu'il n'y a pas lieu de négliger. Après avoir amélioré la dynamique des différents extraits de fenêtres, nous avons produits les compositions colorées fausses couleurs que nous avons exportées vers MapInfo puis définis les étalements urbains de chacune des années ; ceci a été possible car les images sont géoréférencées, donc superposables. Cela est montré par la figure 9.

L'analyse de la série d'images « fausses couleurs » fait apparaître que l'extension urbaine se fait désormais en direction des accumulations de sable (champ de dunes par exemple, mais également lit d'oued). Cette situation devrait être préoccupante à cause des risques multiples (inondation, risque pour la santé des populations). La figure 10 montre ce résultat.

Le canal ACP2 rehausse le construit



Le canal ACP3 rehausse la végétation

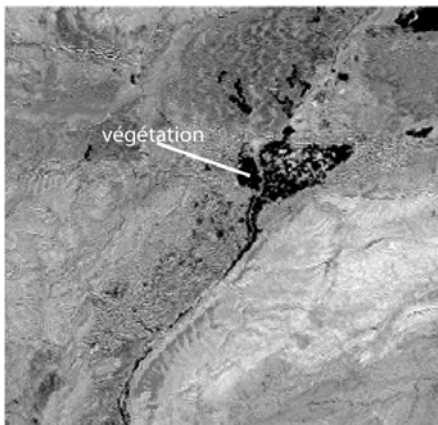


Fig. 8. Rehausser l'apparence de thèmes particuliers par l'analyse en composantes principales

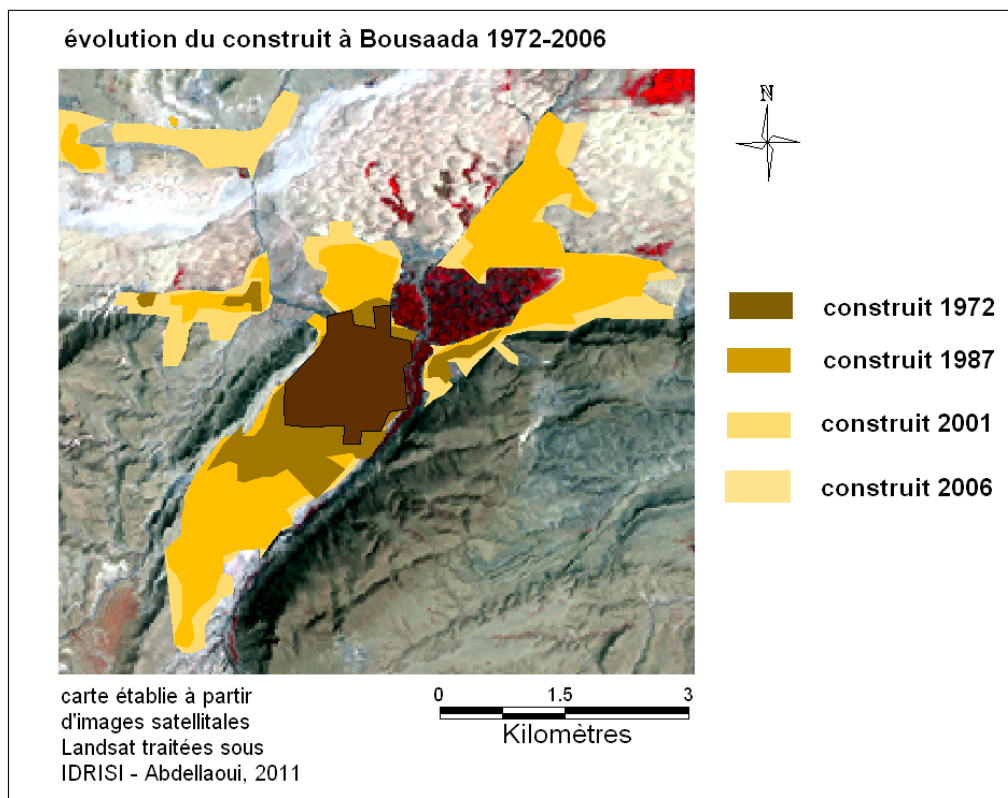


Fig. 9. évolution de l'étalement urbain de Boussaâda entre 1972 et 2006

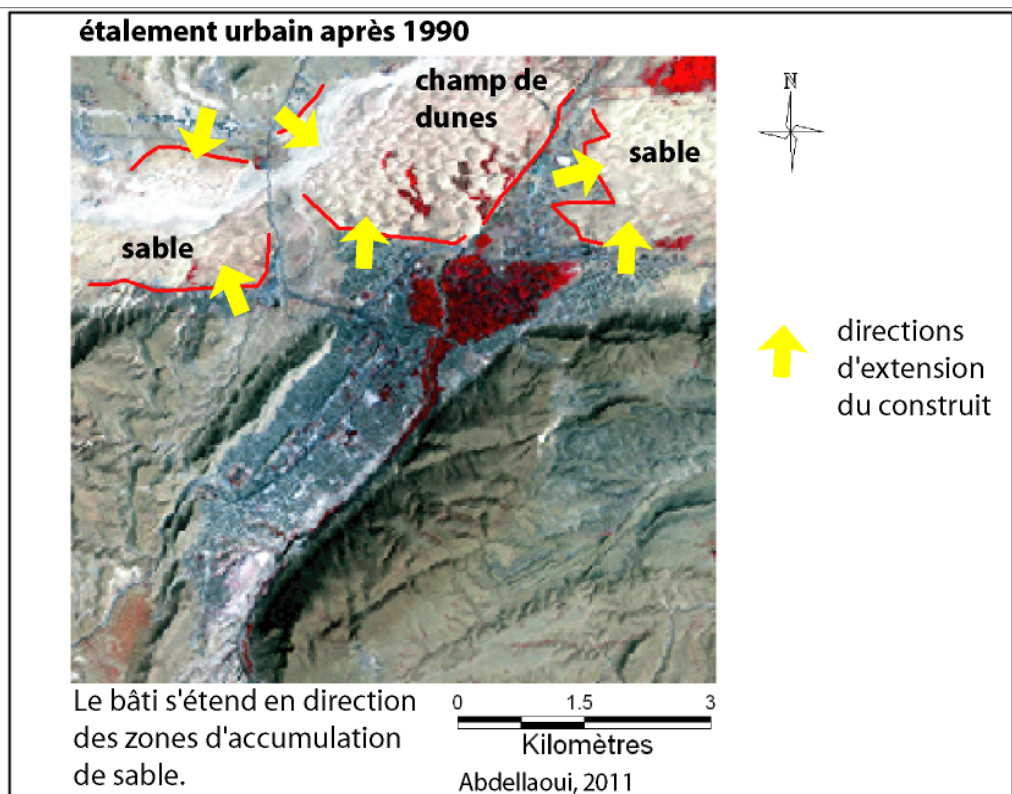


Fig. 10. Direction de l'étalement urbain

4. Résultats

4.1. Conditions géomorphologiques-vulnérabilité des aléas géomorphologiques

4.1.1. Unités géomorphologique

La ville s'est développée dans une dépression allongée d'origine tectonique – érosive, drainée par deux rivières séparées par un interfleuve dont l'altitude relative de 30-40 m. Ces caractéristiques ont favorisé le développement du premier noyau de ville.

Les deux pics qui délimitent le couloir dépressionnaire de la ville appartiennent à une surface morphologique de 700-900 m. Le pic de Djebel Kerdada (947 m), au Sud-Est de la ville, a un caractère structural. À la base du versant de cuesta de la ville il y a l'Oued de Bou-Saâda, une vallée relativement étroite, avec des gorges, qui s'alimente des sources de la base de l'abrupte. L'interfleuve de la partie centrale de la ville, un hogback, formé par les calcaires, grès et lentilles de marnes stratifiés, présente un degré avancé d'altération désagrégation; les éléments de la couche d'altération ont des dimensions de quelques centimètres à plusieurs dizaines de centimètres. La vulnérabilité la plus élevée aux écroulements, glissements de terrains, torrents de pierres n'a pas découragé les habitants pour construire des maisons tout près, en particulier sur le glacis de la base du versant. Vers l'Ouest, les grandes artères de circulations masquent un écoulement souterrain alimenté de Djebel Moubakhera (1052 m).

L'Oued de Maiter appartient à un couloir de vallée avec plus de 3 km de largeur, où le lit de l'oued peut avoir 1 km. Le couloir présente une énergie de relief d'environ 500 m entre Djebel Gorehor nord, 1029 m), Djebel Moubakhera (sud, 1052 m) et 587, 547 m dans le lit de la rivière. Celle-ci favorise canalise les masses d'air, les vents de l'ouest en créant un cordon des dunes qui ne peut pas être stabilisé.

En conclusion, sur une surface relativement réduite, on peut prendre en analyse les suivantes formes majeures de relief: la surface supérieure à 1000 m, la surface moyenne la 700-900 m, le glacis et les pédiments, le couloir de vallée Maiter, le couloir dépressionnaire de Bou-Saâda, le Champ de Bou-Saâda.

4.1.2. Morphométrie - effet et cause de la vulnérabilité

La densité de la fragmentation est un paramètre important pour l'indication de la potentialité des

roches à la météorisation/désagrégation, et aussi des relations d'interdépendance avec d'autres paramètres morphométriques. La densité est calculée par la méthode des cartogrammes, par rapport à la longueur du réseau de drainage à la surface (L/A). Il y a un rapport direct entre les valeurs de la densité de la fragmentation du relief et de l'exposition à la désagrégation des roches dans des conditions de l'absence totale de la végétation. Dans le cas des versants qui délimitent le couloir dépressionnaire de Bou Saâda, la fragmentation de ceux-ci est le résultat des organismes d'ordre 1,2 (dans le système Horton-Strahler), favorisés par la structure, les contacts pétrographiques (fig. 11)

L'analyse en détail est effectuée dans la zone d'expansion urbaine (a) et, aussi, dans le centre-ville et les versants limitrophes de celle-ci (b).

a. L'analyse de la carte de la densité de la fragmentation du relief (fig. 11), l'histogramme (fig. 12a) et le cyclogramme (fig. 12b) de cette carte, on constate que la valeur maximale de la fragmentation du relief est enregistrée dans les zones du Nord-Ouest et le Nord de la partie du centre. Dans la zone du *Djebel Gorehor* atteint les valeurs supérieures à 10 km/km², en occupant une surface de 5 km², d'environ 5,60% du territoire analysé. Les valeurs comprises entre 8,1-10 km/km² se remarquent aussi dans le périmètre du Djebel Gorehor, mais, isolés, dans la partie centrale et du sud du territoire analysé sur une surface de 10 km², environ 11,1% de la surface du territoire analysé. Les grandes valeurs de cet indicateur, comprises entre 6,1 et 8 km/km², sont enregistrées dans la partie centrale et du sud du territoire analysé, dans la région de *Djebel Moubakhera*, *Djebel Aouïdja* et *Djebel Kerdada*, en occupant une surface de 16 km², d'environ 17,7% du territoire étudié.

Dans ces zones la profondeur de la fragmentation a des valeurs relativement réduites, les pentes étant accentuées (fig. 11c), en favorisant l'évacuation des matériaux des versants.

Les valeurs moyennes, comprises entre 4,1-6 km/km², étendues sur une surface de 28 km², détiennent la plus grande partie de la surface du territoire, environ 31,1 % de la région étudiée. Les valeurs moins réduites comprises entre 2,1-4 km/km², se remarquent le long de la rivière, dans la zone du sud-est, mais aussi, isolées, dans la partie centrale sud du territoire analysé sur une surface de 19 km², environ 21,1% de la surface du territoire analysé.

La plus réduite valeur de la densité de la fragmentation du relief, inférieur à 2 km/km², occupe une surface de 12 km², ce qui représente environ 13,30% du totale de la surface d'étude et se

trouve en général dans la zone des *dunes* étendues dans le Nord-Est et l'Est de la région.

Sur toute la région, les valeurs de la densité de la fragmentation du relief varient entre 0 et 12,70 km/km^2 , la moyenne pour l'entière région étant 6,35 km/km^2 , valeurs relativement élevées.

Fig. 11. Des cartes morphométriques :

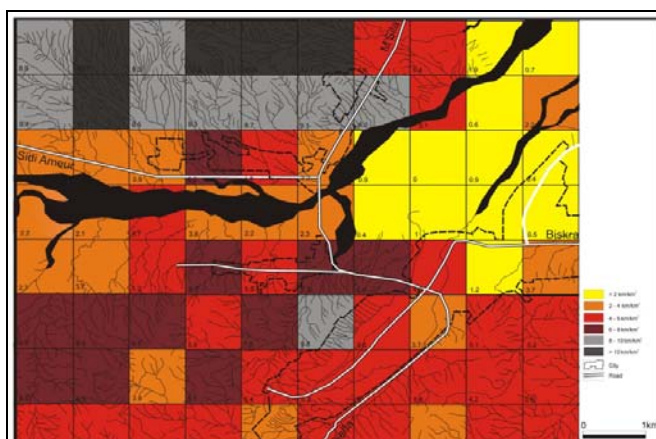


Fig. 11a. La densité de la fragmentation

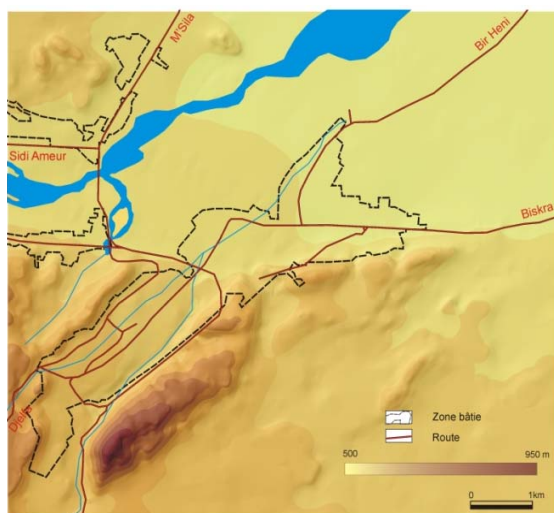


Fig. 11b La carte hypsométrique

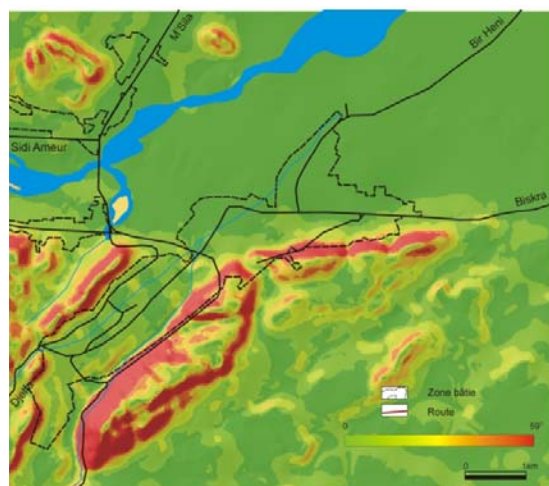


Fig. 11c La carte des pentes

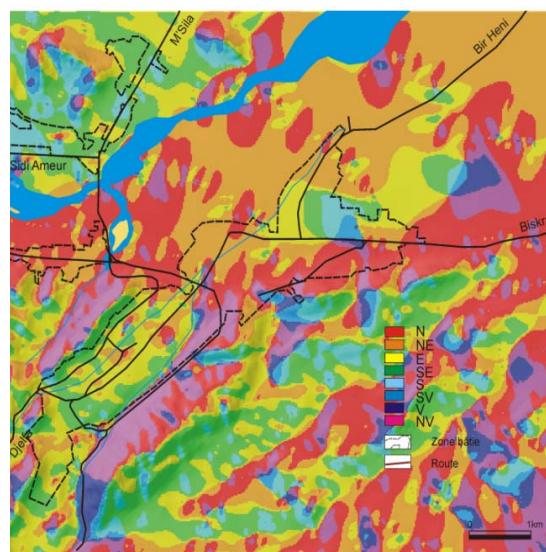


Fig. 11d. Exposition des versants

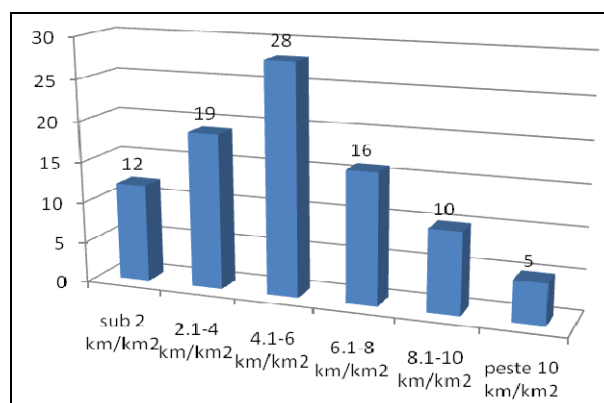


Fig. 12a. Valeurs absolues sur classes des valeurs de la densité de la fragmentation du relief dans la zone d'expansion de la ville

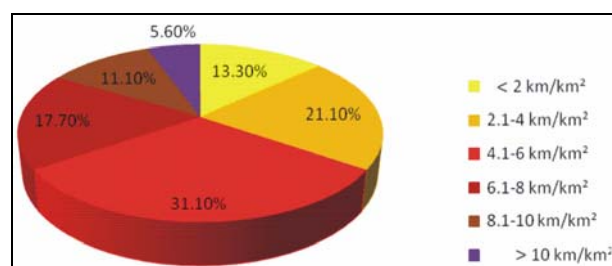


Fig. 12b. Le poids de différentes classes de valeurs de la densité de fragmentation du relief dans la zone d'expansion de la ville

b. En analysant la densité de la fragmentation du relief dans le périmètre de la localité de *Bou Saâda* et tout près de celle-ci, on observe que les valeurs les plus élevées comprises entre 8,1-10 km/km^2 sont enregistrées dans le Sud-Ouest de la surface construite, et en occupe une surface de 1 km^2 , d'environ 4% de la surface de la localité. Les valeurs élevées de la densité de la fragmentation, comprises entre 6,1 et 8 km/km^2 , sont enregistrées dans la partie centrale et en occupe une surface de 3 km^2 , d'environ 12% du territoire pris en étude.

La plus grande partie du territoire, d'environ 48 % de la région étudiée, est détenue par les surfaces dont la densité de la fragmentation est comprises entre 4,1-6 km/km², celles-ci en occupent une surface de 12 km². Les valeurs comprises entre 2,1-4 km/km², se remarquent le long de la vallée de la rivière, dans la partie du Sud et, isolé, dans la partie centrale du territoire étudié, sur une surface de 5 km², d'environ 20 % de la région étudiée. Les valeurs les plus basses de la densité de la fragmentation du relief, inférieures à 2 km/km², en occupent une surface de 4 km², ce qui représentent environ 16% du total de la surface prise en étude et se trouve en général dans la zone des *dunes* étendues dans le Nord-Est de la région. Les valeurs de la densité de la fragmentation du relief varient entre 0,4 et 9,60 km/km², la moyenne pour l'entière région étant de 5 km/km².

La corrélation entre les valeurs de la densité et de la profondeur de la fragmentation du relief est une corrélation inverse, à l'exception des rivières, les organismes torrentielles sur les versants avec une grande densité, qui ne présentent pas des profondeurs considérable. Leur tendance vers la profondeur est évidente, en particulier vers la base du versant.

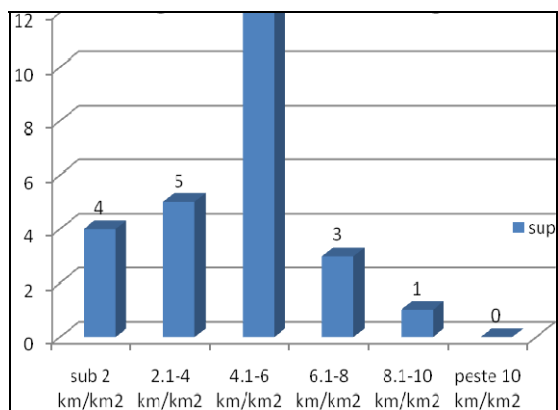


Fig.13a Valeurs absolues sur classes des valeurs de la densité de la fragmentation du relief dans le périmètre de la localité de Bou Saâda et tout près de celle-ci

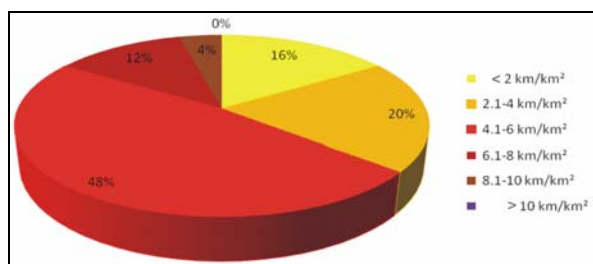


Fig.13b Le poids de différentes classes de valeurs de la densité de fragmentation du relief dans le périmètre de la localité de Bou Saâda et tout près de celle-ci

En faisant la comparaison des deux régions, on constate:

- les valeurs de 4.1- 6 km/km² ont le plus grand poids (48%) dans le centre-ville, comparativement à 31% dans l'extérieur ;
- les valeurs réduites inférieures à 4.1 km/km² sont légèrement élevées (36%) dans le centre-ville que dans l'extérieur de celui-ci (34%) ;
- les valeurs les plus élevées, supérieures à 6 km/km², ont un poids diminué (16%) dans le centre-ville, comparativement à l'extérieur de la ville (36%) ;
- il en résulte que le premier noyau de la ville a eu une position favorable du point de vue de la dynamique du relief; pour l'expansion du territoire de la ville, la morphométrie peut avoir un caractère restrictif.

4.2. Aléas géomorphologiques

La ville est exposée aux trois principaux aléas :

- Le risque d'ensablement est particulièrement sensible pour les extensions du côté ouest; les effets ne se feront pas sentir forcément en terme de recouvrement direct par des matières solides; mais la proximité de zones importante d'accumulation de sable et l'existence de vent violent auront un effet certain sur la qualité de vie des ménages.
- Les flancs de montagne ne sont pas aménagés ce qui induit des risques d'éboulement sur le bâti et la route, non protégés comme on peut le constater (fig. 14);
- Les risques d'écoulement d'eau, les régimes pluviométriques étant ceux du climat semi aride: pluies irrégulières mais torrentielles
- Aléa d'inondation a cause des pluies torrentielles.



Fig.14. Aléa de chute de blocs, de pierres.

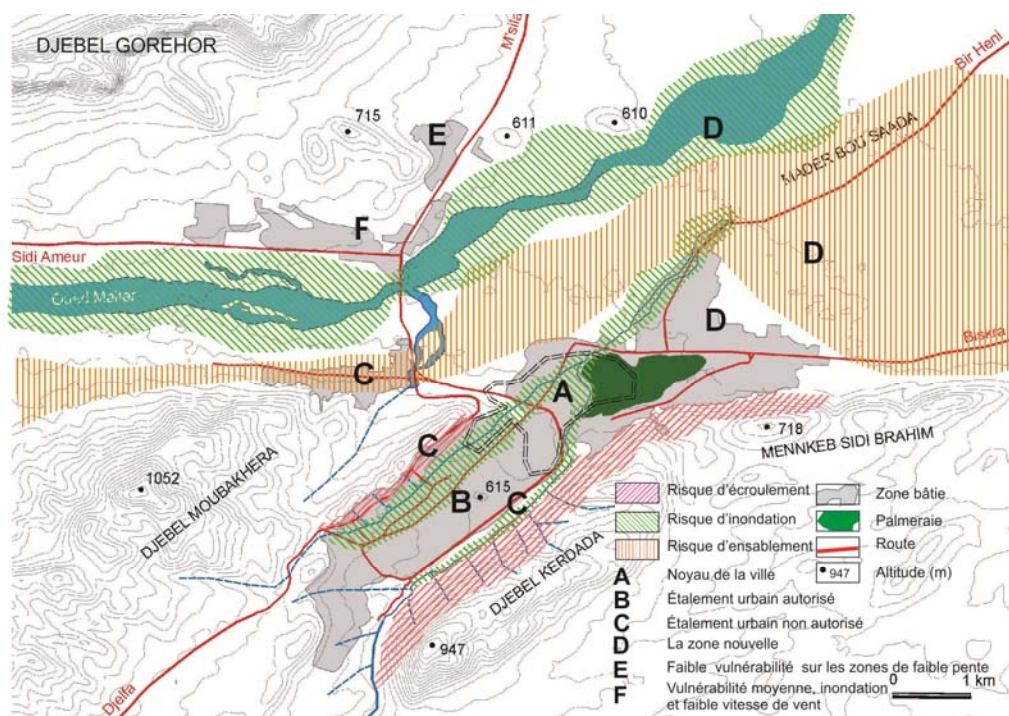


Fig. 15. La carte des vulnérabilité a aleas geomorphologiques

4.3. La carte de vulnérabilité a aleas geomorphologiques (fig. 15)

La vulnérabilité est la conséquence de l'impact de l'aléa sur les enjeux.

Nous décrivons ci-après les principales zones et qualité de vulnérabilité :

- Vulnérabilité importante des accumulations de sable (en dunes) dans le couloir de l'oued Maïter situé entre Gorehore (N) et Moubakhera (S)
- zone illicite de constructions non autorisées à la base du versant du Mont Moubakhera
- Vulnérabilité importante d'écroulement et chute de blocs de pierres au contact de la dépression avec les versants montagneux (le Mont Moubakhera et le Mont Kerdada)
- zone illicite de constructions non autorisées
- Vulnérabilité importante aux inondations le long des torrents qui drainent la dépression
- écoulement sur le versant
- risque à l'érosion hydrique à la surface déterminée par les caractéristiques géomorphologiques (des pentes grandes, défrichement, grande fragmentation)

Vulnérabilité moyenne aux inondations et accumulations éoliennes de sable (dunes) dans le lit de l'oued Maïter.

- Vulnérabilité faible sur le pédiment faiblement incliné à l'est des Monts Gorehore sur la route Bou Saada – M'sila.
- Vulnérabilité moyenne aux inondations et réduite aux processus éoliens sur le sable au Nord-ouest de la localité de Bou Saada, dans la zone d'expansion autorisée (zone résidentielle et industrielle).

5. Conclusions

Les types d'aléas naturels présents dans l'espace urbain de Boussaada, résultent du contexte géographique et climatologique dans cette partie du globe (climat semi-aride). Les caractéristiques physiques locales, associées aux agents d'érosion favorisent l'exposition du tissu urbain aux aléas, qui peuvent être combinés.

Les principaux facteurs qui déterminent l'exposition des enjeux aux aléas géomorphologiques (géologiques, géomorphologiques, climatiques, technologiques) (incohérent) mettent en évidence l'essor peu contrôlé du tissu urbain contemporain. Cela se matérialise par un développement classique déjà constaté; un centre urbain dense ancien, éloigné des zones les plus exposées et des extensions urbaines concentriques dans le secteur où les aléas sont les plus forts.

Les facteurs restrictifs de l'extension spatiale de la cité sont les caractéristiques morphométriques et morphodynamiques du relief, autant que la direction, la fréquence et l'intensité du vent. Dans le cas de la ville Boussaada, les autres éléments (flou) n'ont pas un rôle majeur dans sa dynamique spatiale, parce que ces derniers n'ont que peu d'impact dans le territoire.

Pour établir les classes qualitatives des enjeux face aux aléas géomorphologiques, comme pour élaborer la carte de la vulnérabilité qui en découle,

la recherche sur le terrain ainsi que la cartographie des aléas sont prioritaires.

Remerciements. Des recherches ont été effectuées dans le cadre de « Projet de recherche développement entre les universités de M'Sila, Bucarest et Paris Est/Paris12 » : « Carte des vulnérabilités en milieu oasien ; cas de l'oasis de Bou-Saada » 2008-2009.

BIBLIOGRAPHIE

- ABDELLAOUI A., VIȘAN L., PĂTRU-STUPARIU I., (2010), *Etude de la viabilité du paysage par analyse de grille dans la région sous carpatique de la vallée de la prahova (Roumanie)* ; Revista de Géomorphologie ; vol. 12 – 2010, pp. 81-90.
- BALLAIS J.-L., MARRE A., ROGNON P., (1979), *Périodes arides du Quaternaire récent et déplacement des sables éoliens dans les Zibans (Algérie)*, Rev de Geol. Dyn et Geogr. Phys., vol. 21, fasc. 2, pp. 97-108.
- BENAZZOUC M.T., (1994), *Etude des interactions relief migrations éoliennes de sable dans la région de M'doukal, Algérie. Méditerranée*, Revue Géographique des Pays Méditerranéens. Trimestriel Tome 80, 3.4 1994, pp. 51-58.
- DUBOIS-MAURY JOSELYNE, CHALINE CLAUDE, (2002), *Les risques urbains*, A.Colin, Paris, 208 p.
- GRECU FLORINA, (2009 a), *Hazarde și riscuri naturale*, ediția IV, Ed. Universitară, București, 302 p.
- GRECU FLORINA, (2009 b), *Asupra notiunii de hazard natural urban*, Comunicari de Geografie, Edit. Universitatii din Bucuresti, pp. 7-11, 5 fig.
- HADJAB MAKHLOUFI, OUALI DEHMI, (2007), *La salinisation des sols dans la cuvette centrale du Hodna (Algérie)*, Analele Universitatii Bucuresti, Geografie, anul LVI, pp. 35-46.
- HADJAB MAKHLOUFI, (2012), *L'urbanisation d'une ville oasienne « Boussaâda ».Face aux risques d'inondations et d'ensablement*. Analele Universitatii Bucuresti, Geografie, anul LXI, in press.
- HORTON R.E., (1945), Erosional development of stream and their drainage basins: hydrophysical approach to quantitative morphology, *Bull. Geol. Soc. Am.*, **56**.
- MOSTEPHAOUI T. a DIF A. b, (2009), *Methodology Of Cartography Of The Stranding By The Use Of The Télédétection "Case Of The Area Of Boussaâda- Algeria"*, Tunis.
- PIGEON PATRIK (sous la direction), (2002), *Approches géographiques des risques „naturels"*, Annales de Géographie, N°627- 628, A.Colin ; *Réflexion sur les notions et les méthodes en géographie des risques dits naturels*, pp. 452-470.
- *** (1963), Carte géologique de L'Afrique, 1 : 5 000 000, Association de Services Géologiques Africains, Paris.
- *** (1994), *Croissance urbaine et risques naturels dans les montagnes des pays en développement*, Revue de Géographie Alpine, N°4, Tome LXXXII, 192 p.
- *** Carte tectonique de L'Europe, 1:2 500 000, Feuille 14, Congrès Géologique International Commission de la Carte Géologique du Monde, Sous - Commission de la Carte Tectonique du Monde.
- *** Carte topographique, Feuille Bou Saâda, 1 : 50 000, Projection Lambert, Nord Algérie.
- *** UNCCD., *Convention des Nations Unies sur la lutte contre la désertification dans les pays gravement touchés par la sécheresse et ou la désertification, en Afrique*, texte avec les annexes, pp. 5-78.

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Miscellanea

15-th Joint Geomorphological Meeting (Italy-Romania-Belgium-France-Greece)

Fluvial and coastal system in tectonic active areas

Athens, Greece, June 1-5, 2011

The 15-th Joint Geomorphological Meeting, organized by the Faculty of Geology and Environment, of the National & Kapodistrian University of Athens, under the direct supervision of Dr. Niki Evelpidou, had as theme „Fluvial and coastal system in tectonic active areas”, an apparent limited theme in the sense of the approach possibilities, but which, through the subjects addressed in the presentations, proved to have a large area, while fluvial and coastal geomorphology of tectonic active areas is at present source for various debates. The theme has lent itself very well to field application, which developed over two days in the Quaternary sediment basins comprised in an Alpine orogene system.

The symposium had an international character, in the sense that along representatives of the organizing countries, important participants also came from the international scientific world with interests in the subject mentioned above. The best examples are provided by the key-note speakers:

Chen Z., *Holocene megadeltas of China: Formation and Neolithics*;

Pirazzoli P., *Holocene sea-level changes and tectonic movements in the eastern mediterranean*;

Stanley J.D., *Subsidence of Magna Graecia port facilitates along Calabria's coastal margins, Italy: interaction of multiple natural factors*.

The field application having as subject *Fluvial processes versus tectonic control in the Sperchios River valley*, during June, 3rd and 4th, effectively demonstrated the direct relation which exists between tectonics and relief genesis, comprising detailed explanations about some features or

phenomena in various points: the Arkitsa Fault, the Thermopylae fault and the morphology of the ancient pass; the Sperchios river delta evolution; Lamia city and archeological museum; human occupation in Sperchios river basin; the paleogeographical changes of the north margins of the Sperchios basin; fluvial processes on the footwall of the Sperchios fault etc.

The symposium excelled through:

- the interdisciplinary character of approaches in researching landforms involving: tectonics, sedimentology, geomorphology, geoarcheology, hidrogeology;

- the field application with well chosen points, in agreement with the theme and the effect of the tectono-geomorphic and geoarcheological evolution;

- the cultural – historical aspect in the knowledge of some significant points not only for Greece, but also for the history of culture and civilization worldwide.

We thank our colleagues for the organization and for assuring the scientific level of the symposium: Niki Evelpidou (University of Athens), Konstantinos Vouvadilis (University of Thessaloniki), Aliko Livaditi – Alezouli (University of Athens), Kosmas Pavlopoulos (Harokopion University of Athens), Leonidas Stamatopoulos (University of Patras).

Concluding, the symposium excelled through the high scientific level of the presentations, the field explanations and the excellent organization, while Greece is a book in which geology, historic geomorphology, culture and geoarcheology form a whole which imposes scientific knowledge.



Prof. univ. dr. Florina GRECU

7th SEDIBUD Workshop and Summer School 2012

Trondheim, Loen (Nordfjord), Norvegia

10 – 17 September 2012

Grouped under the generic name of 7th SEDIBUD Workshop - *Towards an integrated analysis of environmental drivers and rates of contemporary solute and sedimentary fluxes in changing cold climate environments - From coordinated field data generation to integration and modeling* - and SEDIBUD Summer School for Doctoral Students *Quantitative analysis of geomorphologic processes: Field methods, experimental techniques and modeling*, scientific manifestations of the 7th SEDIBUD (Sediment Budgets in Cold Environments) Workshop were organized by the International Association of Geomorphologists (IAG), Working Group on Sediment Budgets in Cold Environments (SEDIBUD) and Geological Survey of Norway (NGU) in Trondheim and Loen (Nordfjord), Norway, from 10 to 17 September 2012.

The 30 participants came from 10 countries, their works being published in the first issue of the volume “Abstract and Proceeding of the Geological Society of Norway”. The topics covered a wide range of aspects dedicated to alpine, Subarctic, Arctic or Antarctic areas: slope processes evolution from Holocene to the present, debris flows, avalanches, mass displacement, the dynamics of glaciers, permafrost, fluvial processes, fluvial transportation, sedimentation, channel development, slope - channel coupling, slope sedimentary budgets, landscape development. Among those who held presentations there were A. Beylich, Armelle Decaulne, C. Le Coeur, J. Dixon, Z. Zwoliński, A. Nesje.

Summer School applications were held in Loen region along the Nordfjord. Various locations were visited, measurements and observations being conducted in the area of Erdalen and Bodalen glacial drainage basins up to the present base of Jostedalsgreen glacier. Numerous local aspects were observed, especially those related to ongoing glacier retreat in recent decades. Among the theoretical and practical methodologies presented by Armelle Decaulne were the dendro-geomorphological ones, especially those that can be used for various studies on avalanches.

An important focus point of the application was the place where the greatest natural tragedy in the history of Norway occurred; in 1936, in Bodal locality, blocks collapsed from a slope, from more than 1000 m. The blocks fell into a glacial lake from the end of a fjord, the wave formed burying the nearby villages and killing 74 people.

The event, through the variety of cold areas approaches, was a good opportunity for promoting the awareness on extreme processes in Scandinavian areas, but also in the world, for detailing some of those typical for certain mountain areas, representing an exchange of experience for the participants.

This work was supported by the strategic grant POSDRU /89/1.5/S/ 58852, Project Program for postdoctoral researchers in science education, co-financed by the European Social Fund within the Sectoral Operational Program Human Resources' Development 2007–2013”.





Dr. Anca MUNTEANU

16th Joint Geomorphological Meeting (Italy, Romania, Belgium, France, Greece),
Morphoevolution in tectonical active belts,
Rome, Italy and Central Appenine Mountains, 1-5 July 2012

The Joint Geomorphological Meeting became a tradition in the IAG events'calendar. This year the Italian group of geomorphologists by the AIGeo (Associazione Italiana di Geografia fisica e Geomorfologia) organized at Rome an interesting scientific event, focused on the morphological evolution in tectonical active mountain belts. As usual, the conference was sustained by the collaboration between the geomorphological groups and associations from Italy, Romania, France, Greece and Belgium.

This informal event was organized at the Earth Science Department of University La Sapienza in Rome, in collaboration with The Department of Geological Sciences from University of Roma Tre. Researchers from 11 countries (75 in total) presented their results related on the topic of the conference but also on close research themes like applied and environmental geomorphology.

The International Association of Geomorphology also joined the conference by two vice-presidents, prof. E. Fouache from France and prof. P. Migoń from Poland, together with prof. Morgan De Dapper from Belgium, Secretary General of the IAG and prof. M. Soldati from Italy, executive member of the IAG board.

The aim of the scientific meeting came from the latest dramatic seismic events in the Appenines (2009, 2012), which confirmed the contemporary tectonic evolution of these areas and their active morphodynamics along fault scarps and within basins.

Solicited papers from each of the five countries which initiated the joint meeting were focused on different case studies on the relationship between recent tectonic events and geomorphological evolution: Dating uplift events based on composite metric on fluvial landscapes (A. Demoulin, Belgium), Tectonic control on hillslope processes in The Himalayas (M. Fort, France), Geomorphological evolution of the NW Peloponessus (L. Stamatopoulos, Greece), The age, properties and

morphotectonic meaning of the summit paleosurface in Southern Italy (M. Schiatarella, Italy).

The Romanian Association of Geomorphologists presented a paper entitled River channel morphodynamics at the contact area between Romanian Plain and Curvature Subcarpathian, presented by dr. Gabriela Toroimac and coordinated by professor Florina Grecu, from University of Bucharest, Faculty of Geography.

Poster session was organized with the help of the Paleontological Museum in University La Sapienza and offered a good opportunity of scientific exchange between the participants but mainly between young researcher and experienced researchers.

An important part of the event was the 3 days long field trip. According to the main topic of conference, the Italian colleagues proposed a very interesting excursion covering the some of the representative Pliocene-Quaternary basins from the Central Appenine Mountains. These are an expression of the recent tectonic evolution which can be proved by the morphodynamic features and also by archaeological and historical evidences along the active fault scarp systems. Beyond shore reconstruction issues and the fault around Rieti Depression, the participants visited the area affected by the severe earthquake around L' Aquila basin. The second day focused on recent active faults and stream network evolution along Middle Alterno River Valley and Subequana Basin, in the context of a spectacular morphological inversion. In Sulmona basin, representative slope morphodinamics on active fault scarps were discussed during a hot summer afternoon with the professional references from Italian young colleagues. Third day of the trip focused on the Cassino tectonic depression, where active faults cut the landscapes to the border with the mountain steep slopes.

The Romanian Association of Geomorphologists was represented by professor Florina Grecu and an important number of researchers (14) coming from

the universities of Bucharest, Iași and Craiova. They presented an important number of posters focused on the topic of the conference and on closer subjects like geomorphosites, geomorphological mapping and GIS analysis of natural hazards.

The Joint Geomorphological Session was another good occasion for meeting geomorphologists with a strong interest in connecting geological research with geomorphological research. The next similar event is proposed by the Belgian Group of Geomorphologists, in 2014, after the

Geomorphological Congress to be held in Paris, France (August, 2013).

It was a meeting where high quality scientific expertise, friendship and Italian hospitality joined in a hot summer season days in the heart of the Appennines, probably one of the youngest mountain belts of Europe. This was because of the excellent organisation, coordinated by professor Paola Fredi and collaborators, dr. Marta della Seta and dr. Giandomenico Fubelli.

Prof. dr. Bogdan MIHAI
University of Bucharest, Faculty of Geography

The 38th National Geomorphology Symposium

Baru Mare, June 14-17, 2012

The 38th edition of the National Geomorphology Symposium was organized at Baru Mare by the Romanian Association of Geomorphologists (RAG) in partnership with the West University of Timișoara and the "Babeș-Bolyai" University in Cluj-Napoca. The opening ceremony was officiated by Professor dr. Petru Urdea (RAG President), Professor dr. Virgil Surdeanu (Head of the university branch at Baru Mare) and Professor Dănuț Petrea (Dean of the Faculty of Geography within the "Babeș-Bolyai" University).

The plenary session was opened by Professor dr. Grigore Posea, who made a short account of the results of his research, which will be published in the work titled "Landforms, the basic resource for tourism. Geomorphodiversity and geomorphosites". Subsequently, other contributors presented papers that dealt with river channel dynamics and

evolution under the influence of climatic variability and human interventions, with the evolution of the Black Sea coast and the oscillations of the sea level during the Holocene, as well as with the assessment of landslide hazards.

The 41 presentations were delivered within the following sections: GIS and geomorphometry, slope processes, geomorphology of coastal and lowland areas.

The field trip was carried out along the route Western Jiu valley – Soarbele valley, where the participants had the opportunity to observe the tectono-structural, glacial and periglacial topography.

The large number of young participants (master students, Ph.D. students, assistant researchers) and the high scientific level of the presentations' content, relying on the new geomorphological techniques, are a clear evidence of the continuity of geomorphological research on the national level.



Dr. Cristina GHIȚĂ

The XXVIIth National Symposium on Geomorphology

Craiova, May 19-21, 2011

Al XXVII-lea Simozion Național de Geomorfologie

Craiova, 19-21 mai 2011

In the spring of 2011, the Geography Department of the University of Craiova hosted the traditional symposium of Romanian geomorphologists for the first time. This edition of the National Symposium of Geomorphology was organized by the Association of Geomorphologists from Romania, Geography Department of the University of Craiova and the Institute of Geography of the Romanian Academy.

The works of the symposiums began with the lecture of Prof. dr. Virgil Surdeanu, president of the Association of Geomorphologists from Romania, followed by Prof. Wolfram Mauser (Geography Department from *Ludwig-Maximilians* University of Munich) who presented the GLOWA Project – Danube – The impact of climate change on the upper Danube, and Prof. dr. Emil Vespremeanu (University of Bucharest), synthesizing the IGU Regional Conference of Geomorphology held at Addis Abeba.

The Symposium included six sessions; the first one, associated with plenary lecturers, included presentations on fundamental

geomorphology. In the afternoon, there were parallel sessions, dealing with *Denudation relief* (Second Session), *Present geomorphological processes and human activities* (Third Session), *Costal Geomorphology and mass movements* (Fourth Session), *Problems within the mountainous area* (Fifth Session) and *Poster Presentations* (Sixth Session).

The trip field took place along the left slope of the Jiu Valley, targeting the terraces and the flood plain, where Craiova is situated, following the right slope, in order to study the landslide at Breasta and the homonymous torrential valley.

The National Symposium of Geomorphology gathered geomorphologists from all universities in the country and invited a prestigious German geographer. The attendees tackled various present and future issues for the geomorphological research in Romania.

Hoping that the Oltenia land and spirit were a source of energy for the well-known geomorphologists, as well as for the apprentices, the organizers wish to thank all the participants.



Conf. dr. Sandu BOENGIU

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