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Cover photo: *landslide at Drănic, Dolj county, Romania (photo Vîlcea Cristiana)*

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ISSN 1583-1523 (print)
ISSN 2067-4635 (online)
DOI prefix: 10.5775

Forum Geografic - Studii și cercetări de geografie și protecția mediului
(Geographical Phorum – Geographical Studies and Environment Protection Research)
www.forumgeografic.ro DOI: 10.5775/fg

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Floodplains – Links between Countries and Landscapes

Dénes LÓCZY[1]

[1]University of Pécs, Faculty of Sciences, Institute of Environmental Sciences, Ifjusag utja 6, H-7624 Pecs, Hungary, e-mail: loczyd@gamma.ttk.pte.hu

Received on <December 13, 2010>, revised on <February 14, 2011>, accepted on <March 15, 2011>

Abstract

The primary function of floodplains remains to be to ensure the safe passage of flood waves. As flood control problems are serious along some river sections, this also requires international cooperation. In landscape ecology, floodplains perform two related functions: they are riparian buffer zones (vital for maintaining river water quality) on the one hand and ecological corridors (ensuring connectivity and high biodiversity) on the other. Floodplain wetlands play an important part of the ecological integrity of riverine ecosystems as they fundamentally influence the ecological status of adjacent water bodies. It is all the more important since along most of its length the Danube crosses densely inhabited areas with intensive agriculture, large-scale industries and well-developed communication networks. Consequently, environmental pressure on the active and protected floodplains is of considerable extent and sharp conflicts arise between different land use types. Land use types promoting the fulfilment of the riparian buffer zone function must have priority. Unfortunately, only restricted sections of the Danubian floodplain are retained in seminatural conditions. In the Danube catchment 80% of the former wetlands are now disconnected and cannot fulfil their nature conservation role. The national NATURA 2000 networks are so much dependent on seminatural riparian ecosystems that they cannot be efficient without floodplain restoration measures. Predictable climate change tendencies (increasing drought liability) are also a threat to the survival of floodplains as ecological corridors. Remediation efforts are necessary along extensive floodplain sections and better connectivity is identified as an important target. According to the Danube River Basin District Management Plan (ICPDR 2009, p. 76):"The ICPDR's basin-wide vision is that floodplains/wetlands in the entire DRBD are re-connected and restored. The integrated function of these riverine systems ensures the development of self-sustaining aquatic populations, flood protection and reduction of pollution in the DRBD."

Keywords: *floodplain, flood hazard, riparian corridor, Danube.*

Rezumat. Luncile – legături între ţări şi peisaje

Funcția primară a luncilor rămâne aceea de a asigura trecerea în condiții de siguranţă a undelor de viitură. Deoarece problemele legate de controlul inundațiilor sunt grave de-a lungul unor sectoare de râuri, acest fapt necesită de asemenea cooperare internaţională. În ecologia peisajului, luncile îndeplinesc două funcţii care sunt relaționate: acestea sunt zone tampon riverane (vitale pentru menţinerea calităţii apei râurilor), pe de o parte, şi coridoare ecologice (asigurând conectivitate şi o mare biodiversitate), pe de altă parte. Zonele umede ale luncilor joacă un rol important în integritatea ecologică a ecosistemelor fluviale deoarece acestea influenţează fundamental starea ecologică a corpurilor de apă adiacente. Este cu atât mai important deoarece pe întreaga lungime a Dunării, aceasta străbate zone dens locuite cu agricultură intensivă, industrii pe scară largă şi reţele de comunicare bine dezvoltate. Prin urmare, presiunea mediului asupra luncilor active şi protejate este de proporţii considerabile şi apar neconcordanțe mari între diferite tipuri de utilizare a terenurilor. Tipurile de utilizare a terenurilor care promovează îndeplinirea funcţiei de zonă tampon riverană, trebuie să aibă prioritate. Din păcate, doar sectoare restrânse ale luncii Dunării sunt păstrate în condiţii seminaturale. În bazinul Dunării 80% din fostele zone umede sunt acum deconectate şi nu îşi pot îndeplini rolul de conservare a naturii. Reţelele naţionale NATURA 2000 sunt atât de dependente de ecosistemele riverane seminaturale, încât nu pot fi eficiente fără măsuri de restaurare a luncii. Tendinţele de schimbare climatică previzibile (creşterea riscului la secetă) sunt de asemenea o ameninţare pentru supravieţuirea luncilor ca şi coridoare ecologice. Eforturile de remediere sunt necesare de-a lungul sectoarelor extinse de luncă şi o conectivitate mai bună a fost identificată ca un scop important. Conform Planului de management al Bazinului Fluviului Dunărea (ICPDR 2009, p.76): „Viziunea la nivel de bazin a ICPDR este că luncile/zonele umede din întregul Bazin Fluvial al Dunării sunt re-conectate şi restaurate. Funcţia integrată a acestor sisteme fluviale asigură dezvoltarea populației acvatice care se auto-susţine, protecţia împotriva inundațiilor şi reducerea poluării în Bazinul Fluvial al Dunării ”.

Cuvinte-cheie: *luncă, risc la inundaţii, coridor riveran, Dunărea*.

INTRODUCTION

Floodplains are major binding elements between landscapes of mountainous, hilly or lowland character ensuring the flow of water, sediment and nutrients between them. Floodplains can be investigated from diverse aspects. It is common that the starting point is a geomorphologic one and the objective is to reveal landform assemblages, the origin and age of individual landforms, or the rate of floodplain sedimentation. Particular importance is attributed to hydrological studies which are directed to the energy of flood flows, flood hazard or opportunities for water storage in floodplains. Research from landscape ecological viewpoint is inseparable from riparian vegetation mapping, plant/animal community and habitat surveys as well as from the estimation of communities for nature conservation. For the human utilization of protected floodplains, the potentials for agriculture, forestry, construction, tourism and game management have to be evaluated. Finally, landscape ecological assessments are also concerned with the nature and degree of floodplain restoration and its conditions and tasks.

Why do floodplains deserve particular attention in landscape ecology? In the eastern half of Europe large-scale farming, the spreading of monoculture have deteriorated the ecological structure of the landscape. Landscapes have been impoverished in landscape elements, which are indispensable in ensuring connectivity. In addition to their nature conservation values, the significance of riparian zones, wetlands and forests, parts of the ecological network (Jedicke, 1994), is growing. (In this respect, not only the floodplains of major rivers but those along smaller water-courses can be valuable.)

For the human society, floodplains are important arteries of communication between countries. Focusing on the main hydrological axis of the Carpathian Basin, it can be claimed that the Danube River still has a great potential as an international navigation route (WWF 2002) and, similarly, its floodplain is not yet exploited properly for transportation purposes (VITUKI 2007). Although even in Roman times the limes, the eastern boundary of the Empire ran along the right bank of the Danube over at least 700 km from Vindobona (today's Vienna) to Singidunum (Belgrade) (Visy, 1989), the wide swampy floodplain was essentially a no man's land, a hardly passable natural defense zone between the civilized and the "barbarian" world. The limes road was built parallel with the Danube along the margin of the floodplain, only exceptionally at a distance more than 3 km from the contemporary active channel. On the huge alluvial fan the active channels of the dynamic anastomosing system alternated and shifted position rapidly. In medieval times a characteristic floodplain economy developed. Besides fishery, it involved forestry, orchards, grazing and gathering – human activities which were based on the close interaction between the river and its floodplain. The end of the 18th century and the beginning of the 19th saw the first planned regulation measures (Table 1).

Table 1

Medium-water regulation efforts along the Danube (by Lóczy, based on UNESCO 1999)

Section	Period of main activities	Reduction of river length (%)	Measures
Upper Danube in Baden- Württemberg	1820–1890	-73	channel straightening, cut-offs, flood-control dykes, bank stabilization
in Bavaria	1826–1867	-15	channel straightening, cut-offs, flood-control dykes, bank stabilization, channel deepening by dredging and explosions
in Austria	1850–1914	ca. -15	by-channel closures, bank stabilization, flood-control dykes, training walls
Middle Danube in Hungary	1871–1914	-18	flood-control dykes, by-channel closures, cut-offs, bank stabilization, groynes, confluence relocations, protecting walls along urban sections
in Serbia	1894–1977	ca. -10	flood-control dykes, bank stabilization, groynes
Lower Danube in Romania/Bulgaria	no regulation	-	only dredging and some bank stabilization, flood-control dykes
Danube Delta (Sulina branch)	1860–1901	-30	straightening, dredging, longitudinal structures, canal building

Flow regulation measures disrupted this connection but, at the same time, opened the opportunities for navigation along the Danube and the intensive agricultural utilization of floodplains

  DOI: 10.5775/fg.2067-4635.2011.001.i

protected from floods. Explained by a range of political and economic reasons, at the dawn of the industrial age railways and major roads were not built on the Danubian floodplains. This proved to be partly an advantage in the 20th century, when the new concept of nature conservation could primarily rely on the narrow belts of forests on the active floodplain constrained between flood-control dykes.

The significant changes in the political systems of the countries of the Danubian region and their accession to the European Union opened up new opportunities for the joint exploitation of the active and protected floodplains. The elaboration of a long-term strategy for the development of the Danubian region, which is also expected to underline the significance of floodplains, is under way.

DIRECTIONS IN FLOODPLAIN STUDIES

Scientific studies of floodplains are conducted from a range of starting-points (Lóczy et al., 2011) and the term floodplain is used in different senses. Hydrologically, a floodplain means the active floodplain only or the floodway: the strip of land along the river where inundation can be expected with some probability. The geomorphological or genetic floodplain has a much wider extension: it covers the whole area where a typical landform assemblage (including point bars, natural levees, abandoned channels, backswamps etc.) is found. The mapping of floodplain morphology (Kis and Lóczy, 1985) supports the identification of locations in the floodplain with the greatest inundation hazard. The geological floodplain is delimited by the occurrence of fluvial deposits on both sides of the river, while in a pedological approach the presence of fluvisols indicates the floodplain. Since in physical geographical analyses Geographical Information Systems are an increasingly commonly applied tool, it is worthwhile to propose a topographic floodplain definition: a floodplain is a flat surface identifiable by an automated procedure taking advantage of the parameters of curvature and altitude (Lóczy et al., 2011).

In publications on landscape ecology, the term riparian zone often replaces the floodplain. This strip of land is usually much narrower than the genetic floodplain but fulfils buffer and corridor functions (Bohl, 1986). In the identification of wetlands hydrophilous vegetation, hydromorphic soils and characteristic soil conditions are equally regarded major criteria (Environmental Laboratory 1987). In many countries, increasing attention is devoted to the legal definition of floodplains. In Hungary Government Decree 21/2006 mentions the floodplain of design flood (i.e. the 100-year flood) as"high-water channel" and regulates building and other human activities within its limits. However, even hydrologists are in problem when they have to deal with a design flood (Hankó et al., 2003).

Since physical and social influences have been combined to shape floodplains, a holistic view (embracing both the active and the protected floodplain) seems most appropriate in their study.

FLOOD HAZARD

The primary problem of floodplains worldwide is flood hazard, i.e. their primary function is to allow the safe passage of flood waves. This had been often emphasized for large rivers but in recent decades a re-assessment of flood hazard became necessary (Lóczy, 2010). The traditional explanation of floods in the Danube system has to be modified. Probably as a corollary of climate change, the flow regime of the Danube and its tributaries are changing: the threat from ice-jam floods is decreasing, while the probability of floods from winter rainfall is increasing, the beginning of snowmelt is shifting to later dates and often coincides with spring rainfall periods.

Another sign of the changing assessment of flood hazard is the increasing attention devoted to floods of smaller watercourses induced by local cloudbursts. In recent decades inundations along small rivers (like the Zagyva, Bódva, and Kapos in Hungary) or even along minor streams caused considerable damage. In small hilly catchments with steep slopes the collection of unsaturated runoff may raise water levels in streams extremely rapidly and such flash floods sweep through the narrow floodplains along channelized beds of low flood conductivity (Czigány et al., 2010). As a recent example the flood of the Tolcsva Stream (Tokaj-Eperjes Mountains, NE-Hungary) can be mentioned. On May 7, 2010, a hailstorm of 120 mm per day intensity flooded the stream, which inundated the village of Komlóska. (For further examples see Czigány et al., 2010; Lóczy, 2010.)

With remarkable efforts flood waves are usually retained within the confines of dykes but the prolonged high water of rivers causes excess water inundations over extensive areas of agricultural land. For instance, on June 7, 2010, the Hungarian Ministry of Environment and Water Management announced that – as a consequence of monthly precipitation above 300 mm in May – 167 000 hectares of land were covered with water. The entire area could not be drained since then. The conclusion to be drawn from such weather extremes is that land use priorities have to be reconsidered by authorities. In the previously waterlogged floodplains crop cultivation and pasturing lands should be restricted, while in the vicinity of settlements building permits have to be issued with utmost care to prevent later damage to houses.

FLOODPLAIN PATTERN AND BIODIVERSITY

Floodplains are important structural elements of catchments. The connections are equally manifested in a longitudinal (between river reaches or between tributaries and the trunk river), horizontal (slopes-floodplain-channel) as well as vertical sense (channel-groundwater) (Ward, 1997). As buffer zones floodplains reduce the flow of natural or anthropogenic pollutants from the catchment towards the channel. The landscape pattern of floodplains is generally controlled by the geomorphologic conditions (landform assemblages) and the variations in habitat due to water availability and soil formation, while it is often transformed by human intervention (first of all, flow regulation interrupting the communication between the active and protected floodplain zones) (Poole, 2002). (River and floodplain restoration aims at re-establishing such connectivity.)

For the longitudinal distribution of aquatic biota, adjusted to changing resources, the River Continuum Concept (Vannote et al., 1980) is applied. Along the upper reaches of a river biodiversity is limited by the minimum range of temperature, lack of light and nutrients. Along the lower reaches bed material is homogeneous, the water is turbid and deficient in oxygen. Consequently, biodiversity is usually highest along the middle reaches, where the conditions for life are optimal from all the mentioned aspects. More emphasis is put on floodplains in the Flood Pulse Concept (Junk et al., 1989), which emphasizes horizontal connectivity. The seasonal floods of more or less regular occurrence provide the riparian zone with water and nutrients, the co-existence of aquatic and terrestrial vegetation and – naturally in function of the geomorphologic pattern – high biodiversity (Hughes, 1997).

At the early stages of succession, allogenic abiotic disturbances (floods, sedimentation) are major factors in the distribution of pioneer vegetation, while subsequently, when the mosaical pattern of the landscape is already stabilized, autogenic biotic factors (such as competition for resources) become predominant (Hughes, 1997). The exceptionally high biodiversity survives even if human intervention makes abiotic conditions (e.g. water availability) unfavourable for the natural vegetation. Research in the Danubian floodplain area of the Szigetköz in NW-Hungary (Szabó, 2004) confirms that only minimum maintenance is necessary to ensure the ecological corridor function of floodplains and, thus, species and landscape diversity. At the same time, this function also has an unfavourable effect: the dispersion of weeds and invasive plants takes place along these corridors.

SIGNIFICANCE AND LAND EVALUATION FOR THE FLOODPLAIN OF THE DANUBE

There are 71 international river basins in Europe, which cover 54% of the total area of the continent. On the average more than 10% of the water used in European countries arrives as river discharge from neighbouring countries and five countries draw 75% of their resources from upstream countries. The drainage basin of the 2860-km-long Danube is of special significance as the river crosses ten countries and it is the most international stream in Europe. To promote its role as a communication line, sustainable navigation plans are being elaborated for the various sections of the Danube. Coordinating efforts in the Danube basin towards the implementation of the European Water Framework Directive (WFD), the International Commission for the Protection of the Danube River (ICPDR) has prepared a survey of the impact of human activities and an economic analysis of water use. The WFD calls for a new appreciation of floodplain functions and new priorities in floodplain management.

Natural resources are difficult to evaluate in monetary terms. In spite of the methodological difficulties, the first attempt has already been made to evaluate water and land resources in the Danubian floodplain (Andreasson-Gren and Groth, 1995). Based primarily on ecosystem productivity and substitutability, the average economic value of the Danube floodplains was estimated at EUR 383 per hectare per year. Since the total floodplain area is about 1.7 million hectares, its value added up to EUR 650 million every year – at the 1990 course. Although some ecologically valuable wetlands may have disappeared in two decades, the value of the remaining areas must have considerably increased since then.

As a matter of fact, this estimation does not include all the potential values of floodplains as links between landscapes and countries.

  DOI: 10.5775/fg.2067-4635.2011.001.i

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 10 – 19
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.003.i

Geohazard Assessment in the Eastern Serbia

Slavoljub DRAGIĆEVIĆ[1], Ivan NOVKOVIĆ[2], Ivana CAREVIĆ[3], Nenad ŽIVKOVIĆ[4], Radislav TOŠIĆ[5]

[1] University of Belgrade, Faculty of Geography, Institute for the Environment and GIS, e-mail: slavoljubdragicevic@eunet.rs
[2] University of Belgrade, Faculty of Geography, Institute for the Environment and GIS, e-mail: novkovic.ivan@gmail.com
[3] University of Belgrade, Faculty of Geography, Institute for Geography, e-mail: carevic.ivana@gmail.com
[4] University of Belgrade, Faculty of Geography, Institute for Geography, e-mail: ocaha@eunet.rs
[5] Faculty of Natural Sciences, Republic of Srpska, e-mail: rtosic@blic.net

Received on <November 8, 2010>, revised on <February 14, 2011>, accepted on <March 31, 2011>

Abstract

The territory of eastern Serbia is characterized by a variety of igneous, sedimentary and metamorphic rocks formed through different paleogeographic developments. As a result of varied natural conditions, the region is vulnerable to various geohazards, such as earthquake, landslide, excessive erosion, flood, rockfall, cave collapse and subsidence. The occurrence of any geohazard depends on the intensity of the process causing it. An assessment of each type of hazard or combination of all hazards is necessary for this region of Serbia which accommodates major power-generation, industrial and mining facilities and has rich mineral resources. Depopulation of eastern Serbia reduces the ability of local communities to invest in the hazard control works. This assessment of the geohazards begins with the reference to the available seismic maps and proceeds with the research in the landslide, potential flood and excessive erosion hazards, then rockfall and rock collapse. Research results suffice to prepare a generalized geohazard map of eastern Serbia showing areas vulnerable to particular natural hazards and to estimate a total area endangered by hazardous processes. The purpose of this work is to locate and classify areas of potential hazards on which future protective actions may be based.

Keywords: *geohazard assessment, vulnerable areas, natural conditions, eastern Serbia*

Rezumat. Evaluarea hazardelor geologice in Serbia de Est

Teritoriul din estul Serbiei este caracterizat de varietatea rocilor magmatice, sedimentare şi metamorfice formate în urma unor evoluţii paleogeografice diferite. Ca urmare a condiţiilor naturale variate, regiunea este vulnerabilă la diferite hazarde geologice, cum ar fi cutremure, alunecări de teren, eroziune excesivă, inundaţii, căderi de pietre, surupări de peşteri şi subsidenţă. Apariţia unui hazard geologic depinde de intensitatea procesului care l-a cauzat. O evaluare a fiecărui tip de hazard sau a tuturor hazardelor este necesară pentru această regiune din Serbia care deține mari generatoare de energie electrică, amenajări industriale şi miniere şi are resurse minerale bogate. Depopularea estului Serbiei reduce capacitatea comunităţilor locale de a investi în lucrări pentru controlul hazardelor. Această evaluare a hazardelor geologice începe cu referirea la hărţile seismice disponibile şi continuă cu cercetarea alunecării de teren, posibile inundaţii şi riscuri de eroziune excesivă, apoi căderi şi prăbuşiri de roci. Cercetarea este suficientă pentru a întocmi o harta a hazardelor geologice generalizate din estul Serbiei indicând zonele vulnerabile la anumite riscuri naturale şi pentru a estima o suprafaţă totală pusă în pericol de hazarde. Scopul acestei lucrări este de a localiza şi de a clasifica zonele cu potențial de risc pe baza cărora se pot implementa acțiuni viitoare de protecție.

Cuvinte-cheie: *evaluarea hazardelor geologice, zone vulnerabile, condiții naturale, Serbia de Est*

INTRODUCTION

The growing intensity and frequency of natural disasters that endanger global population gave rise to international cooperation in this sphere that intensified from 1990 when UN General Assembly proclaimed 1990-2000 period a decade of natural hazard control. To reduce the consequences of the ever greater natural disasters, regional and international efforts were felt necessary. In result, the UN General Assembly passed two Resolutions in late 2003: (A/RES/58/214: International Strategy for Disaster Reduction) and (A/RES/58/214: Natural Disaster and Vulnerability).

Many countries in the region and the world signed the 2005 Hyogo Declaration (International Strategy for Disaster Reduction Program 2005-2015, www.unisdr.org), which inter alia promotes organization of agencies at regional, institutional and national levels for monitoring and acting to reduce the impacts of natural hazards on property and population. Control of natural hazards and disasters are given much consideration in the UN, with the result of numerous projects financed from EU funds (INTERREG III B CADSES NP PROJECT).

Natural hazards on the territory of Serbia are various and vulnerability to them is not uniform but depends on the type of hazard and potential damages. Natural conditions of eastern Serbia are varied and require a complex study of geohazards in the region. Hence, the objective of this paper is to individualize and research geohazard areas and to assess their vulnerability to hazards. Major potential geohazards are earthquake, landslide, rockfall, flood and torrent, excessive or high potential of erosion, cave collapse, all resulting from natural processes that directly or indirectly threaten people, property and terrain itself.

In addition to natural processes, geohazards may result from human activities related to exploitation of mineral resources. In the region of petrologic diversity, numerous surface and subsurface mines of eastern Serbia generate conditions for geohazards. This work will designate zones of human activities in which geohazards may be expected.

This contribution is important for presenting the distribution of geohazards in the selected region as the first step towards the control of natural disasters and prevention of their consequences. Given the conterminous position of the region with Romania and Bulgaria, the research exceeds the national and acquires regional and even international significance.

Geospatial characteristics

Eastern Serbia occupies an area of 17,060 square kilometres, or 17.3% of the Republic of Serbia territory (Table 1). It is bordered by the Danube on Romania in the north, Bulgaria in the east, by the rivers Velika Morava and Juzna Morava in the west, and the Nisava watershed in the south.

Table 1

General characteristics

Study area, P	17060.15 km^2
Perimeter, O	906.82 km
Maximum altitude	2169 m
Minimum altitude	28 m
Mean elevation, N_{mn}	455.5 m
Mean altitudinal difference, D	2141 m
Mean slope of area, J_{mn}	9.06º
Drainage intensity, G	1.3 km/km^2
Mean precipitation amount (1961-1990)	768 mm
Average air temperature (1961-1990)	8.86º C

The entire territory gravitates to the Danube, the lower base of erosion, and major rivers (Velika Morava, Nisava, Timok, Mlava, Pek) are either its primary or secondary tributaries.

METHODOLOGY

A proper assessment of the geohazard vulnerability of eastern Serbia, or of the limitations for land use, must be based on a comprehensive analysis of natural conditions which are the basic factor in producing geohazards on the territory. This was the approach to the work that resulted in the Potential Geohazard Map with designated geohazard zones. The map is particularly important for the fact that previous studies of natural hazards on the European and world scale were without relevant information about the territory of Serbia.

This work focuses on scientific knowledge and achievements in recognition and prediction of geohazards, preventive action and adequate protection of people, property and environment.

The description of geology is based on the Geological Map of the Carpatho-Balkanides region between Mehadia, Oravita, Niš and Sofia at the scale 1:300,000 (Kräutner and Krstić, 2003). The modifications and additions in the Map are based on the Geological Map of Serbia at scale 1:2,000,000 (Dimitrijević, 2002) and compilations from different publications. In order to facilitate the study of the influence of geology on the development of geohazards, geologic complexes are divided and considered from the aspect of the potential erosion. After a detailed study of geological and topographic maps (vertical variation of land configuration maps, land surface slope-angles maps), the territory is divided into the potential erosion areas. The assessment of vulnerabilities to potential cave collapses, landslides and other rock or soil mass movements is based on the knowledge of the engineering-geological and geomorphologic characters of the terrain, and the knowledge of the effects of external factors on the geological environment. Seismic hazards were assessed using the existing seismic maps (Vukašinović, 1987). Potential landslides, rockfalls and intensive erosion were assessed using respective methods (Guzzetti et al., 1999; Dragićević et al., 2007, 2009, 2010), reference maps: the Erosion Map of Serbia (Lazarević, 1983) and the Geomorphologic Map of Serbia (Menković et al., 2003).

Field research data (Manojlović and Dragićević, 2000; Manojlović et al., 2003; Dragićević et al., 2009) were used in establishing the intensity of recent geomorphological processes.

DOI: 10.5775/fg.2067-4635.2011.003.i

The complex study of natural conditions in eastern Serbia produced the most important result of the research work – the Geohazard Vulnerability Map of its territory showing the geohazard vulnerability zones. The recent state of impact by natural hazards in Serbia, based on the mentioned maps, is combined into a unified map, which shows the areal distribution of different hazards believed to exert a limiting influence on the regional land use for development. Thus, the areas threatened by particular natural hazards are designated and their respective surface and proportion of the territory of Serbia are calculated.

Natural conditions as a factor of geohazards

The complex geologic nature of eastern Serbia is the main factor of the geohazard threat in the region. Mosaic geologic pattern and marked vertical diversity of the relief account for the varied climate and hydrogeology. Depending on the complexity of the given natural conditions, each region on the Earth surface is particular in character and tendency to some natural occurrences and processes, consequently to the threats by various natural hazards. The region of eastern Serbia has natural conditions complex enough to give rise to geohazards.

The facts that natural conditions are potential sources and that hazards are the limiting factor for a planned land development justify their consideration from different aspects. Analysis and quantification of natural conditions anywhere on the Earth are impossible without the proper knowledge and understanding of natural processes. This is because natural conditions result from both natural processes and human activities which directly cause and activate natural hazards in the area. Consequently, the knowledge of the distribution of natural conditions and of the process intensities is the first step to a proper control of geohazards and prevention of their consequences. A geohazard activity may in extreme events greatly endanger human life and property, in which case it is taken for a natural disaster.

An analysis of natural conditions is considered to include the recent state formed by different natural processes and human activities. A change in the intensity of any process may disturb the natural balance and is both the cause and the consequence in a point of time and an area.

Geological and geomorphological setting

The knowledge of regional geology is very important for planning and protection from natural hazards. The lithologic composition, age and structural pattern and the effect of other factors determine the possible manifestations of geodynamic processes and consequent geohazards. Dominant geomorphic processes are related to the geologic character (e.g. frequent landslides, heavy erosion, cave collapse are characteristic of carbonate rocks in the areas built of Neogene deposits). In order to establish the distribution of geohazards in eastern Serbia in relation to lithology, we grouped lithologic units into lithologic complexes, because their behaviour to exodynamic processes is different (in intensity of weathering, washout, etc.).

Eight major lithologic complexes are recognized, then each complex is studied for the types of geohazard threat (landslide, rockfall, cave collapse, etc.). In addition, structural features are studied for an assessment of the seismic hazard.

The tectonic setting of eastern Serbia is complex, composed of structures that belong to the east-Serbian segment of the Alpine system and to Romania. The units are from west to east the following: Serbian-Macedonian, Supragethic, Lower and Upper Danubian (Krstić et al., 1996; Dimitrijević, 2002; Kräutner and Krstić, 2003) (Fig. 1a).

Geological framework is deliberately simplified to show only major petrologic complexes, some of which have played dominant role in the source and distribution of geohazards (Fig. 1). These are:

- Precambrian and Lower Paleozoic metamorphic rocks, mostly complexes of crystalline schist, amphibolite, gneiss, mica schist and quartzite, susceptible to thermal disintegration and consequent formation of thick deposits of debris by sliding, rockfalling, rapid gully and slope-washing.
- Precambrian ultrabasic rock massifs (dunite and hartzburgite) and serpentinite.
- Igneous rocks: older Upper Proterozoic/ Cambrian gabbro, Caledonian and Variscan granitic rocks, and younger Upper Cretaceous/Paleocene plutonic complexes of granodiorite, diorite, andesite and dacite.
- Upper Paleozoic and Mesozoic sandy carbonate flysch. The complex of flysch deposits, highly varied in lithology and facies, has properties unsusceptible to geohazards. Weathering products of these rocks form blankets that may start a sliding process. Occurrences, additional to slides, are rill and other forms of erosion, even by torrents.

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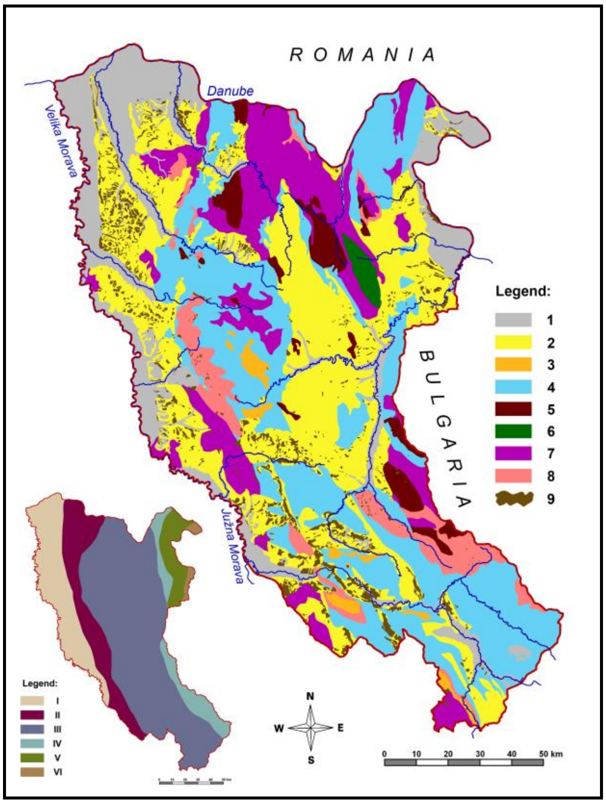

Fig. 1. Lithology as a factor of landslide distribution Simplified geologic outline of eastern Serbia (1) and schematic map of tectonic units (1a). In (1): 1. Quaternary cover; 2. Neogene deposits; 3. Mesozoic complex of carbonate rocks; 4. Upper Paleozoic and Mesozoic clastics; 5. Flysch; 6. Igneous rocks; 7. Precambrian ultrabasic rock massifs and serpentinites; 8. Precambrian and Lower Paleozoic metamorphic formations; 9. Landslides areas. In (1a): I. Serbian-Macedonian unit; II. Supragethic unit; III. Gethic unit; IV. Upper Danubian; V. Lower Danubian; and VI. Moesian plate.

- Upper Paleozoic sandstone, conglomerate, arkose and accessory Jurassic coal shale are clastic deposits (Table 2).
- Thick Mesozoic carbonate rocks (limestone and dolomite) are susceptible to chemical decomposition, corrosion, detachment and fall. Corrosion wears outer and inner parts of calcareous rocks forming surface and subsurface karst features prone to collapse. Limestone is in the group of rocks highly susceptible to temperature disintegration. Rockfalls are common where limestone is dominant.
- Neogene conglomerate, sandstone, breccia, marl, shale post-tectonic deposits readily disintegrated and producing thick loose covers. Owing to a clay constituent, most of landslides in Serbia occur in Neogene deposits. Surface and subsurface erosion evolves in places of dominantly coarse, slightly cemented sand constituent.
- Quaternary cover.

An analysis of recent relief characteristics as a source of geohazards is complex and requires designation of major and representative ones for the set target. The relief impacts have been considered in relation to the morphogenic, morphodynamic and morphometric parameters. This, with the aid of numerical analysis, is the basis for a proper assessment of the relief impact on the occurrence of geohazards.

Table 2
Areas of lithologic complexes

Geologic complex	Area (km^2)	Total percentage
Quaternary	2860.19	16.77
Tertiary	5585.84	32.74
Flysch	214.37	1.26
Mesozoic carbonate rocks	4510.13	26.44
Igneous rocks	586.21	3.44
Serpentinite	121.28	0.71
Metamorphic rocks	2244.44	13.16
Paleozoic and Mesozoic clastics	937.69	5.50
Total	**17060.15**	**100.00**

The relief parameters expressed in altitudes, vertical and horizontal slope diversity, are basic for consideration of the land configuration conditions and of their genetic and morphometric influence on the intensity of natural, particularly geomorphologic, processes and eventual occurrence of geohazards. A quantitative geomorphologic map has to be prepared before embarking on the selection of areas susceptible to erosion and deposition processes, or before establishing the erosion potential in an area (on the basis of "Erosion Potential Method" (EPM) (Gavrilovic, 1972).

Related to the regional geology and geomorphology, the territory of eastern Serbia may be divided into the areas of high, medium and low potential erosion. More than half the territory (66.41%) is in the group of low erodibility, and a smaller part (32.87%) is medium erodible.

Erodibility of landforms, however, should be correlated with other factors of physical geography. Designated areas of each natural factor overlap in the composite map of potential erosion.

Surface areas divided by altitude zones are divided into: 7.32% below 100 m, 13.65% from 100 m to 200 m, or 21% below 200 m, 42% from 200 m to 500 m, 31.72% from 500 m to 1000 m, and only 5.32% above 1000 m. The average altitude of the

DOI: 10.5775/fg.2067-4635.2011.003.i

terrain is 455.5 m. The topographic map was the data base in the research of lands threatened by slope erosion, which is widespread in the region.

It is well known that certain relief characteristics represent one of the major conditions for the appearance of slope processes. Also, it is essential to carry out hypsometric analysis, as well as the analysis of “energy” and inclination of topographic surface, which at the same time present the core of the quantitative geomorphologic analysis. The hypsometric map presents the starting point in the analysis of terrain potentially at risk of slope processes, especially since the fact that the upper limit of neogenic sediments in Serbia is 420-450 m (Dragićević et al., 2009).

According to the relief characteristics of eastern Serbia (63% or 10740.5 square kilometers to 500 m), and the fact that Neogenic sediments include the surface of 5585.84 square kilometers (32.74% of the total area), slope processes as dominant geomorphologic processes on this territory are established.

Land surface inclination is one of the basic factors for geohazards. Surface areas divided by the slope angle are the following: 10907.3 km^2 (63.93%) to 10º, 4781.28 km^2 (28.03%) from 10º to 20º, and 1371.59 km^2 (8.02%) higher than 20º. The dominant area susceptible to landslide processes in eastern Serbia is on the slope angle from 5º to 15º, 73.8 %, which is according with the distribution of Neogene deposits (Table 3).

Table 3
Lithology and Potentially landslide areas

Rocks	Area (km^2)	Percent proportion
Quaternary deposits	57.42	7.98
Tertiary deposits	609.70	84.78
Flysch	1.72	0.24
Mesozoic carbonate rocks	9.55	1.33
Igneous rocks	1.65	0.23
Serpentinite	0.44	0.06
Metamorphic rocks	20.15	2.80
Paleozoic and Mesozoic clastics	18.49	2.57
Total	**719.12**	**100.00**

Climate conditions

While varied in many geographic aspects, eastern Serbia is not much heterogeneous in climate. Difference in the values of climate elements is more local than resulting from circulation processes in the atmosphere. The Karpatho-Balkan mountain range, the largest morphostructure of eastern Serbia, acts as a barrier between cold air masses from the north of Europe, especially from the Valachian depression, and warm humid masses from the west of Europe and the Mediterranean. The barrier effect is reduced, however, by infrequent coincidence of the air masses and the discontinuous height of the mountain range (only 5.32% above 1000 m), so that the exposure to either side is comparatively equal.

Major climate elements that directly or indirectly form hazards are precipitation and temperature. Divided by Živković (2005-a), roughly a third of eastern Serbia is between isohyets 600-700 mm and 700-800 mm, a fifth between isohyets 800-900 mm, and the rest (2340 km^2 or 13.4%) receives more than 900 mm or less that 600 mm precipitation. The area with more than 1000 mm occupies 737 km^2 or 4% of the territory. Average precipitation depth in the area is 768 mm for period1961-1990. Converted into the volume of atmospheric precipitations, eastern Serbia annually receives 13.4 km^3 of water.

The precipitation depth, on average, is the lowest (560-590mm) in SW, in the Niš-Aleksinac depression, and the highest (about 1500 mm) on Stara Planina peaks (Živković and Anđelković, 2004). The half-period 1991-2005 is characterized by much lower precipitation depths, when the area below the 600 mm isohyet was notably larger (500 mm in Niš and Negotin) (Anđelković, 2009). The pluviometric range had two maximum and two minimum mean amounts of rainfall: one maximum in late spring/early summer (May-June) and the other in late autumn (November); one minimum in early autumn (September) and the other in late winter/early spring (February/March). Snow discharges occur from November to mid-March at low altitudes, and from October to mid-April on mountains. Average depth of fallen snow recorded in meteorological stations ranges from 8 cm in Niš to 35 cm on Crni Vrh (highest zones in the region are believed to receive 50 cm of snow). Mean maximum snow cover is 20-30 cm in Timočka Krajina, 70-110 cm on Kučaj, and 110-150 cm on Stara Planina (Dukić, 1975).

Precipitations, extreme in intensity or duration, or lacking, which influence geomorphologic processes and consequently the physiognomy of the land surface or configuration, are important for the occurrence of hazards. Daily maximum is an important indication of the actual danger e.g. from flood, torrent, landslide, etc. The research data for central Serbia indicate that precipitations of only 25 mm and 50 mm respectively cause overflow of streams and large-scale floods. The threshold of intensive precipitation, an alert of serious danger in eastern Serbia is 40 mm in the south and 50 mm in the north (Anđelković, 2009), in western Serbia is

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30 mm (Dragićević, 2007); at that, it may occur any time of the year, though rarely in the end of winter or early spring. The absolute maximum values are recorded in Veliko Gradište (116 mm) and on Crni Vrh (136 mm). It should be said that vulnerability of the region depends on the interaction of all natural factors, not on the precipitation alone.

Hail falls any time of the year, commonly in May and June. In depressions it may fall once or twice a year, and more often in mountains (to four times on Crni Vrh). The number of hail fall days in the period 1991-2005 was 5 in V. Gradiste, 8 in Niš and Ćuprija, 14 in Dimitrovgrad, 15 in Negotin and 24 on Crni Vrh.

Unlike precipitation, air temperature has an indirect influence on geohazards, which is expressed in soil saturation in winter and drying in summer. An abrupt rise in air temperature in winter causes rapid melting of snow, torrents and floods in the former event, and rainless summer heat dries up soil in the latter. Both processes are well at work in eastern Serbia. The trend of the mean annual temperature rise is registered in Serbia from 1980, with highest rise in the eastern region. Annual rise for the period 1951-2005 was 1.8ºC/100 year in Negotinska Krajina and even 5ºC/100 year since 1990 (Popović, 2007). Floods from melting snow are more frequent in the last twenty years due to the alternating cold and warm intervals during winter and spring. Then, with the snow cover still on, temperature rises much above normal for the season and holds for 2-4 days or longer. The latest example was the Beli Timok flood in the town of Zaječar. First discharge occurred in December 2009, another in the end of February and successively continued into spring 2010. Similar events occur almost every year, mainly in the drainage basins of Timok, Mlava, Pek, and Resava. On the other hand, Timočka Krajina is exposed to long draughts in the rainless and hot summers. This area is rapidly expanding under the impact of draught, with the obvious continuous reduction of crop yields (Živkovic et al., 2005).

Hydrological conditions

The distinctive hydrologic features of the region are related to the position, orography, lithologic and pedologic character, vegetation and climate, each particular in itself. What is most important is the influence of calcareous rocks on both surface and subsurface waters. Karst of the Carpatho-Balkanides in eastern Serbia occupies somewhat more than 4510 km^2 or 26.44% of the territory. Karst aquifers are abundant and each major river runs from a strong resurgence or is fed from its downstream. There are more than 70 springs of the minimum flow rate over 10 l/s, including 16 resurges of over 100 l/s. This is why the central mountainous area has a continuous runoff, unlike the rest of Serbian territory of similar physiognomy and many periodical streams. Eastern Serbia also has few intermittent streams in the low Neogene areas surrounded by higher limestone massifs. Sinking streams, another feature of karst, are many (about 70) but they are short (1-3 km), the longest being Busovata (8.8 km), Nekudovska (8.5 km) and Blato (8.3 km) (Gavrilović, 1992).

All streams have the hydrologic rain/snow regimen, but the Danube, the northern border of the region, has combined flow characteristics. Stream flows are high in late summer, September and August. The stream catchments receive annually 600-800 mm precipitation, of which much more water evaporates than runs off. The runoff coefficients for the streams fed less or more by groundwater are between 20% and 30%, and up to 50% (Zlot River), respectively. The runoff proportions in relation to the altitude are similar: one fifth from low drainage basins and two thirds from small basins at the altitudes above 800 m, respectively. In any case, the difference is great, related to slopes, vegetation and soil properties in addition to the mentioned factors. The bordering rivers have the highest discharges: Danube 565 m^3s^{-1}, Velika Morava 230 m^3s^{-1}, Južna Morava 100 m^3s^{-1}, Nišava 30 m^3s^{-1}, and Veliki Timok 30 m^3s^{-1}. The tributaries discharge up to 10 m^3s^{-1} which is drained by the rivers into the Danube.

Man's impact on hydrology in eastern Serbia is mostly manifested in the artificial lakes formed by dams. The two largest lakes, among the largest in Europe, are on the Danube: Đerdap I and Đerdap II. The former is more than 120 km long and has a volume of 1.28 milliard cubic metres, and the latter, downstream lake has a volume of 716 million cubic metres. Both lakes are formed primarily for the purpose of power generation. Other storage lakes, Bor and Grliš Lakes (12 mil. m^3 each), Bovan and Zavoj Lakes (170 mil. m^3), are small, used for water supply and for sediment control.

A common characteristic of all streams in eastern Serbia, excluding the Danube, is very high variation of medium and extreme flows. Mean monthly maximum/minimum discharge ratios are 2.1 for the Danube, 5 for the Velika Morava, 12.5 for Grliška, and as high as 28 for the Sikolska (March-September). An even better indication is the ratio of high (1% probability of occurrence) and low (95% probability) flows. These parameters are 9 for the Danube, 70 Velika Morava, 186 Južna Morava,

DOI: 10.5775/fg.2067-4635.2011.003.i

707 Crni Timok, 790 Trgoviški Timok, 909 Pek, and as high as 1055 the Beli Timok in Zaječar, which indicate the torrential character of the streams and low retentive capacity of the drainage basins after intensive rainfalls. Moreover, seasonal runoff is not constant as indicated by the variation coefficients for monthly discharges. These coefficients are less than 0.5 for steady flows (e.g. the Danube by Veliko Gradište has least steady flows of 0.35 in October and 0.37 in November), and much higher for minor rivers. This parameter is slightly below 0.5 only in March and April at two gauge-sections in the Nišava drainage basin. The variation coefficient values are higher than unit, especially in October, for most streams (Sikolska 2.63, Grliška 3.64). The inadequate forest cover and erosion processes are also factors contributing to frequent stream overflows and often to torrents and floods. Flood plains occupy 7.7% of the region, the largest plains located in the valleys of major rivers (Velika Morava alluvium, Niš-Aleksinac depression of the Južna Morava and Zaječar depression of the Timok, Negotin field, etc.). In the Timok valley alone, high water of the hundred-year probability endangers 7700 hectares of land, and an almost double larger area in the immediate catchment of the Velika Morava. There is no doubt that the flood protection and river regulation system is passive at present consisting essentially of embankments and channel regulation works, whereas active measures with beneficial effects such as artificial lakes are secondary. A general impression is that little has been done in eastern Serbia for protection from floods. Voluminous works completed were the regulation of the Velika Morava (after 1950) that included cutting off sixteen meanders to reduce a fifth of the river length. The mouths of the tributaries and their channels in the alluvial plain through towns also were regulated. Some ten kilometers of levees in the Timok basin were built to protect major towns (Knjaževac, Zaječar). The Mlava and its tributaries also were regulated in a total length of 30 km.

The case example of Zavoj Lake well indicates how serious the threat of hazards may be. The lake formed during two days in 1963 after a mass landslide dammed the Visočica valley. The slide was 1.3 km long, about 200 m wide and moved at the rate of 7 m per hour. About two million cubic metres of rock and soil formed a dam 530 m wide at the base and 140 m at the crest, and 30 m high above the river. With the surface of 3 km^2 it was one of the largest natural lakes (later the dam was developed for the power generation purpose). The landslide caused an ecologic disaster; among other effects it flooded two villages with 150 inhabitants. This is not the only case example in Serbia. A much smaller landslide (28000 m^3) formed the Alušontu Lake in 1883 (Stanković, 2007).

Human activities as a factor of geohazard

A change in land configuration exerted by human activities may result from mining (coal, copper, gold) or groundwater pumping. The two mentioned activities leave caverns in the lithosphere subsurface that may easily collapse and modify the land surface producing a geohazard.

Geological and petrological diversity or abundant mineral resources are related to the paleogeography of the region. A large number of surface and subsurface mines have created conditions for the occurrence of geohazards in many areas. The Crna Reka andesite-dacite bodies is a rich resource of copper (Bor), gold, zinc, lead, iron, wolfram, etc. Coal is exploited in many locations of eastern Serbia, to mention Zaječar, Knjaževac, Niš, Sokobanja, Pirot. The joint contributions of man and nature in creating a hazard are best illustrated by the case example of the Bor Mineral Basin. The Borska stream has been for decades a collector of wastewater from the many mine workings. It is now probably the cleanest river in the world devoid of any life, without a single bacterium. A tributary of the Timok~~, it~~ transforms this river of eastern Serbia into a dead stream over a length of 50 metres, to its confluence with the Danube. The scenery of the Timok alluvial plain, thickly covered by pyrite gangue, looks more like ~~e~~ a picture from another planet. Groundwater and air are polluted, and even rainwater indicates that it contained radionuclide like after the Chernobyl disaster. Many conscious persons keep warning of the serious health problems and of grave diseases in the Timok basin, but the warnings are long and successfully covered up because economic development is priceless.

RESULTS AND DISCUSSION

A geohazard vulnerability map is prepared based on a study of natural conditions in eastern Serbia, which has national importance, and is useful on a larger, regional or European scale. The map delineates zones of geohazard vulnerability, which for the lack of data were omitted in most of researches of natural hazards in Europe or over the world (Berz et al., 2001; Grimm et al., 2002; Peduzzi, 2005; Barredo, 2007; Gaume et al., 2009). As there can be seen on the Map, the seismic hazard is greatest along the Morava fault, western area of

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the east-Serbian region. Broken by the earthquake intensity, 79.24% of the territory may expect earthquakes of VII to VIII MCS-64, 19.71% earthquakes of VIII to IX, and only 1.05% is in the intensity zone of IX to X MCS-64.

The Map of potential erosion (Fig. 2) shows that 16.67% of the territory is highly erodible. The erosion hazard is particularly great in Neogene deposits at steep slopes. Excessive erosion occur on 0.72% (Table 4).

Table 4
Areas of potential erosion

Erosion potential	Area (km^2)	Total percentage (%)
Very high	122.68	0.72
High	2843.80	16.67
Medium	2764.29	16.20
Low	11329.38	66.41
Total	**17060.15**	**100.00**

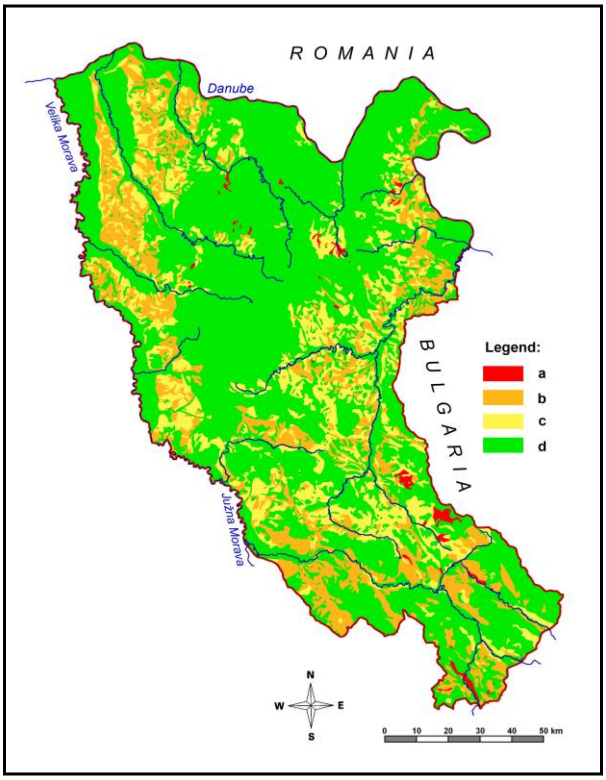

Fig. 2. Map of potential erosion
a) Very high; b) High; c) Medium;
d) Low potential erosion

As to the potential landslides (4.2%), their distribution is related to the lithology and ground slope. The relation to altitudinal distribution of Neogene deposits in Serbia, 83.20% of landslide hazard zones are below the altitude of 500 m, and 96.51% on slopes lower than 15º.

Rockfalls occur in many locations (less than 1% of the east-Serbian territory); mostly carbonate rocks at the sides of canyons and gorges.

Potential cave collapses zones are numerous in places where the lithosphere surface is cavernous either from natural processes or human activities. Large or extensive caves or caverns, numerous crevices and cave passages have formed by erosion in carbonate rocks. Natural and artificial factors may lead to break down of surface layers and their collapse into subsurface caverns. A cave collapses of excessively thinned surface layers may be triggered by earthquake, thunder, or rockfall. The average annual total mineralization of Carpatho-Balkanian mountains in Serbia, coressponding to the average annual discharge is to be found within span of 100-413 mgl^{-1}. The intensity of chemical erosion is in range of 10-167 tkm^{-2}yr^{-1} (Manojlović and Dragićević, 2000).

Carbonate rocks, limestone and dolomite, cover 26.44% of the east-Serbian territory. In the mosaic distribution of limestones, karst features are found all over eastern Serbia. A plausible estimate of the number of caves is between 1500 and 2000 (Djurović, 2005).

Potentially flood plains constitute 7.69% of the total research area.

It results from the above stated that 6479.19 km^2, or 38.17%, are endangered by geohazards. Let it be noted that the accuracy of surface areas should be taken with due caution, because the considered region is large and the generalization degree of the reference maps is fairly high. Nevertheless, the Geohazard Vulnerability Map of eastern Serbia is very useful as a data base for land use planning. For any specific conclusion, a geohazard cadastre at the local level will be needed.

CONCLUSION

Geohazards are an important segment of the land use and town plans, especially in the hazard vulnerable areas. This work is important for presenting the acquired geohazard data that can be used to select appropriate methods for the land use planning, development and utilization in relation to the vulnerability to their manifestations. Natural geohazards are a limiting factor in the land use planning, which needs a model to be developed for the proper control of natural conditions.

This approach allows in all subsequent stages of planning to determine an acceptable level of natural hazards in eastern Serbia and to develop a system of preventive, organizational and other measures and instruments for intervention against the occurrence

DOI: 10.5775/fg.2067-4635.2011.003.i

or for mitigation of hazard consequences to a tolerable level.

Land use planning with reference to The Hazard Vulnerability Map of Eastern Serbia (Fig. 3) has a long future in the prevention of geohazards and in minimizing damages they may inflict (Table 5).

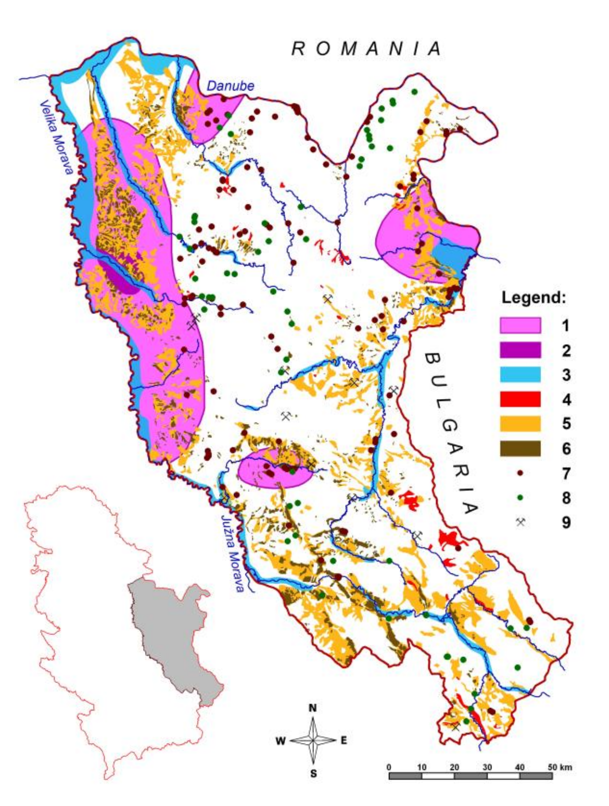

Fig. 3. Composite map of geohazard vulnerability of eastern Serbia
1. Seismic hazard VIII to IX MCS; 2. Seismic hazard IX to X MCS; 3. Potential floodable areas; 4. Excessive erosion areas; 5. Strong potential erosion; 6. Landslide hazard areas; 7. Rockfalls; 8. Potential cave collapses; 9. Subsurface mines.

Table 5
Geohazard areas in eastern Serbia

Geohazard type	Area (km^2)	Percent proportion
VIII to IX MCS	3361.75	19.71
IX to X MCS	179.82	1.05
Potential floodable areas	1311.61	7.69
Excessive erosion areas	122.68	0.72
Strong potential erosion	2843.80	16.67
Landslide hazard areas	719.12	4.22
Rockfalls	19.76	0.12
Total endangered	**6479.19**	**38.17**

The research results may be contained in a model of the geohazard control, as the key component of an integral plan of protection against natural hazards. The risk of natural hazards remaining after the implementation of relevant geohazard control measures must not be greater than what a local community may be allowed to suffer.

The composite geohazard vulnerability map of eastern Serbia has a wider than national importance because natural hazards strike irrespective of administration borders. Hence, it may be a base for cross-border cooperation and for a geohazard vulnerability map of all countries within the Danube lower basin.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Science and Technological Development of the Republic of Serbia (Project No 43007).

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DOI: 10.5775/fg.2067-4635.2011.003.i

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume 10, Issue 1 / June 2011, pp. 20-26
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.007.i

Application of object based image analysis for glacial cirques detection. Case study: the Ţarcu Mountains (Southern Carpathians)

Florina ARDELEAN[1], Marcel TÖRÖK-OANCE[1], Petru URDEA[1], Alexandru ONACA[1]

[1] West University of Timişoara, Department of Geography, V.Pîrvan Street, No.4, 300223,
e-mail: florina.ardelean@cbg.uvt.ro

Received on <December 29, 2010>, revised on <February 26, 2011>, accepted on <April 24, 2011>

Abstract

Geomorphologic mapping is an important fact in many research studies and the traditional methods are time consuming and expensive. This paper aims to develop a semi-automated rule-based method for the detection of glacial cirques for a test area located in the Ţarcu Mountains (Southern Carpathians) in an object-oriented approach. In this study we have established the morphometric characteristics of the glacial cirques developed in a particularly geomorphologic context at the edge of planation surfaces, using a 10 m horizontal resolution DEM (Digital Elevation Model). The parameters extracted from DEM (i.e. curvature) were further used in segmentation and classification process. Also, other factors were introduced in the rule set, as the context regarding neighboring objects like planation surfaces to the target class. The most important factor in segmentation was the curvature and to choose an appropriate scale factor we have used the available ESP (Estimation of Scale Parameter) tool. The results achieved were very close to the field reality, except for some areas where there are large negative landforms such as gullies and torrents, which were identified as objects belonging to glacial cirques class and also some roches moutonnées with high positive curvature values, objects that could be filtered manually by the user based on previous field knowledge and ancillary data such as orthophotoplans and the geomorphologic map of glacial relief in the Ţarcu Mountains. For further research, we intend to identify the characteristic thresholds for morphometric parameters that can be integrated in a set of rules in order to detect and classify other type of landforms in the alpine domain of the Ţarcu Mountains.

Keywords: *landforms classification, OBIA (object based image analysis), segmentation, geomorphometry, glacial cirques, the Ţarcu Mountains, Southern Carpathians.*

Rezumat. Analiza şi clasificarea orientată-obiect a circurilor glaciare din Munţii Ţarcu (Carpaţii Meridionali)

Cartarea geomorfologică oferă rezultate cu importanţă mare pentru foarte multe studii, iar metodele tradiţionale de cartare necesită foarte mult timp și sunt costisitoare. Acest studiu prezintă un set de reguli pentru identificarea semi-automată a circurilor glaciare pentru arealul test din Munţii Ţarcu (Carpaţii Meridionali) utilizând metode de analiză orientate-obiect. În lucrarea de faţă au fost stabiliţi parametrii morfometrici caracteristici ai circurilor glaciare aparţinând reliefului glaciar de tip Godeanu, cu circuri glaciare dezvoltate la marginea suprafeţelor de nivelare, pe baza unui model digital de elevaţie cu o rezoluţie spaţială de 10 m. Parametrii morfometrici ai reliefului generaţi din acest model au fost folosiţi în procesul de segmentare şi apoi de clasificare a circurilor. Astfel, în setul de reguli de clasificare au fost introduşi atât factori morfometrici, precum curbura terenului, dar şi de context, cum ar fi vecinătatea faţă de suprafeţele de nivelare. Factorul cel mai important utilizat în procesul de segmentare este curbura medie, iar pentru stabilirea unui factor de scară cât mai obiectiv, s-a folosit un instrument implementat în Definiens, numit – ESP. Rezultatele obţinute sunt apropiate de realitatea din teren (exceptând unele areale cu forme de relief negative, precum organismele torenţiale sau pozitive, cum sunt rocile mutonate din cadrul circurilor, elemente ce pot fi filtrate manual de către utilizator) demonstrează că metoda utilizată este una de interes, aceste rezultate fiind verificare cu date din teren şi cu ortofotoplanuri, hărţi existente ale reliefului din domeniul alpin ai Munţii Ţarcului. În studiile viitoare intenţionăm să îmbunătăţim metoda prezentată şi să determinăm parametrii morfometrici şi valorile-prag caracteristice, care să fie incluse în reguli de identificare semi-automată, pentru localizarea și clasificarea altor forme de relief din etajul alpin al Munților Ţarcu.

Cuvinte-cheie: *clasificarea semi-automată a formelor de relief, analiza imaginilor orientată-obiect, segmentare, geomorfometrie, circuri glaciare, Munţii Ţarcu, Carpaţii Meridionali.*

INTRODUCTION

Object based terrain analysis and semi-automated classifications in geomorphology create new possibilities for landforms and landform elements delineation and analysis, and represent a new alternative that increase the accuracy of mapping, which is time and cost efficient compared to other methods, i.e. total station survey, LIDAR data etc. The process of image segmentation in objects at different levels of detail is used as a mandatory step in the development of the rule set for classification in OBIA environment. The way of representing the world in objects rather than in cells is closer to human perception of reality, this being one of the big advantages of this method. Some mountain regions represent difficult terrain regarding classical methods of mapping and require a lot of time to generate geomorphologic maps. This method provides a new perspective in the study of landforms and landforms mapping and integrates GIS and remote sensing in a more appropriate way of representing the world in human perception about the landscape than the cell-based approach (Drăguţ and Blaschke, 2006; Drăguţ et al., 2010).

Sensor development in the last decade increased spatial and spectral resolution and one negative aspect of data processing is that it leads to high heterogeneity inside classes of interest (Schneevoigt, 2008), problem that could be better solved if we use image segmentation and classification based not only on pixel values, but also including the context and the shape of the objects.

The use of DTMs (Digital Terrain Models) and other remotely sensed data in landforms detection and analysis is a common approach in earth sciences and geomorphometry (Pike et. al, 2009). In the field of geomorphometry there were several studies that developed methods for automated landforms classification based on Hammond system (Dikau, 1989, 1990, Dikau et al., 1995), delineation of slope types (MacMillan et al., 2000), automated classification of topography using derived features from DEMs (Iwahashi and Pike, 2007), automated extraction of landform elements (Drăguţ and Blaschke, 2006), automated delineation of valleys (Straumann and Purves, 2008) etc.

In Romania the study of automated detection of planation surfaces in the Godeanu and Mehedinţi Mountains is to be mentioned (Török-Oance et al., 2009).

In high mountain areas regarding glacial relief and related processes there are few studies that deal with object oriented approach in delineation of specific landforms: Schneevoigt et al., 2008, for alpine landforms multi-scale classification, and Eisank et al., 2010, for automated extraction of glacial cirques.

Glacial cirques are the most representative landforms of the glacial relief in high mountains and sustain the existence of past Pleistocene glaciation. Clear cirque forms are accepted as one of the best proof of glaciation in mountains. The form of cirques consists essentially of a "steep headwall slope arcing around a gentler floor" (Evans and Cox, 1974). The floor of cirques in the mountains is the morphologic result of glacial erosion (scouring, quarrying, plucking, abrasion, breaching etc.). Glacial cirques have generally concave shape both in plan and profile curvatures (Eisank et al., 2010) and variable extend up to few kilometers (Benn and Evans, 1998). The cirques are connected with valleys by means of rocky thresholds (Hambrey and Alean, 1992) and as in all landforms delineation, the borders between those two landforms interfere due to high heterogeneity and transitional nature of natural limits. In this context, the object-based approach in cirques delineation best fitted the purpose of this study.

STUDY AREA

Ţarcu Mountains are located in the north-western flank of the Southern Carpathians being part of the Retezat-Godeanu range. This mountaineous area, with altitudes over 2000 meters, is characterized by considerable development of planation surfaces especially at altitudes above 1800 m, where Borăscu sculptural complex occupy large areas. The highest peaks from Ţarcu Mts. have altitudes between 1800 and 2192 m, high enough to support small glaciers during the glacial periods of the Pleistocene. Although the amplitude of the glacial periods is not as remarkable here as in Retezat Mts., an expressive glacial relief was left behind after melting the glaciers at the end of Pleistocene. Niculescu (1990) mapped 37 glacial cirques in this area developed especially at the edge of the planation surfaces at over 2000 meters. The glaciers from these cirques were short, their tongues having less than 3 kilometers, being considered by Niculescu pyrenean glaciers. Most of the cirques are simple cirques, but we found also compound cirques and even cirque complexes (Olteana glacial complex).

The presence of the glacial features in the Ţarcu Mts. was first noticed by Schafarzik (1899) so that in 1907, Emmanuel de Martonne described some glacial cirques and Kräutner (1929) carried out a first draft of the glacial landscape of this area. In 1990 Niculescu described the glacial landscape from the Ţarcu Mts. presenting the first comprehensive map of the glacial cirques distribution from the Ţarcu, Bloju and Baicu Massifs. Further, Urdea (2004) recalculated the length of main Pleistocene glaciers from Ţarcu and got over 4 km length for the Hideg, Şuculeţ and Netiş glaciers. He also found two plateau glaciers in this area: Pietrele Albe and Ţarcu-Căleanu. In 2006 Mândrescu brought new information on the number of glacial cirques (he counted 60 cirques) and their morphometric characteristics (Mîndrescu, 2006).

The morphology of glacial cirques from the Ţarcu Mountains is strongly influenced by the complex lithology (granitoide, schists, conglomerates, gneisses and amphibolites) and by a dense network of faults as a result of the geographical position between two main geotectonic domains (Danubian Domain and Getic Nappe).

The test area from the Ţarcu Massif (Fig. 1), was chosen because of the representative glacial cirques developed at the edge of planation surfaces. The area of the site is 87 km², with elevation ranging between 1034 and 2190 m a.s.l. The highest peaks from this test area exceed 2100 m: Ţarcu (2190 m), Căleanu (2190 m), Bodea (2160 m), Nedeia (2150 m) and Brusturu (2116), but their appearance is more like a rounded plateau rather than reshaped in a periglacial manner. The glacial cirques are distributed in the upper part of the Olteana, Şuculeţu, Râu Rece and Râu Alb watersheds. Besides glacial cirques other expressive glacial landforms were mapped in the field, like: moraines, glacial thresholds, roches moutonnées.

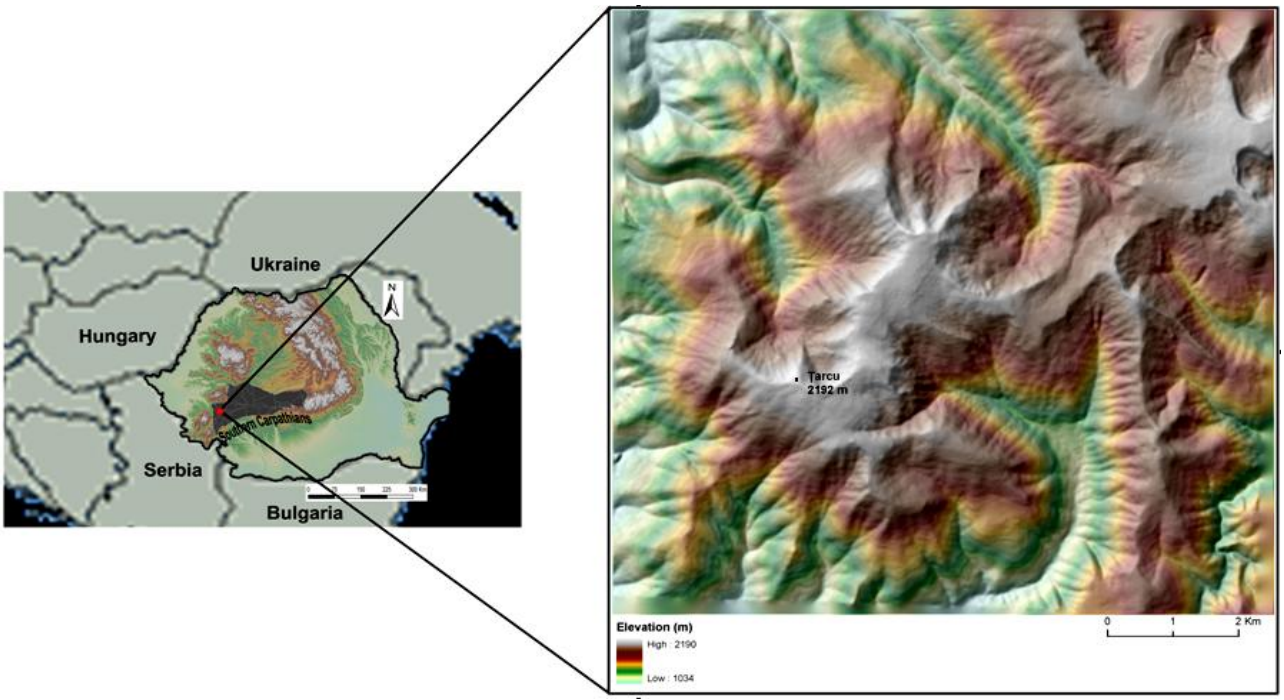

Fig. 1. The location of the Ţarcu Mountains and of the test site

DATA AND METHODS

"To be a landform, a part of the Earth's surface must have some coherence of form (shape) or process or both" (Smith and Mark, 2003, cited by Mark, 2009, p. 13). The landforms are defined in a specific geomorphometric fashion as discrete surface features (Evans, 1972), thus to obtain proper semi-automated delineation we need to define which morphometric parameters best describe the landform (glacial cirques) and how to apply that knowledge into a rule set based algorithm for classification. This approach of using preexisting knowledge and defined concepts and integrate them into software to achieve results as close as possible for an objective representation of the reality, was realized through semantic modelling (Dehn et. al, 2001) developed for the glacial cirques in Alps, with study area located in Carinthia, Austria (Eisank et al., 2010).

In this paper we have used a 10 meters horizontal resolution DTM generated from contour lines based on topographic map scale 1:25000 for the central part of the Ţarcu Mountains. The model was obtained in ArcGIS using TopotoRaster function and ancillary vector data as rivers, ridges, altitude points and was filtered in a 5x5 moving window to reduce noise.

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From this DTM we derived the models representing morphometric parameters such as slope, mean curvature, profile curvature, plan curvature. These derived models best describe the concavity of glacial cirques through positive or negative values in all curvatures and they were–further used in the segmentation and classification process.

The methodology presented in this paper consists of few steps: the identification of the glacial cirques in the field and based on old geomorphologic maps (i.e. glacial relief map of the Ţarcu Mountains made by Niculescu in 1990), image segmentation using ESP (Drăguţ et al., 2010), glacial cirques visual identification (i.e. based on hillshade DTM), morphometric parameters of glacial cirques analysis, glacial cirques classification and validation of the method applied.

Given the already known limitations of pixel based relief analysis on DEMs, the most important being the context information and the shape of the objects (Blaschke & Strobl, 2002), the method of object based analysis can be used as a new solution in glacial cirques detection.

The upscaling from pixel level to object or spatial primitives level was realized in Definiens Developer v.7 and this is a step that require specification of scale, which regards the homogeneity of the objects. This task required a lot of time before and was realized in a subjective manner depending on the user knowledge.

To avoid the subjective selection of the segmentation scale, this being a key factor of analysis, we used the ESP tool available for Definiens Developer v.7. This tool allows a more objective segmentation of the layers based on the local variance, a value that indicates the local variability within an image, so in a graph representation of the local variance, the breaks will indicate the optimal scale for segmentation, actually defining the objects that are very similar in the image and probably belonging to the same class in reality (Drăguţ et al., 2010).

The morphometric parameter that we used as base layer in segmentation is the mean curvature (Eisank et al., 2010), because this parameter is the one that best describe the glacial cirques morphology. Applying the ESP tool we obtained several characteristic scales, the most representative being 60 for cirque delineation and 24 for glacial cirques components, but in the end 24 was chosen for future analysis, because the value of 60 identified too large areas well beyond the limit of the cirques.

In the Ţarcu Mountains the glacial cirques being developed at the edge of planation surfaces, we identified two connected classes in the field (glacial cirques and planation surfaces). For the glacial cirques identification we have used threshold values defined for other land surface models like altitude (above 1800 m), mean general curvature, mean plan curvature and mean profile curvature (negative values).

Also we have used the context rules - neighbour to class for the classification of cirques in order to identify those objects which are always located at the edge of the planation surfaces (cirques class border to planation surfaces class).

We have identified also the planation surfaces (Fig. 2), based on the rules developed in a previous study, as being objects with mean slope values less than 14 degrees and minimum slope value less than 2 degrees, runoff less that 80, positive mean curvatures close to 0 (Török-Oance et al., 2009).

RESULTS AND DISSCUSIONS

In the case of the Ţarcu Mountains, the cirques are located at the edge of planation surfaces, well developed above 1800 m altitude. Using the knowledge about planation surfaces and some conditions developed for the planation surfaces in a previous article mentioned above and also the existing maps and longitudinal profiles over the cirques and glacial valley, we have delineate the shape of cirques (vectorized polygons) for the central part of the Ţarcu Mountains for comparison reasons. The objects identified as cirques were overlaid on a hillshade model (Fig. 3) and compared with the geomorphologic map (Niculescu, 1990) and with the results of objects detection using Defininiens.

In a specific geomorphometric analysis, there are some stages to follow, among those in the beginning being important the conceptualization and complete delimitation from the neighbour landforms (Evans, 1987).

The results achieved were compared to the map of glacial relief in the Ţarcu Mountains made by Niculescu in 1990. In this context, we must take into account that many maps about glacial landforms made for the Romanian Carpathians only identify the upper part of cirques as bounded by ridge or planation surfaces, but there is no delineation on the contact with glacial valleys.

The objects identified as cirques by applying the rule set delineate more the walls of this landform and less the contact with the glacial valley or the floor of the cirques due to low values of mean curvature and some high positive values in profile curvature and the existence of areas that are similar with the planation surfaces.

DOI: 10.5775/fg.2067-4635.2011.007.i

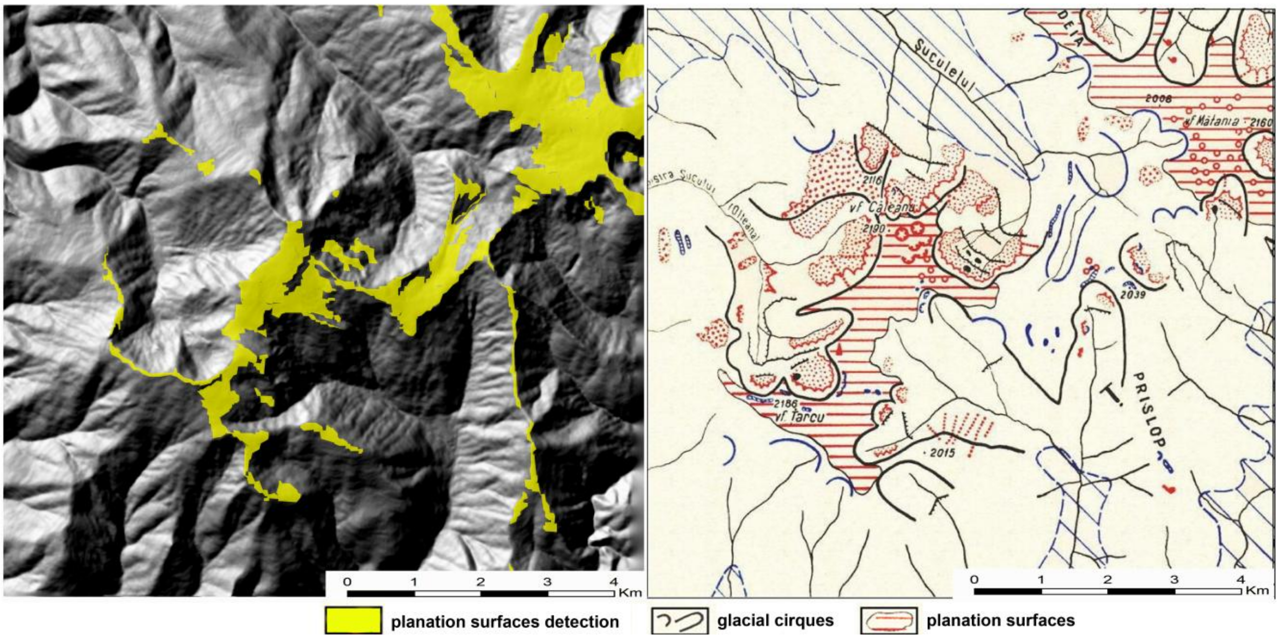

Fig._2. The planation surfaces detection compared to the geomorphologic map (Niculescu, 1990)

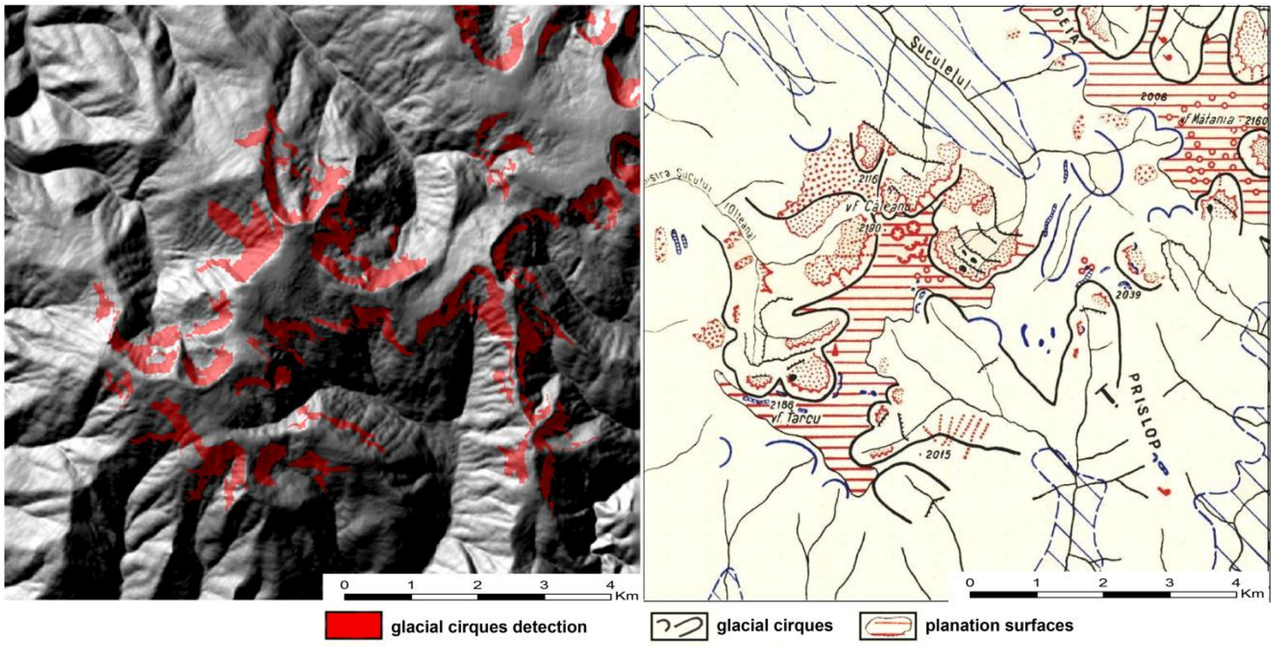

Fig._3. The cirque detection overlaid on DEM - comparison with the glacial relief map by Niculescu, 1990.

Some negative landforms with the same morphometric characteristics (negative mean curvatures) were identified as cirques and these objects were manually filtered based on previous knowledge about the test area.

Because of the similar extent of individual cirques in the test area we used only a single scale of analysis for glacial cirques detection, but it is desirable to use multiscale analysis for more complex topographic conditions and cirques extent (Eisank et al., 2010).

CONCLUSIONS

This study is a preliminary research and presents only the first results of the application of a semi-automated method for glacial landforms delineation based on DTMs in the alpine domain of the Țarcu Mountains. In this case the location of glacial cirques was well identified, but the

  DOI: 10.5775/fg.2067-4635.2011.007.i

estimation of their extension could be improved if we use in further research a hierarchical system for cirques detection and more characteristic scales of analysis and different spatial resolution of the data. Also the method could be improved by identifying and integrating the glacial slope breaks as the limit line between glacial cirques and glacial valley. This research will be improved in further studies and extended in a more complex analysis for a complete delineation of glacial cirques and also for the classification of other landforms from the alpine domain of the Ţarcu Mountains (moraines, rock glaciers).

ACKNOWLEDGEMENTS

This work was supported by CNCSIS – UEFISCSU, project number PNII – IDEI 1075/2009. We are grateful to dr. Lucian Drăguţ, associate researcher at Salzburg University, for his support.

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Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume 10, Issue 1 / June 2011, pp. 27 – 34
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.008.i

Glacial and periglacial relief in the Făgăraş Mountains, with special focus on the Vâlsan river basin

Marius-Florin MARCU[1]

[1]University of Bucharest, Faculty of Geography, e-mail: marius3marcu@yahoo.com

Received on < December 29, 2010>, revised on < February 25, 2011>, accepted on <April 29, 2011>

Abstract

The glacial modeling has created two well individualized geomorphologic landscapes in the Transylvanian Alpes: Borăscu, characterized by the large extension of the platform and high peaks, and Făgăraş, where cirques were multiplied and have developed until they reduced the platform to a very sharp ridge (gipfelflur). The layout of the main ridge on the West-East direction and the overall morphography of the two slopes, the northern one short and steep and the southern long, with gentle slopes, were also reflected in the way of development of glaciers in the Quaternary. In the Vâlsan basin there are distinguished some particularities of the glacial landform. Thus, the glacial landform of this sector of the Făgăraş Mountains is characterized by a small steep (200-300m) which favored the development of a long glacial valley with gentle slopes and led to the forming of the moraines at the glacial valley floor. The Vâlsan glacial cirque is at 2300m altitude, is small and has small lakes. The bottom of the cirque is flat and is predominantly grafted on mica-schist and gneisses. The Vâlsan *glacial valley* is North-South oriented and has several glacial thresholds. The slopes surrounding the Vâslan valley are symmetrical, being affected by torrents and avalanches. Other characteristic landforms are: *narrow glacial crests, glacial replats ridges, nunataks and moraines*. The frost wedging caused the residual relief represented by *sharp ridges, peaks, landforms of accumulation, debris cones, glacis, stone arches, protalus ramparts*. Overall, the Vâlsan glacial valley is a typical valley where the intensive post-glacial processes have hidden most of the features resulting from the glaciers action, which kept the characteristic „U" shape and the glacial replats appear from place to place under glacises and rock debris.

Key words: *the Vâlsan, gipfelflur, narrow glacial crest, glacis.*

Rezumat. Relieful glaciar şi periglaciar din Munţii Făgăraş, cu privire specială la bazinul Râului Vâlsan.

Modelarea glaciară a creat în Alpii Transilvaniei două tipuri de peisaje geomorfologice bine individualizate: *Borăscu*, caracterizat prin larga extensiune a platformei şi a vârfurilor înalte şi *Făgăraş*, unde circurile s-au înmulţit şi s-au dezvoltat până au redus platforma la o creastă foarte ascuţită, (*gipfelflur*). Dispunerea culmii principale pe direcţie V-E şi morfografia de ansamblu a celor doi versanţi, cel nordic scurt şi abrupt, iar cel sudic prelung, cu pante mai domoale, s-au răsfrânt şi în modul de dezvoltare al gheţarilor în Cuaternar. În cadrul bazinului Vâlsan se disting anumite particulariăţi ale reliefului glaciar. Astfel, relieful glaciar din acest sector al munţilor Făgăraş se caracterizează prin prezenţa unui abrupt de mici dimensiuni (200-300m) ce a favorizat dezvoltarea în lungime a văii glaciare, cu pante domoale şi a determinat depunerea morenelor la baza văii glaciare. Căldarea glaciară a Vâlsanului se găseşte la altitudinea de 2300 m, are dimensiuni reduse şi cantonează mici lăculeţe. Fundul circului este plat fiind grefat predominant pe micaşisturi şi gnaise. *Valea glaciară* a Vâlsanului este orientată pe direcţia N – S şi prezintă mai multe praguri glaciare. Versanţii care încadrează valea Vâlsanului sunt simetrici fiind afectaţi de torenţialitate şi avalanşe. Alte forme de relief caracteristice sunt: *custurile, umerii glaciari, striurile, rocile mutonate şi morenele.* Gelivaţia a determinat apariţia reliefului rezidual reprezentat de *creste ascuţite, vârfuri*, forme de relief de acumulare, *conuri de grohotiş, glacisuri, ghirlande de pietre, potcoave nivale.* În ansamblu, valea glaciară a Vâlsanului este o vale tipică în care procesele postglaciare intense au ascuns în cea mai mare parte elementele caracteristice rezultate în urma acţiunii gheţarilor, se păstrează forma caracteristică de " U", iar umerii glaciari apar din loc în loc de sub glacisurile şi poalele de grohotiş.

Cuvinte-cheie: *Vâlsan, gipfelflur, custură, glacis.*

INTRODUCTION

The study of the glacial landforms of the Romanian Carpathians started with *Beobachtungen über Tektonik und Gletscherspuren im Fogaraschen Gebirge*" in 1881, work in which P.W. Lehmann makes references to the tectonics and glacial traces from Făgăraş Mountains. Here there are described for the first time a few glacial cirques and glacial lakes on the north slope of these mountains, between the peaks Negoiu and Gălăşescu. The moraine sediments are not so visible in the relief because of the advanced decay which makes them so hard to identify; moraines are hard to recognize from the point of view of the shape and of the structure of the material; striated rocks are rare, and the erratic nature of many blocks is hard to recognize as well.

For this reason Lehmann does not succeed to identify moraines and cannot establish the maximal expansion of the ice age. Demonstrating the law of Partsch, he establishes the altitude of 1700 m as the limit for the permanent snow during the ice age, he insists over the independence of the cirques related to the structure and the lithology, emphasising their dependence on the altitude and the exposition. Among the researchers who showed interest for the study of the glacial landforms in the Carpathians were the Romanian geologysts L. Mrazec, Gh. Munteanu-Murgoci and Popovici-Haţeg. L. Mrazec notices the predominant exposure of the glacial cirques from the Alps of Transylvania towards north and east.

Their dimension is bigger in comparison to the southern slope. He identifies roches moutonnees, glacial thresholds and lakes in the cirques. Starting with 1898, Emmanuel de Martonne starts his field campaigns in the Alps of Transylvania, giving a special importance to the glacial landform (Fig. 1).

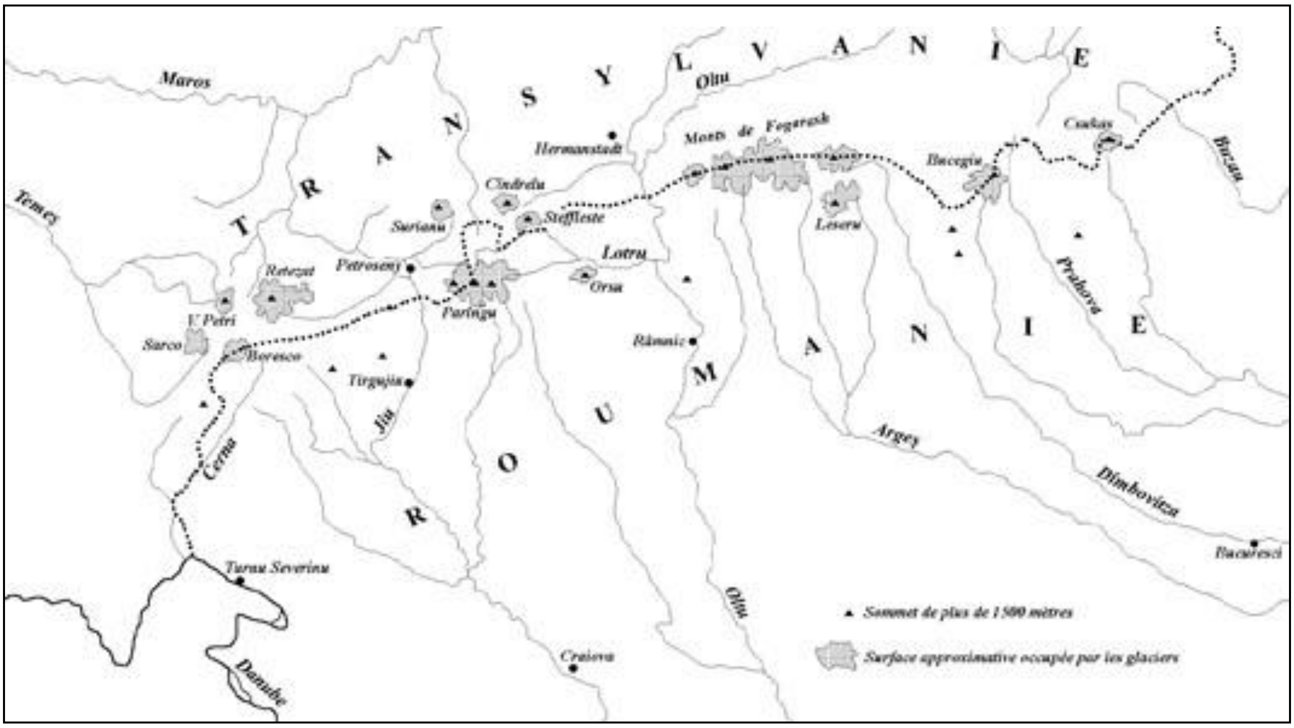

Fig. 1 Glacial extension in the Alps of Transylvania. Emmanuel de Martonne (1900)

In his opinion, the glacial shaping of the landform left in the Alps of Transylvania two very characteristic types of geomorphological landscapes well individualised:

- Borăscu type, present in Godeanu, Ţarcu, Şureanu, Cindrel, Lotru, a part of Retezat and Parâng and the eastern branch of Făgăraş, characterized by a large extension of the platform of the high peaks, spotted with glacial cirques.
- Făgăraş type, present in Parâng, Retezat and Făgăraş, where the cirques propagated and developed till they reduced the platform to a very sharp crest, while the glacial valleys which were descending on the mountain's slopes were themselves separated by sharp crests (gipfelflur).

DATA AND METHODS

The study of the glacial relief from the valley of Vâlsan river started with bureau methods, by this meaning the study of the scientific literature (Urdea, 1994,1998) but which referes especially to others areas from the Făgăraş mountains, the basin of Vâlsan being less known. The numerous field trips consisted in observations, measurements, photographs while studying the existing maps (sc. 1:25000), satellite images LANDSAT ETM +, aerials images. The obtained results were processed with the help of the programs: GLOBAL MAPPER and ARCVIEW 3.2. There were made measurements and map drawings of the glacial

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cirques, of the thresholds and identified the moraines that were under big amounts of detritus, a result of the postglacial cryonival processes.

The Făgăraş Mountains

Until now, there were carried out many studies on the field about the glacial morphology from the Făgăraş mountains. The most well-known are those carried out by **Emm. de Martonne** (1907), **R. Luzerna** (1908), **E. Nedelcu** (1959) (Fig. 2), **I. Sârcu** (1958), **Gr. Posea** (1982) and **M. Florea** (1986, 1989, 1998). Several studies on the morphological and hydrological features of the glacial lakes from the mountains were published by **O. Phleps** (1914), **A. Năstase** (1960a, 1960b) and **I. Pişota** (1956, 1957, 1958). Information about the ice age from the Făgăraş Mountains can be found in the works of **Th. Kräutner** (1930) or **St. Pawlowski** (1936). The Făgăraş Mountains have over 175 glacial cirques (Posea et al., 1974), grouped in glacial complexes, at the source of the hydrographic thoroughfare. On the north slope, between Moaşa (2034m) and Luţele (2176m), a cirque or a group of several cirques may be found at the source of every valley. All the rivers here flow into the Olt: Jibra, Avrig, Şerbota, Sărata, Laiţa, Valea Doamnei, Bâlea, Arpăşel, Arpaşu, Podragu, Ucea Mare, Ucişoara, Viştea Mare, Viştişoara, Sâmbăta, Brezcioara, Urlea, Valea Dejanilor, Berivoiu and Sebeşu. On the southern slope, the cirques form big glacial complexes due to the presence of several hydrographic thoroughfares that are more developed than the northern ones. Here, the glacial landform groups itself at the sources of the rivers Boia, Topolog, Capra, Buda, Vâlsan, Valea Rea, Zârna and Dâmboviţa.The W-E direction of the main crest and the landform ensemble of the two slopes, the northern one –short and steep-, towards the Făgăraş Hollow, and the southern one – long, with gentle slopes, towards the Subcarpathians basins, influenced the manner in which the glaciers developed in the Quaternary. In this way, even if the exposure is not favourable, the longest valley glaciers formed in the south, reaching in numerous cases 7 km in length (Florea, 1998), while on the northern slope the valleys are shorter, at most 5 km, but they are very deep. The glacial cirques are well developed on the northern slope Suru (2283 m) and Luţele (2176 m), having steep walls and deep floor. In some situations, their morphology is complicated by the presence of many horizontal lobes and vertical stairs, as it happens on Laiţa, Arpaş, Sâmbăta or Valea Dejanilor. On the southern slope, there are present suspended cirques at the source of the valleys whose glaciers were coming out onto big glacial valleys as Capra, Buda or Valea Rea.

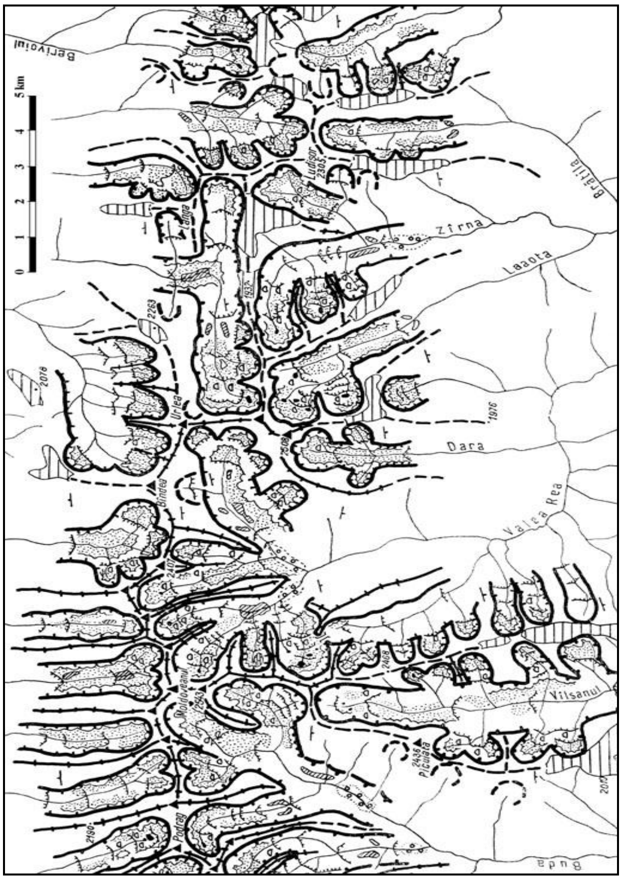

Fig. 2 The glacial morphology of the Făgăraş Mountains. E. Nedelcu (1960)

There occur cirques complexes with many floors, sideway lobes and lacustrian hollows and glacial channels. The glacial valleys of Făgăraş, especially those on the northern slope, have a unique morphology for our country. Because of the local base level, near and very low, represented by the Făgăraş Basin, the preglacial hydrographic thoroughfare became deeper in the slope of the mountain, delimitating the alignment of the secondary crests, perpendicular on the main one (gipfelflur).

The valley glaciers start the glacial modelling from the inferior side of the slopes and from the fluviatile beds. Coarse rock as the crystal schist of the Getic Nappe maintains the secondary crests sharp and high, with steep slopes, while the former fluvial valleys get an U - shape and in the longitudinal profile they have steps. The great relief difference between the surrounding peaks and the former floor of the valley glacier can be found only in the glacial valleys from the Făgăraş Mountains, due to the strong vertical erosion by the preglacial rivers from Făgăraş. For example, we can mention

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the Bâlea, Ucea Mare, Ucişoara, Viştea Mare and Sâmbăta glacial valleys, on the northern slope, or Capra, on the southern one.

The landscape of the glacial valleys is completed by the presence of a system of narrow glacial crests and pyramidal peaks from our country, developed on the both sides of the main crest, between the peaks Şerbota (2331 m) and Urlea (2473 m). These were formed by glacial and periglacial processes and it separates today a good part of the glacial cirques and the valleys. The detailed morphology of the cirques and the valleys is completed by the presence of numerous micro and meso-scale forms, glacial and sculptural forms as the hollows from the erosion of the surface under the glacier filled with lakes, the transfluence saddles, nunataks, roches moutonnées, thresholds and polished surfaces or glacial grooves.

The glacial lakes are on the both sides of the main crest, at an average altitude of over 2000m. Most of them occupy a central position in the glacial cirques; a few are installed on the steps of the glacial valleys, behind the thresholds. 26 lakes have a permanent character, and in the years with more humidity, there can be formed temporary lakes (Pişota, 1971). The frontal and lateral glacial moraines are better kept on the southern wing than on the northern one, where they have been strongly washed by the postglacial erosion, because of the high potential of erosion of the landform, due to the inclined slope of the valley. Concerning the ice ages, the majority of the studies (de Martonne, 1907; Phleps, 1914; Niculescu et al. 1960) bring arguments in favour of the two glacial ages, Riss, when the maximal expansion is reached, and Würm, of less intensity. In 1982, Gr. Posea launches and provides arguments with paleoclimatic and morphological arguments regarding the manifestation of the quaternary ice age in one Würm period, with more levels of evolution.

For the limit of the permanent snows in the Făgăraş Mountains, during the glacial ages, there were obtained different values, depending on the author and on the used method. Lehmann (1885) establishes a value between 1500 m - 2000 m, de Martonne (1907) appreciates it at 1900 m, during the first ice age, and 2100 during the second one, and Lucerna estimates it at 1700 m (Florin, 2005).

The glacial landform of the Vâlsan river basin

The Vâlsan river basin is located between the Doamnei and Argeş rivers, from east to west, on the soutern side of the Făgăraş Mountains. In the Vâlsan basin, we can distinguish certain particularities of the glacial landform. So, the glacial landform of this branch of the Făgăraş mountains is characterized by the presence of a small steep (200-300m), which favoured the development of a long glacial valley with gentle slopes and entailed the moraines sediments at the foot of the valley. During the pre-Quaternary age, through a faster deepening, the valleys pushed their springs towards north, forming several levels of erosion. In a transversal profile, the valleys have a U shape, with periglacial glacises (Nedelea, 2005).

The main glacial forms on the Vâlsan valley

The Vâlsan glacial cirque (Fig. 3) or the Corrie of Vâslan is located at the altitude of 2300 m, it has small dimensions and small lakes, having its springs here.

Fig. 3 The Vâlsan Glacial cirque

The bottom of the cirque is flat, being grafted on mica-schists and gneiss which developed in small hollows made by glacial erosion. The glacial threshold situated at 2000m, with a height of 100 m, is grafted on amphiboles (Fig. 4).

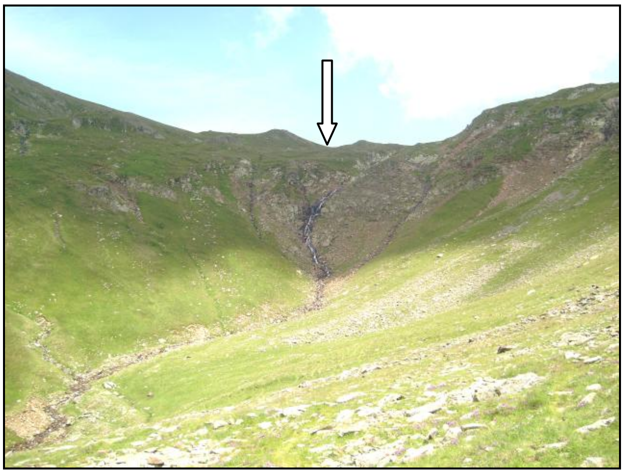

Fig. 4 The Vâlsan glacial threshold

The glacial micro-landform of erosion within the glacial cirques and valleys can be identified with

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difficulty because of the big amount of disintegrated sediments from the slopes (the glacial striations – forms that resulted from the friction between the glacier and the lithological level) (Fig. 5, 7).

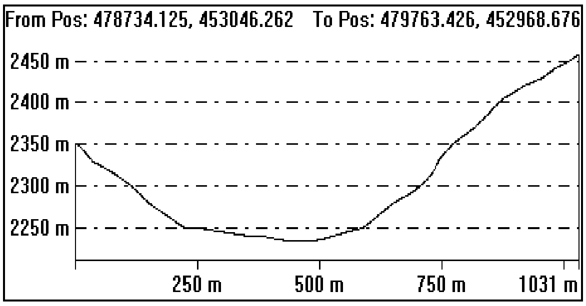

Fig. 5 The Vâlsan glacial cirque, cross section

Fig. 6 The Vâlsan glacial valley

Other landforms that are characteristic to this glacial branch of the Vâlsan valley are: the pyramidal peaks, which can be found on the both sides of the valley, especially on the ridge between Vâslan and Argeş; ***glacis*** and ***roche moutonnées*** (Fig. 6).

The accumulation landforms are represented by detritus resulted from the erosion manifested on the riverbed and the lateral walls by the glaciers, adding the effects of the weathering from the nearby regions, and which is transported by the glaciers, forming **moraines** (Fig. 8, 9).

The periglacial landform

The periglacial domain had an extended development over the Făgăraş Mountains during the Upper Pleistocene. The cryonival processes affected the region situated in the neighbouring of permanent snow. The results of the periglacial processes can be found in the studied area, in the high mountains region, in the alpine and subalpine areas and at the timberline.

The old periglacial sediments are mostly found in the soils and vegetation. The postglacial evolution took place on the background of a transition to a softer climat which induced the modification of the types of processes.

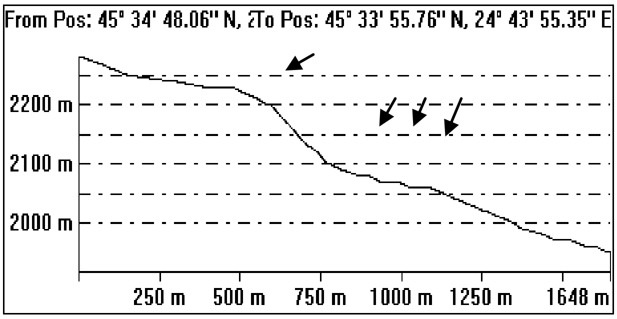

Fig. 7 Longitudinal profile of the valley, with emphasis on structural thresholds grafted onto amphibolites

Fig. 8 Accumulation of debris from the slopes

Fig. 9 The glacial debris in the Vâlsan cirque (west slope exhibition)

For the southern branch of the Făgăraş mountains, a change of the timberline with almost 1000 m can be observed, so a part of the old preglacial sediments were covered (Nedelea, 2005). The cryonival processes imposed themselves and they are in progress in various ways, depending on the local conditions (altitude, the exposure of the slopes, the massivity, and the angle of the slopes, rocks, but also temperature, wind and precipitation amount). Mean temperatures are -2; – 0º C, while the average precipitation amount is 1000 – 1400 mm per year. The snow lasts for 150 – 200 days per year, while the frost days are very numerous.

Micro cryogenic -landform

The gelifraction manifests itself accordingly to the lythological structure on mica-schists, paragneiss, gneiss and dolostones. The result is a ruiniform landform, represented by pyramidal crests: Picuiata, Piatra Tăiată, Scărişoara, etc. (Fig. 10)

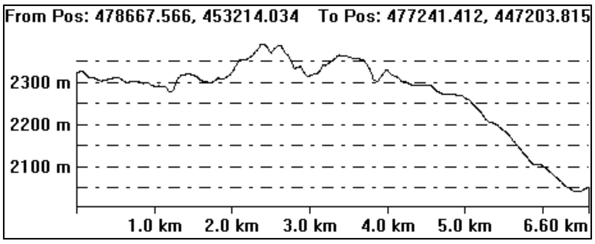

Fig. 10 Profile interfluve where ruiniform apparent appearance, the result of gelifraction (Peak Picuiata)

Periglacial sediments and structures

The screes formed as a result of the gelification. They can be encountered at altitudes of over 1800m and they are widely spread in the Vâlsan valley. The avalanches and the downfalls created the screes that often end up in the bed of the rivers. They formed during the Pleistocene (big masses of scree, fastened by the soil and vegetation), but also during the Holocene (Fig. 11).

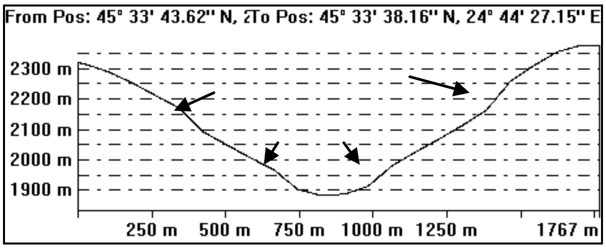

Fig. 11 Cross section highlighting the valley glacial replate (2150-2250 m) and scree cones (1950-2000 m)

Rock glaciers

Rock glaciers are important accumulations of desintegrated material that took the shape of lobes which can move, taking the form of scree flows (Haeberli, 1985). On the Vâlsan valley they are inactive, being covered by the alpine meadow. Judging by relief's aspect, the hillocks' succesion, waves, micro-hollows, some moraines which can be found at over 1800m is possible to have functioned as rock glacier in postglacial era. Nowdays these forms can be met on the eastern and western slope of the valley, at altitudes of 1700-1900m, with a deplyoment of 200-300m lenght, being covered with vegetation and recent gelifracts. They oriented on the deployment direction of the glacial valley, north – south. In spring the temperatures in this sector are 5-6^{0}C, indicating the lack of ice and confirming the fossil character.

Solifluction

Solifluction implies a displacement of the superficial bed, oversaturated with water that produces in general on a waterproof or permeable substratum. The solifluction lobes produce the slopes with slopes of over 25º, being particular especially during spring, and it can be met on alpine meadows above 1500m. This process is accentuated by streaming and surface erosion. The solifluction process is also favoured by the anthropic intervention (sheep paths). They can be met on the both slopes of the glacial valley, but it is more spread on the western slope (the Scărişoara Peak)

Hillocks

They are at over 1800 m altitude (very rarely beyond), on flat surfaces or with slopes of 10 – 15 degrees, on Borăscu surface or in the cirque glacier (Fig. 12). Its diameter measures 0.5 – 1m and they don't get over 0.5m in height. Next to solifluctions, they are very widely spread. The hillocks have an ice core that doesn't melt till late spring. The hillocks are formed from fine materials, from clay and sandy clay with a few stones. They can be encountered on the western slope of the Scărişoara Peak and on the eastern slope of the Piatra Tăiată Peak. Their shaping is due to the gelifluction processes, in humid conditions and to seasonal ice which favours cryoturbation.

Fig. 12 Hillocks

Nival micro-landform

Avalanche corridors present a higher frequency in the superior branch of Vâlsan, being at over 1900 m. These corridors have a higher frequency on the left side of Vâlsan's valley. The avalanche corridors

  DOI: 10.5775/fg.2067-4635.2011.008.i

from here are large, and at their basis we can see important amounts of screes (Fig. 13).

Fig. 13 Avalanche corridors - Scărişoara Mare 2489m

Nival micro-hollows develop themselves on the slopes, at their basis in the deposits of scree or on the ridge surfaces with a reduced slope. They can be located on the Borăscu platform and on the Ţuica Peak. Other landforms which can be found in the nival micro-landform are: nival niches on the western slopes of the Vâlsan's valley and the protalus ramparts (accumulation forms found at the basis of the nival niches) (Fig. 14).

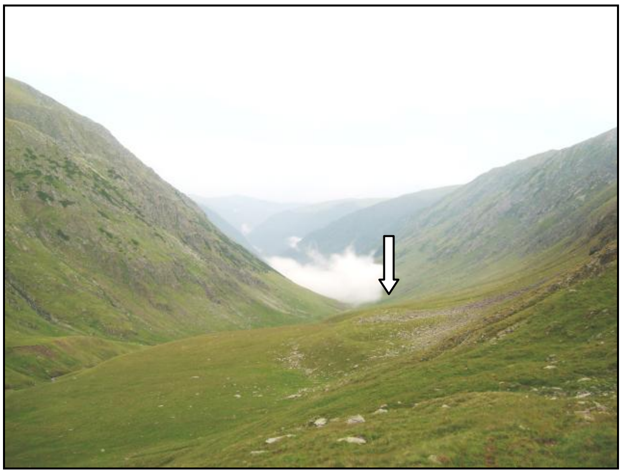

Fig. 14 The protalus ramparts on the right side of the glacial valley

CONCLUSION

The Vâlsan glacial valley is a typical valley, where the intense postglacial processes have hidden the most of the characteristic elements resulted from the action of the ice. The reduced slope determined the modelling of a prolonged glacial valley, which keeps the characteristic U – shape, and the glacises show up from place to place under the foothill scree. The manifestation of the postglacial cryonival processes determined the covering of the bottom of the valley with scree on wide areas, the water of the river getting deeper until the basis level, uncovering the old thresholds imposed by the structure or, on certain zones, it created meanders imposed by avalanches and scree cones. The advancement of the timberline in the postglacial area makes difficult the field reasearch, often being necessary that the studies and the estimations to be made on the basis of the information from the topographical and geological maps (Fig. 15).

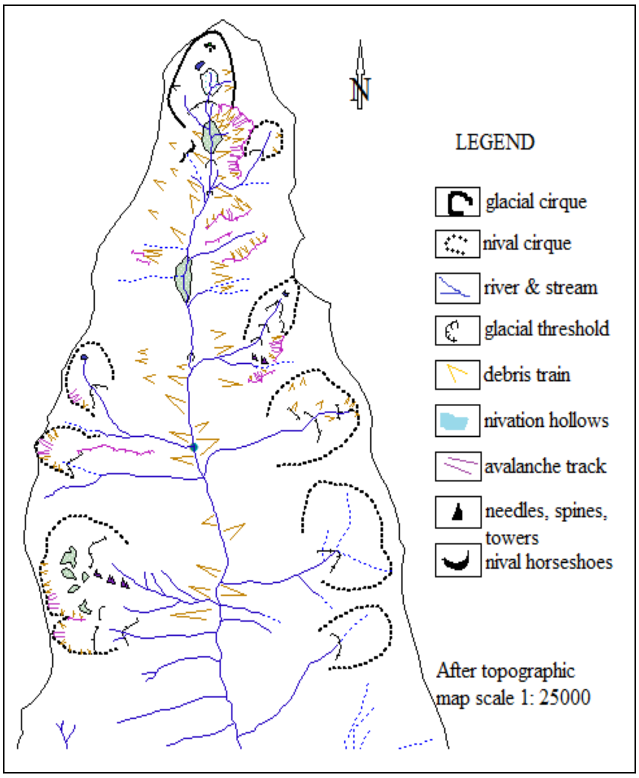

Fig. 15 The glacial landforms in the Vâlsan river basin (drawn by the author, after the topographic map, scale 1:25000)

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 35-49
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.015.i

Typological and Morphometric Characteristics of the Glacial Cirques in Doamnei River Basin (Făgăraş Massif)

Smaranda SIMONI[1]

[1]University of Piteşti, Faculty of Economics, e-mail: tsmaranda@yahoo.com

Received on < December 30, 2010>, revised on < February 2, 2011>, accepted on <April 26, 2011>

Abstract

The Doamnei River basin, situated on the southern slope of the Făgăraş Massif, is a proper field to study the glacial landforms, because it preserves the two types of glacial landscape identified by Emm. De Martonne even since 1907 for the Meridional Carpathians: the Făgăraş glacial landscape (typical alpine landscape) and the Borăscu glacial landscape. This paper intends to explain some theoretical and practical aspects regarding the correct definition and identification of glacial cirques, and to provide a glacial typology that includes morphological, genetic and topographic criteria. The paper also contains a geomorphologic map (the result of a more extensive analysis) of the glacial landforms in the Doamnei River basin (with 7 glacial complexes, isolated glacial cirques, glacio-nival cirques), the periglacial landforms and the Borăscu erosion surface.

Keywords: *glacial cirques, typology, morphometry, geomorphologic map, Doamnei River basin, Făgăraş Massif*

Rezumat. Caracteristici tipologice şi morfometrice ale circurilor glaciare din bazinul Râului Doamnei (Masivul Făgăraş).

Bazinul Râului Doamnei, situat pe versantul sudic al Masivului Făgăraş, este un teren adecvat de lucru pentru studiul reliefului glaciar, deoarece cuprinde cele două tipuri distincte de peisaje glaciare identificate de Emm. De Martonne încă din 1907 în Carpaţii Meridionali: peisaj glaciar de tip Făgăraş (peisaj alpin tipic) şi peisaj glaciar de tip Borăscu. Lucrarea încearcă să lămurească unele aspecte teoretice şi practice legate de definirea corectă şi identificarea circurilor şi văilor glaciare, oferind o tipologie glaciară care include criterii morfologice, genetice şi topografice. De asemenea, lucrarea cuprinde şi o hartă geomorfologică (rezultat al unei analize mai ample) a reliefului glaciar din bazinul Râului Doamnei (cu cele 7 complexe glaciare, circuri glaciare izolate, circuri glacio-nivale), alături de formele periglaciare şi suprafaţa de nivelare Borăscu.

Cuvinte-cheie: *circuri glaciare, tipologie, morfometrie, harta geomorfologică, bazinul Râului Doamnei, Masivul Făgăraş*

INTRODUCTION

The eastern-central part of the southern side of the Făgăraş Massif corresponding to the Doamnei River basin (Fig.1) preserves considerable fragments of all Carpathian erosion surfaces originally combined with relict glacial landforms to form a unique and representative landscape of the Romanian glaciated mountain areas.

The mountain basin of the Doamnei River is characterized by a typical alpine, subalpine and mountainous morphology. The main features of this subunit are: prevalence of high hypsometric steps (Fig. 1) that exceed 1600m altitude (including 4 peaks over 2500m and 18 peaks over 2400m); high values of landform energy (400-600m, exceeding 1000m locally for the areas adjacent to the glacial valleys); high and steep slopes (predominant slopes of and over 30^0-50^0); high massiveness; well developed river network, with a characteristic river density of 2-4 km/sq.km; slopes moderately (W, SE) and well (S, SW) exposed to solar radiation.

Geology is represented by the mesozone crystalline rocks (micaschists, gneisses, paragneisses and insertions of crystalline limestones and especially amphibolites). The lithologic complexes are arranged in parallel east-west stripes and most of them belong to the Argeş Nappe (Cumpăna Unit), except for the main Făgăraş ridge (Fig. 2) that belong to the Moldoveanu Nappe (Supragetae Unit).

The two types of glacial landscape identified by Emmanuel De Martonne for the Meridional Carpathians even since 1907 have their counterparts in the intramontane basin of the Doamnei River. The north-western intramontane basin shows a typical alpine landscape (glacial landscape of Făgăraş type, Fig. 3): alpine ridges and sharp peaks that form two distinct gipfelflur (Sârcu, 1958) levels, separated by large glacial cirques and valleys. The great variety of landforms (sharp ridges and arêtes, horns, deep glacial cirques and valleys, high and steep glacial thresholds, deep cols, truncated spurs, etc.) is controlled by aspect, structure and lithology. To the east and south, there is gradual passing to the glacial landscape of Borăscu type, with a large extent of the Carpathian pediplaine, fragmented from place to place by smaller glacial cirques (Fig. 4). In addition the relict and actual periglacial landforms, the fluvial, structural and lithological landforms occur.

The glaciers have occupied the heights of the Meridional Carpathians since Riss and continued in Würm. The most favourable climatic conditions for valley glaciers were in Riss, Würm I and Würm III. There are questions regarding the number and age of the glacial stages that affected the Meridional Carpathians (Niculescu, et al. 1960; Niculescu, 1965; Nedelcu, 1965; Posea et al., 1974; Reuther et al., 2004; Urdea, 2004, 2005). Almost all researchers of the last century concluded that there were two distinct glacial stages: the first glacial stage, older and more extended, favored large valley glaciers that shaped the mountains at 1050-1300m or 1300-1450m altitude (according to different authors) and some terminal moraines preserved partially; the second glacial stage, more recent and shorter than the previous, favored glaciers that descended to 1300m or 1600-1800m altitude (according to different authors) and left better preserved moraines arranged in stairs, corresponding to their retreat periods. There is still the problem of dating these two glacial stages. Most researchers accept either a Riss stage and a Würm stage with three periods, or one Würm stage with four periods.

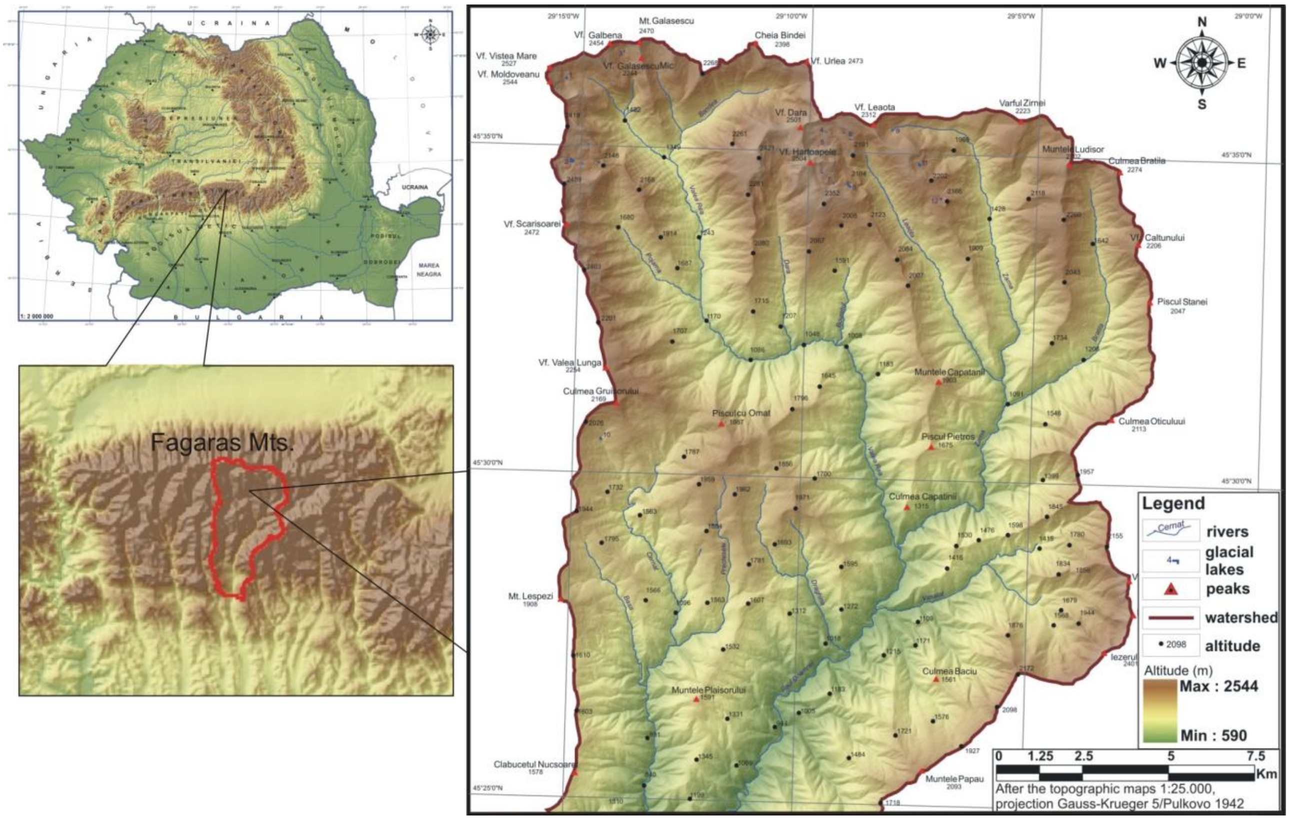

Fig. 1 The location of the studied area: the mountain basin of Doamnei River – area with relict glacial landforms

DATA AND METHODS

The identification of the 36 glacial cirques in Doamnei River basin (Fig. 5) is based on:

- the existing topographic maps (scale 1:25000, editions I, II, 1982-1983);
- the digital maps made in the programs ArcView GIS 9 and CorelDraw 11 (starting from the above mentioned topographic maps);
- the comparison of the digital maps with a satellite image LANDSAT ETM+2000, made at 705 km height on April 15, 1999;
- the existing references (Nedelcu, 1959; 1962);
- the field observations, surveys and photographs made in 2001-2006.

DISCUSSIONS

Glacial cirque operational definition, identification and delimitation in the basin of Doamnei River

The glacial cirque - *căldare, zănoagă, hârtop* (Romanian), *cirque* (French), *corrie* (Scotch), *cwm* (Welsh), *kar* (German), *nisch* (Swedish), *oule* (in the Pyrenees), *botn* and *kjedel* (Scandinavia) – is well known to be the most characteristic form of

  DOI: 10.5775/fg.2067-4635.2011.015.i

glacial erosion. Therefore it is important to start from a unanimously accepted definition of the glacial cirque and its distinct morphologic elements, and to find an accurate method of glacial cirque identification and delimitation.

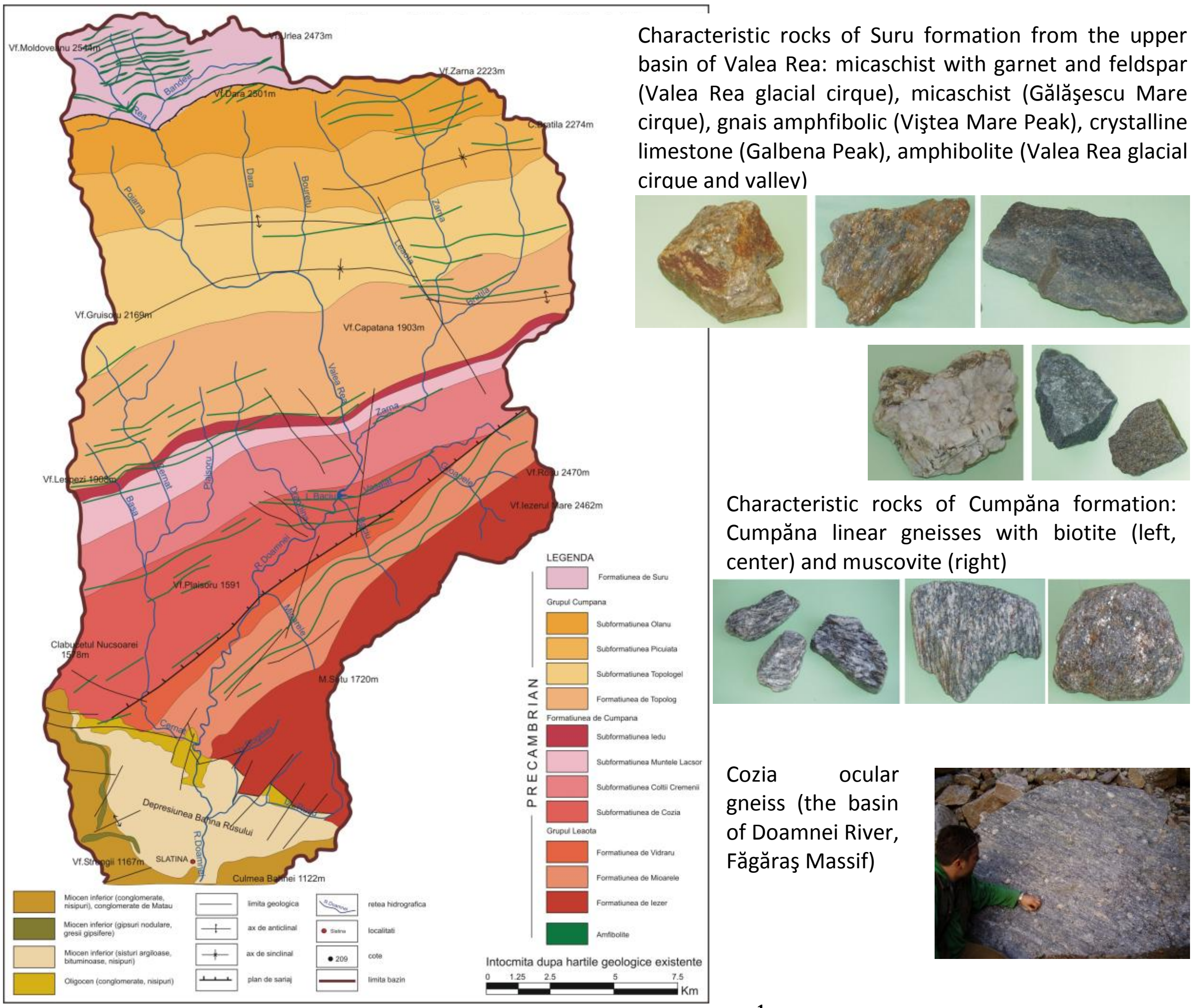

Fig. 2. The geological map of the mountain basin of Doamnei River[1] (with representative rock samples)

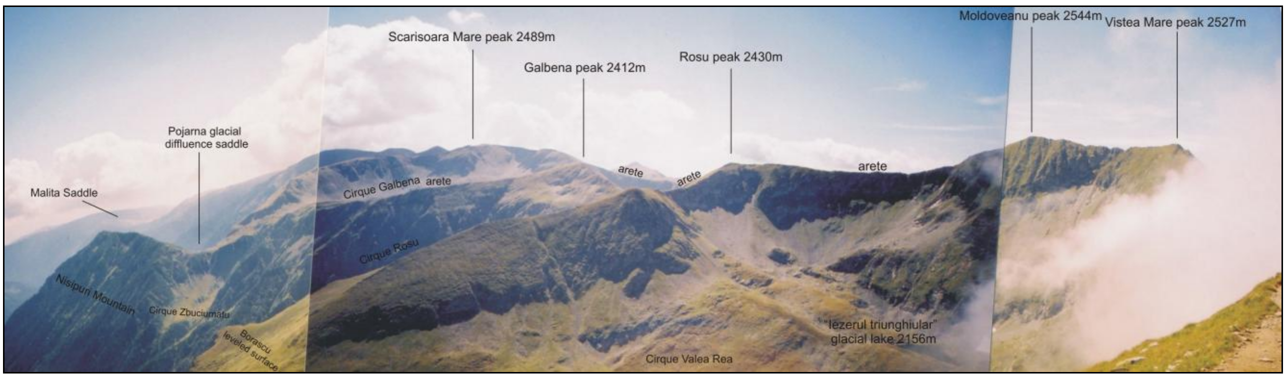

Fig. 3. Alpine landscape (of Făgăraş type) in Doamnei River basin: Valea Rea glacial complex

[1] This geological map is the result of a complex study that involved field research and reference study (Balintoni et al., 1986; Codarcea, Stancu, 1968; Gheuca, 1988; Pană, 1990; Harta geologică a R.S.R., scara 1:200000, foaia 92 c Sibiu, 1975; Harta geologică a R.S.R., scara 1:50000, foaia 109 c Cumpăna, 1985).

DOI: 10.5775/fg.2067-4635.2011.015.i

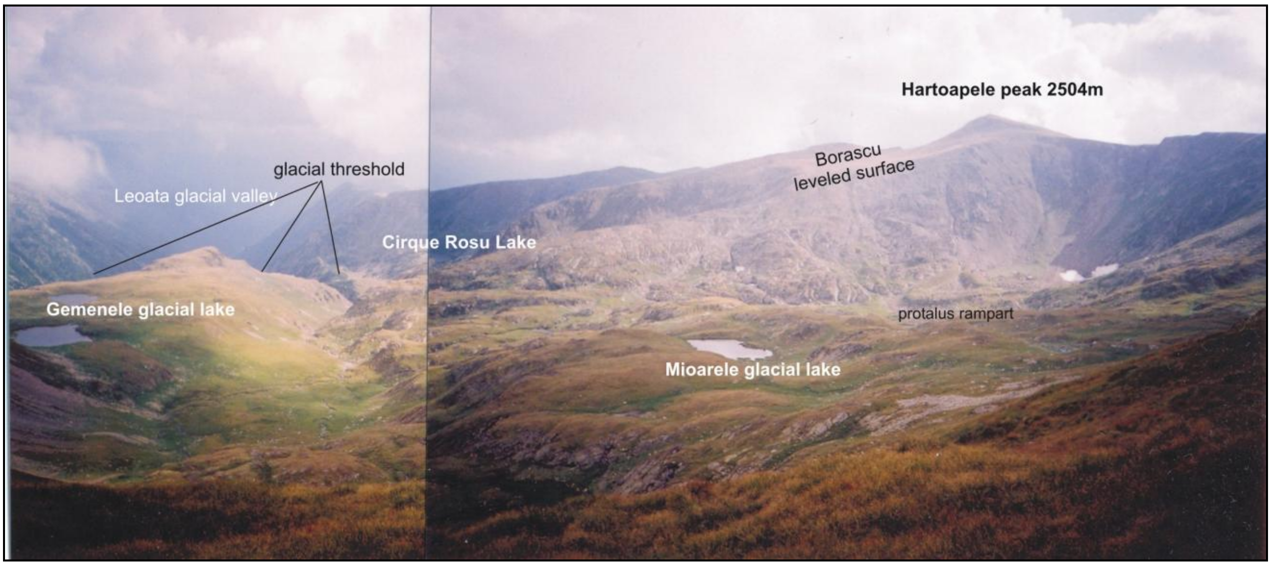

Fig. 4. Landscape with glacial cirques (of Borăscu type) in Doamnei River basin: Hârtoapele Leaotei glacial complex

There have been many definitions of the glacial cirque, but the definition accepted by most geomorphologists was formulated by I.S.Evans and N.Cox in 1974: *„A cirque is a hollow, open downstream but bounded upstream by the crest of a steep slope (headwall) which is arcuate in plan around a gentler sloping floor. It is glacial if the floor has been affected by glacial erosion while part of the headwall has developed subaerally, and a drainage divide was located sufficiently close to the top of the headwall (the cirque crest) for little or none of the ice that fashioned the cirque to have flowed in from outside". Generally, the headwall slope exceeds 35^0, and the floor slope is lower than 20^0. The floor slope is lower than the slopes of the upstream headwall or the downstream threshold.*

In most cases, the glacial cirque is made up of a rounded basin, partially closed by steep walls, that sometimes holds a small lake or cirque glacier (Embleton and Hamann, 1988). In 1976, A.S. Trenhaile defined a mature cirque as *"one with an arcuate plan shape, a steep headwall, a gently sloping floor, and a raised lip".*

A glacial cirque has three distinct morphologic elements: *the headwall,* arcuate in plan, *the glacial floor* or basin, often concave, and *the glacial threshold*. These elements help distinguish the glacial cirques among other landforms of amphitheatre shape (torrential basins, landslide scarp, etc.). Though cirque sizes vary, the proportions of well developed (mature) cirques are similar enough at first sight to recognize them (Embleton and Hamann, 1988). Comparing the results of glacial cirque research from different regions of the world, Derbyshire and Evans (1976) concluded that a common glacial cirque would have 700m in length, 250m in width, an area of 0.4 sq.km, an average slope of 20^0-30^0 (average slope above 45^0 or below 12^0 should be considered suspicious, as they do not provide conditions of rotational ice flow).

The 36 glacial cirques we identified in the studied area have distinct characteristics due mainly to the influence of preglacial landforms and aspect, and less local tectonics, structure and lithology. They are grouped in glacial complexes at the springs of Doamnei River and its tributaries: Valea Rea, Pojarna, Bândea, Dara, Leaota, Zârna, Brătila, to which there are added some additional isolated cirques. The geomorphologic map (Fig. 6) shows the glacial landforms in the Doamnei River basin, with 7 glacial complexes, isolated glacial cirques, as well as nival cirques, periglacial landforms and fragments of the Borăscu erosion surface.

Glacial cirque classification in the basin of Doamnei River

The geomorphologic refereces provide different classifications of the glacial cirques:

- according to the genetic criterion and the glacier type (Evans and Cox, 1974);
- according to the size category, Evans and Cox (1974) introduced a classification similar to the hydrographic basins, with maximum 3 classes;
- according to the qualitative criterion, meaning the development degree of a cirque, Trenhaile (1976) distinguished between mature and immature cirques. We consider mature cirques those with well defined headwalls, extended floor of low slope, formed by the coalescence of more lobes and having sometimes more steps (for examples the Valea Rea, Buduri, Galbena, Bândea, Hârtoape,

  DOI: 10.5775/fg.2067-4635.2011.015.i

Lacul Roşu, Zârna, Jgheburoasa, Scărişoara Mare cirques). The immature cirques have less defined elements, a relative uniform slope crest – headwall – floor; the floor is small, but it has a lower slope.

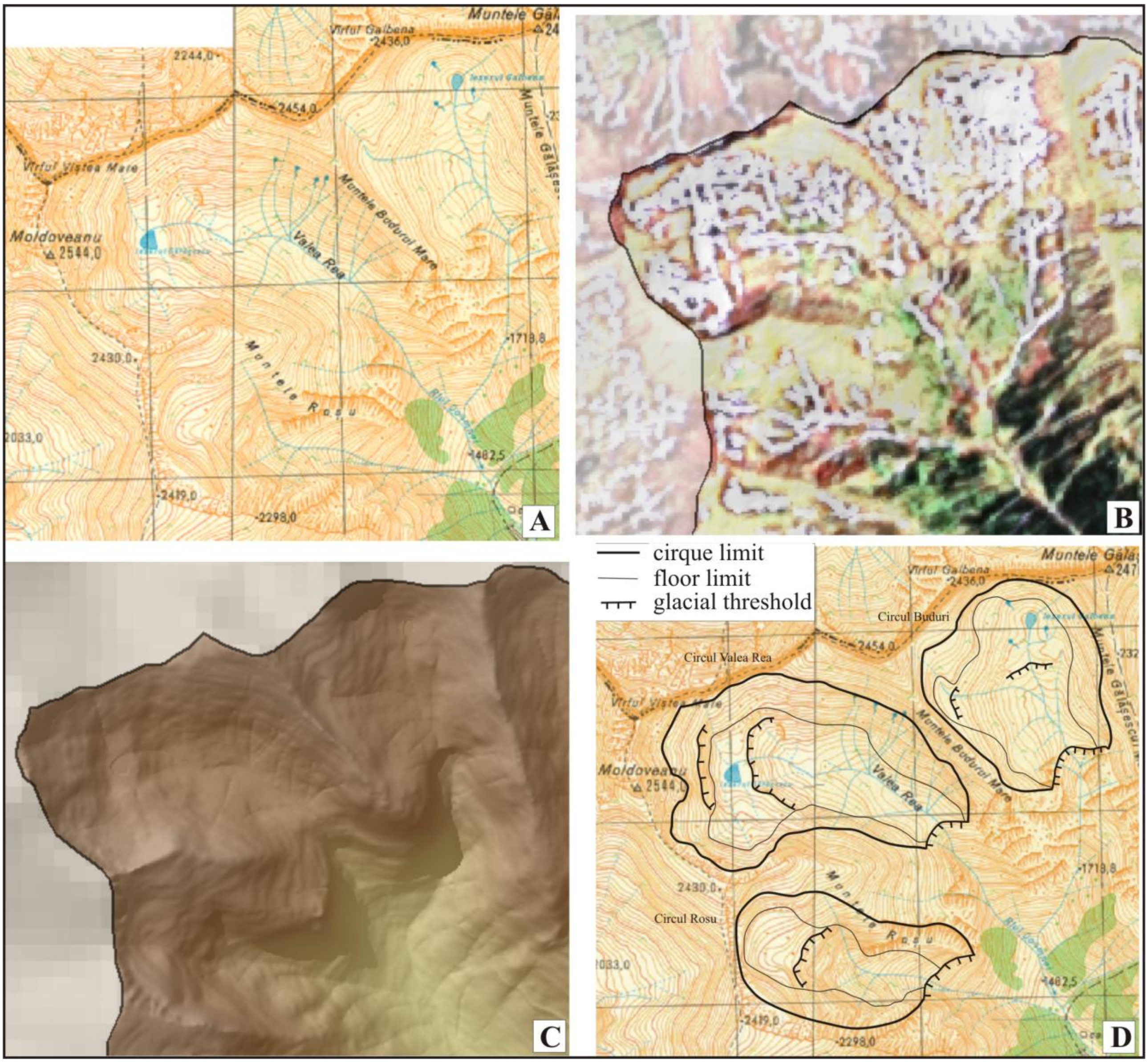

Fig. 5. Glacial cirque identification using the topographic map (A), a satellite image LANDSAT ETM+ (B), the digital model (C) and cirque delimitation (D)

- They are located laterally and hang above a major glacial valley, just below the Borăscu erosion surface (for examples the Ludişor Sud, Jgheburoasa Sud, Boureţu, Dara Est, Bândea Vest, Mutătoarea Sud, Mocanul cirques). In the case of the Doamnei River basin, one may add another cirque category of intermediate development stage, with one or two steps less defined and intermediate sizes compared to the first mentioned two categories (for examples the Scărişoara Mică, Tăiat, Maliţa, Gălăşescu Mare, Dara West, Brătila cirques), a fact proven by the morphologic analysis herein;
- according to the cirque general form, L. Vilborg (1977) classified these glacial landforms into well developed cirques, less developed cirques, shallowed cirques and destroyed cirques;
- according to the genetic criterion combined with that of cirque location in relation to major valleys, A.S. Trenhaile (1976) found the groupings: valley-head cirques (simple or twinned), valley-head complexes (simple or twinned), valley-side cirques (simple, twinned or valley-side complexes), isolated cirques (simple, twinned or isolated cirque complexes), and in addition nivation hollows and mass movement hollows;

DOI: 10.5775/fg.2067-4635.2011.015.i

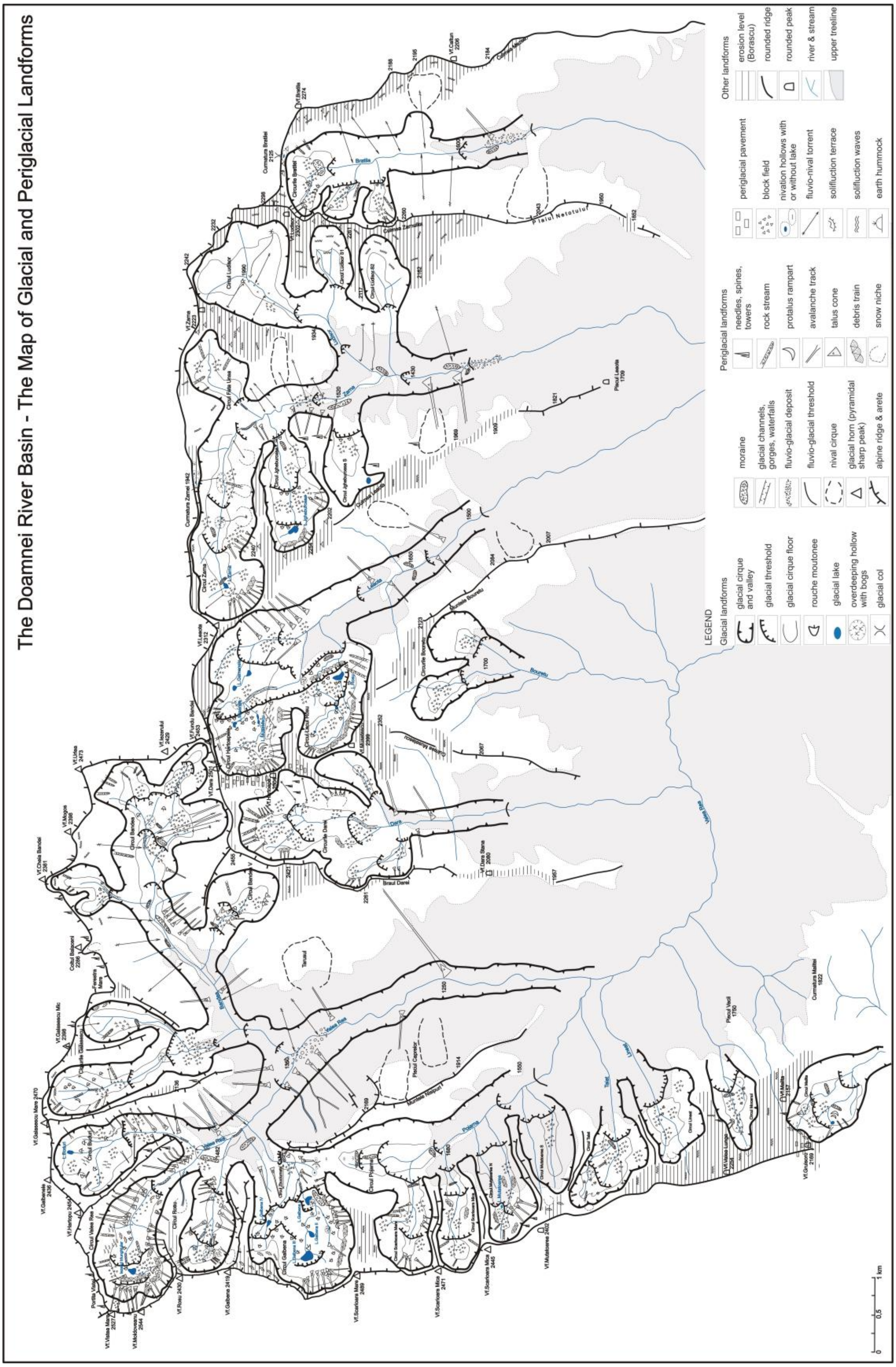

Fig. 6. The Doamnei River basin: the map of glacial and periglacial landforms[2]

[2] This geomorphological map is the result of a more complex study that involved field research and the existing reference study (Barco, Nedelcu, 1974; Coteț, Nedelcu, 1976; Evans, 1969, 1977; Grigore 1979; Ielenicz, 2004; Popescu, Ielenicz, 1981; Popescu, 1984; Posea, Grigore, Popescu, Ielenicz, 1974; Posea, Popescu, Ielenicz, Grigore, 1987; Simoni, 2005, 2008; Simoni, Flueraru, 2006; Sîrcu, 1958; Summerfield, 1994; Monografia geografică a R.P.R., 1960; Enciclopedia geografică a României, 1982; Geografia României, 1983, 1987; Geomorphology: Critical Concepts in Geography, vol.IV. Glacial Geomorphology, 2004).

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- according to the form in plan, probably the most important characteristic of the glacial cirque, Gh. Niculescu (1965) and other geographers (Nedelcu, 1965; Posea et al., 1974; Urdea, 2000, 2005; Toma, 2001) established the following cirque types, characteristic of the Romanian Carpathians:

- *simple cirque*, with moderate sizes, well defined elements (floor, headwall, threshold), semicircular contour, no steps. Examples of such simple cirques in the Doamnei River basin are: the Zbuciumatu, Cheia Bândei, Bândea Vest, Brătilei cirques, Pojarna, Lineaţ, Maliţa, Boureţu cirques;
- *elongated cirque*, an intermediate cirque-valley form, widely open toward the glacial valley, and its length at least one and a half higher than its width (Niculescu, 1965). In the Doamnei River basin, most elongated glacial cirques have steps (twinned elongated cirques) and the last threshold toward the glacial valley is the highest: Roşu, Gălăşescu Mare, Gălăşescu Mic, Dara West, Zârna, Jgheburoasa Sud, Faţa Unsă, Ludişor Sud, Scărişoara Mică, Mutătoarea North and Mutătoarea South;
- *complex/ compound/ conjugated cirque*, made up by the joint of two or more lobes, separated by small crests, and therefore having a festooned contour. In the studied area, these cirques would belong to the category of mature cirques, well developed, with steps (twinned), having large sizes: Valea Rea, Buduri, Galbena, Dara, Hârtoape, Roşu Lake, Jgheburoasa, Ludişor, Scărişoara Mare, Tăiat;
- *„cirque in cirque" type* has the headwall festooned by smaller cirques of nivation hollow aspect. These smaller cirques have small floor, but all converge to the floor of the "mother" cirque which is larger, located at a lower altitude and bounded by a headwall actually representing the thresholds of the smaller hanging cirques. The only example in the studied area is Bândea glacial cirque;
- *glacial complexes/ cirque complexes* represent a grouping of different types of glacial cirques (simple, elongated, complex), with different locations in relation to major valley (valley-head, valley-side), separated by crests, ridges, peaks, all situated at the origin of a major glacial valley. The following glacial complexes developed in Doamnei River basin: Valea Rea, Bândea, Dara, Leaota, Zârna-Ludişor and Pojarna (detailed analysed in my PhD thesis).

Other glacial cirque classifications (Nedelcu, 1959; Niculescu et al., 1960; Velcea, 1961; Urdea, 2000; Toma, 2001) are based on other qualitative criteria:

- the relation with the structure: consequent, obsequent and subsequent cirques;
- the cirque aspect;
- the cirque form in the long profile: twinned cirques (with steps) and simple cirques (without steps). There are many causes of cirque step formation: the change/ lift of snow limit (Taylor, 1914, quoted by Embleton and King, 1975), the intermittent lift of mountain area (Fels, 1929, quoted by Embleton and King, 1975), the simultaneous formation by ice joint between cirques located at different altitudes (Cotton, 1942, quoted by Embleton and King, 1975), the existence of more glaciations of different magnitudes (Seddon, 1957, quoted by Embleton and King, 1975);
- the shape of the cross profile: symmetrical and assymmentrical cirques.

These classifications correspond, or may be applied to the regions the respective studies were performed. Therefore, for a better characterization of the glacial cirques in the studied area, we tried to combine these classifications within a taxonomic system that includes suitable morphologic, genetic and topographic criteria (Table 1).

The advantage of this classification resides in the combination of many classification criteria, so that anyone looking such table may state a few general, but important characteristics of a glacial cirque. For example, Roşu glacial cirque belongs to Valea Rea glacial complex, is located valley-side to the homonymous glacial valley, elongated, twinned (with steps), symmetric and subsequent. The morphometric characteristics and correlations add details to these general characteristics.

Glacial cirque morphometry

The detailed morphometric analysis (including the morphometric correlations) of the 36 glacial cirques in Doamnei River basin aims at stating some conclusions regarding the distribution, genesis, shape and size of glacial cirque population (Table 2).

DOI: 10.5775/fg.2067-4635.2011.015.i

Table 1
Glacial cirque classification in Doamnei River basin

Classification criteria		Location in relation to major glacial valley		Form in plan				Shape of long profile		Shape of cross profile		Relation to structure		
Glacial complex	*Cirque name*	valley-head	valley-side	complex (cmpound)	cirque in cirque	elongated	simple, semicircular contour	twinned (with steps)	simple (without steps)	symmetric	asymmetric	consequent	subsequent	obsequent
Valea Rea	Valea Rea	*		*				*			*		*	
	Buduri		*	*				*		*		*		
	Roşu		*			*		*			*		*	
	Galbena		*	*				*			*		*	
	Zbuciumatu		*				*		*	*				*
Bândea	Bândea	*			*			*			*		*	
	Cheia Bândea		*				*		*	*		*		
	Bândea West		*				*	*			*		*	
	Gălăşescu Mare		*			*		*		*		*		
	Gălăşescu Mic		*			*			*	*		*		
Dara	Dara	*		*				*		*		*		
	Dara West		*			*		*			*		*	
	Dara East		*			*			*		*		*	
Leaota	Hârtoape	*		*				*			*		*	
	Lacul Roşu		*	*				*			*		*	
Zârna - Ludişor	Zârna	*				*		*			*		*	
	Jgheburoasa		*	*				*			*		*	
	Jgheburoasa S.		*			*		*			*		*	
	Faţa Unsă		*			*			*		*		*	
	Ludişor		*	*				*			*	*		
	Ludişor South 1		*			*			*		*		*	
	Ludişor South 2		*			*			*		*		*	
Brătila	Brătila	*					*		*	*		*		
	Brătila South 1		*				*		*		*		*	
	Brătila South 2		*				*		*		*		*	
Pojarna	Pojarna	*					*	*		*		*		
	Scărişoara Mare		*	*				*			*		*	
	Scărişoara Mică		*			*		*			*		*	
	Mutătoarea N.		*			*		*			*		*	
	Mutătoarea S.		*			*			*		*		*	
Isolated cirques	Tăiat			*				*			*		*	
	Lineaţ						*		*		*		*	
	Mocanul						*		*		*		*	
	Maliţa						*	*		*		*		
	Bouretu West						*		*	*		*		
	Bouretu East						*		*	*		*		

The glacial cirque morphometry was analysed in order to:

- identify the glacial cirques and differentiate them among other landforms (nival cirques, nival niches, torrential basins, etc.);
- establish their sizes and shapes;
- find relations between glacial cirque size and shape;
- establish the importance of different parameters of glacial cirque size, shape and localtion;
- design models of glacial cirque development in a certain area and/ or glacial complex.

Figure 7 shows the main lines that define a glacial cirque. It is more difficult to map correctly the cirque limit or the cirque crest on the topographic maps; one should consider that the upper headwall evolved under supraglacial conditions, and this contour line includes all the contour lines widely concave toward the cirque, of circular shape, having a steep wall upstream (headwall). In case a cirque is directly cut in the Borăscu erosion surface, the delimitation is simple, as the steep headwall is easily observed (e.g.

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Jgheburoasa, Maliţa cirques, etc.). But there are many cases (especially the glacial cirques located below the Făgăraş main ridge) where above the upper cirque limit there are sharp ridges and pyramidal peaks representing fragments of a relief older than the glacial one, although they were eroded during the glacial periods under supraglacial periglacial conditions and it is a mistake to include them within the glacial cirques. Therefore it is important to combine field observations with satellite images, digital maps and topographic maps in order to map correctly the separation line between the cirque headwall and the steep slope of the ridge or pyramidal peak above.

Secondly, one should trace a separation line between cirque floor and headwall. The secondary thresholds within the cirque are considered part of the floor. The ideal floor gradient is below 200, while the ideal headwall gradient exceeds 350, and the limit between them should be traced at about 270 (Evans and Cox, 1995).

Figure 7 and Table 3 show the main lines and elements that define a glacial cirque, while Table 2 shows the 26 morphometric parameters calculated and analysed for the 36 glacial cirques in the studied basin. The morphometric parameters introduced by I.S.Evans and N.Cox in 1995 are generally used in such studies. We added other parameters that we consider important for a better morphometric characterization of the glacial cirques (Table 2).

Table 2
The morphometric parameters of a glacial cirque

No.	*Morphometric parameter* [3]	*Unit of measurement*	*Method of calculation*	*Category*
V1	Lowest floor altitude (lowalt)	m		
V2	Medium floor altitude (flooralt)	m	(V3 + V1) / 2	
V3	Maximum floor altitude (maxflalt)	m		
V4	Crest altitude on median axis (medcralt)	m		
V5	Median cirque altitude (medalt)	m	(V4 + V1) / 2	altitudes
V6	Maximum crest altitude (maxcralt)	m		
V7	Maximum above, within area draining into cirque (maxabalt)	m		
V8	Height on median axis (H)	m	V4 – V1	
V9	Maximum floor amplitude (maxflampl)	m	V3 – V1	
V10	Length of median axis, crest to threshold (L)	m		
V11	Maximum width perpendicular to the median axis (W)	m		
V12	Headwall height crest to floor, on the median axis (wallht)	m	V4 – V3	
V13	Width/ length ratio (widlen)		V11 / V10	
V14	Length/ width ratio (lenwid)		V10 / V11	sizes
V15	Length/ height ratio (lenH)		V10 / V8	
V16	Perimeter (P)	m		
V17	Floor area (flS)	km^2		
V18	Cirque area (S)	km^2		
V19	Relative size	km	V18 / V8	
V20	Main size	km^3	$2 \cdot V18 \cdot V8 / 3$ (measured) $\pi \cdot V10 \cdot V11 \cdot V8 / 6$ (calculated)	
V21	Circularity index (CI)		$4 \pi \cdot V18 / V16^2$	
V22	Aspect of median axis (axgrad)	degrees		aspects
V23	Relative aspect			
V24	Axial gradient (axgrad)	degrees	arc sin (V8/ V10)	
V25	Medium floor gradient (medflgrad)	degrees	arc sin (V9/ L floor)	slopes
V26	Medium wall gradient (medwallgrad)	degrees	arc sin (V12/ L headwall)	

[3] The letter symbols of the morpfometric parameters are those introduced by Evans, Cox, in 1995.

DOI: 10.5775/fg.2067-4635.2011.015.i

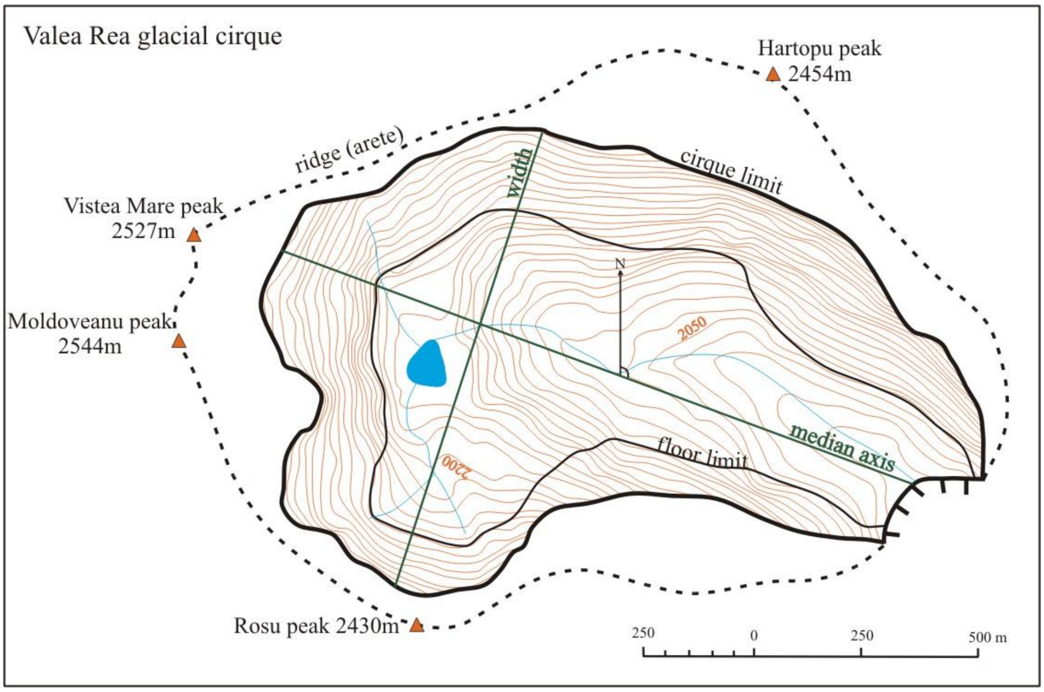

Fig. 7. The main lines that define a glacial cirque (e.g. Valea Rea glacial cirque)

Table 3

The morphometric parameters that define a glacial cirque (e.g. Valea Rea glacial cirque)

No.	*Morphometric parameter*	***Value***	*No.*	*Morphometric parameter*	***Value***	*No.*	*Morphometric parameter*	***Value***
V1	lowalt	2000 m	V11	W	1125 m	V21	CI	0.73
V2	flooralt	2125 m	V12	wallht	140 m	V22	axgrad	110^0
V3	maxflalt	2250 m	V13	widlen	0.75	V23	exp	E
V4	medcralt	2350 m	V14	lenwid	1.33	V24	axgrad	13^0
V5	medalt	2175 m	V15	lenH	4.28	V25	medflgrad	9.5^0
V6	maxcralt	2350 m	V16	P	4475 m	V26	medwallgrad	38^0
V7	maxabalt	2544 m	V17	flS	0.60 km^2	V27	overdeepening hollow with lake/ lakes	*
V8	H	350 m	V18	S	1.17 km^2	V28	overdeepening hollow with bog/ bogs	*
V9	maxflampl	250 m	V19	relsize	3.34 km			
V10	L	1500 m	V20	V	0.29 km^3			

The morphometric parameters of the glacial cirques seem to vary within certain limits and average values for most areas studied by now. A glacial cirque is a landform that allows a very efficient ice flow and therefore the mature cirques tend to similar forms and sizes, similar and constant size ratios, no matter their locations. The differences are caused by local factors (topography, climate – the duration and intensity of the frost period(s), structure, lithology, tectonics). Therefore we analized each morphometric parameter, considering its medium and extreme (minimum and maximum) values, and explaining each situation (general rule, exceptions, influencing factors and comparisons with the entire Făgăraş Massif and, if possible, with other mountain regions studied by other researchers).

The morphometric analysis of the glacial cirques in Doamnei River basin[4] provided interesting conclusions regarding the distribution, genesis, form and size of cirque population. All types of glacial cirques developed here, from the point of view of form in plan (simple, elongated, complex, cirque in cirque), shape of long profile (simple, twinned/ with steps), location in relation to the

[4] A detailed analysis of the glacial cirques in Doamnei River basin is the subject of a future paper.

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major glacial valley (valley-head, valley-side), affiliation to a glacial valley (glacial complexes/ cirque complexes, isolated cirques). From the point of view of cirque sizes (length, width, perimeter, area, volume/ main size), all cirque categories (large, medium/ common – lightly more numerous, and small) are equally represented in the studied basin.

Large glacial complexes, with well developed or mature cirques (large sizes, large floors of low gradient, evident headwalls, impressive glacial thresholds) developed under the main ridge (corresponding to the studied basin) of the Făgăraş Mountains. Under the secondary ridges (cut in the fragments of the Borăscu erosion surface, or on sheltered slopes), there are either valley-side (often hanging) or isolated glacial cirques; in both cases, these cirques have less developed elements (smaller size, small floor with higher gradient, smaller thresholds) and therefore belong to the immature cirque category.

Most morphometric parameters show the difference between very large and well developed cirques (Galbena, Valea Rea, Buduri, Bândea, Dara, Hârtoape, Lacul Roşu, Zârna, Ludişor), large and developed cirques (Roşu, Gălăşescu Mare, Jgheburoasa, Brătila, Pojarna, Scărişoara Mare and Mică, Tăiat, Maliţa), an intermediate category (Zbuciumatu, Gălăşescu Mic, Bândea West, Faţa Unsă, Mutătoarea Nord, Lineaţ), and small and immature cirques (Boureţu cirques, Brătila South cirques, Ludişor South, Mutătoarea South, Mocanul, Lineaţ, Cheia Bândei, Dara East, Jgheburoasa South).

The glacial cirques decrease in altitude (lowest, medium and maximum floor altitudes, medium cirque altitudes) and sizes (length, width, area) from west to east and from north to south, as the altitude, massiveness and landform energy of this part of the Făgăraş Mountains (corresponding to the Doamnei River basin) decrease. The number, distribution, size and shape of the glacial cirques are generally influenced by their location – altitude, distance to the main ridge, and aspect – on a mountain side.

The morphometric indicators of glacial cirque altitude decrease from north to south and form west to east (as mentioned above) and vary between the following values:

- the lowest floor altitude (V1 lowalt) measured at the rim of the glacial threshold varies between 1800m and 2000m for most studied cirques;
- the medium floor altitude (V2 flooralt) records 1950-2150m for most cirques;
- the maximum floor altitude (V3 maxflalt) records 2050-2250m for most cirques;
- the medium cirque altitude (V5 medalt) varies between 2120m and 2300m for the Valea Rea, Bândea, Dara, Leaota glacial complexes and 1980-2110m for the other cirques located in the eastern or southern glaciated area.

The analysis of cirque area (V18 perhaps the most relevant size morphometric parameter of such landform) provides eloquent conclusions on cirque population in Doamnei River basin. 11 large cirques (with areas above 0.8 km^2, out of which 5 cirques exceed 1 km^2), 14 medium cirques (with areas of 0.4-0.8 km^2), and 11 small cirques (with areas of 0.16-0.4 km^2) developed here.

The circularity index (V21) characterized the form in plan of the glacial cirques and records 0.6-0.8 for most studied cirques. The values close to 1 characterize 5 glacial cirques with round and regular contours, while the values lower than 0.6 (0.26-0.59) are specific either to some very elongated cirques (3 such cases), or to some cirques with a very festooned or irregular contours (5 cases).

The main size of developed cirques varies between 0.2 and 0.3km^3, and in case of smaller and less developed cirques under 0.1 km^3. Those glacial cirques developed in similar genetic conditions (the same glacial complex, similar location on the same slope, similar aspect, lithology and structure) have proximate values of their main sizes.

The number, shape, size and altitude of the glacial cirques are in most cases influenced by their location and aspect on a mountain side. In Doamnei River basin, the eastern and north-eastern aspects provided the most favourable conditions for glacier development, a fact proven by many researchers for other mountain regions in Romania or Northern Hemisphere (Fig. 8). The southern and south-eastern aspects are also numerous for the studied cirques, but they are dictated by the local topography, the aspect of ridges and preglacial valleys, and probably the existence of some nivation hollows on the southern slopes (favoured by a greater extent of the freeze-thaw phenomena).

Glacial cirque distribution in Doamnei River basin was definitely influenced by aspect. Considering the topography (the east-west main ridge or the north-south secondary ridges) and aspect of present and preglacial valleys, most glacial cirques face east (14 cirques), south (7 cirques) and south-east (5 cirques); the south-west and west aspects provided improper conditions for glacier development, while the north-west and west aspects were limited by topography (Fig. 9, Table 4). The largest glacial cirques developed in sheltered areas, generally under eastern, north-eastern and south-eastern slopes of some high peaks or ridges.

DOI: 10.5775/fg.2067-4635.2011.015.i

In the case of medium cirque gradients, they register values between 12^0 and 30^0, integrating in the range providing rotational ice flow, established by certain researchers.

The morphometric parameters of the glacial cirques correlate positively or negatively, or do no correlate at all. The method used for such analysis was the linear regression on scatter diagrams (Simoni, 2007), resulting in some relations between the form and shape of the glacial cirques.

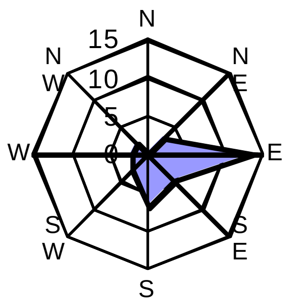

Fig. 8. Glacial cirque aspect in Doamnei River basin

Aspect class	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
Azimuth range	337.5°- 22.5°	22.5°- 67.5°	67.5°- 112.5°	112.5°- 157.5°	157.5°- 202.5°	202.5°- 247.5°	247.5°- 292.5°	292.5°- 337.5°
No. of cirques	**0**	**3**	**14**	**5**	**7**	**3**	**2**	**2**
% cirques	0	8.3	38.8	13.8	19.4	8.3	5.5	5.5

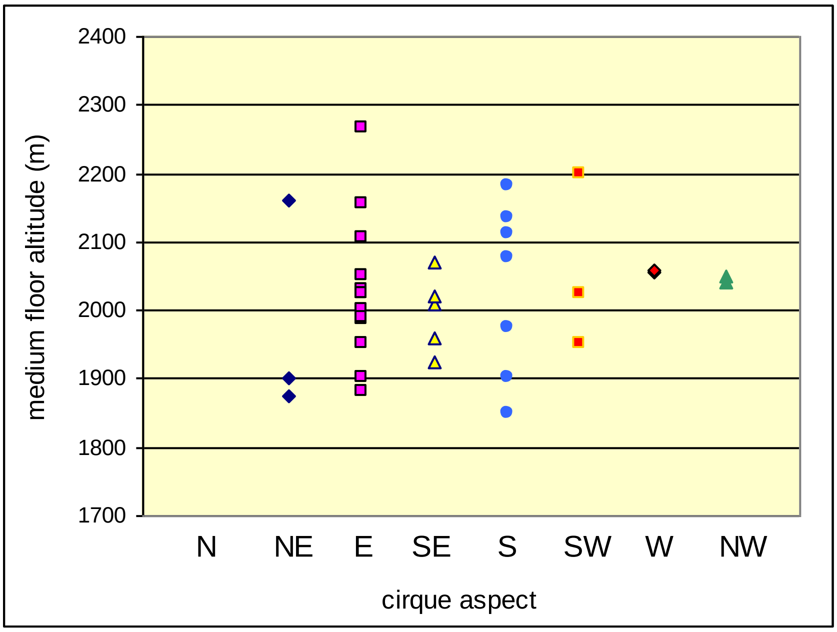

Fig. 9. Medium floor altitude in relation to the glacial cirque aspect in Doamnei River basin

Table 4

Average values of some morphometric parameters in relation to aspect classes

Aspect class	*N*	*NE*	*E*	*SE*	*S*	*SW*	*W*	*NW*
Number of cirques	*0*	*3*	*14*	*5*	*7*	*3*	*2*	*2*
Average medium floor altitude (m)	-	2047	2094	2077	2091	2105	2150	2142
Average floor area (km^2)	-	0.44	0.33	0.29	0.24	0.29	0.13	0.39
Average cirque area (km^2)	-	0.78	0.68	0.55	0.60	0.70	0.39	0.92
Average cirque main size / volume (km^3)	-	0.14	0.22	0.11	0.14	0.23	0.05	0.32

CONCLUSIONS

The Doamnei River corresponds to the eastern-central part of the southern side of the Făgăraş Massif and preserves a great variety and complexity of landforms, ranged in tiers from north to south, as age and altitude decrease: relict erosion and glacial relief, periglacial relief, fluvial relief, and additional structural and petrographic landforms.

The landscape is unique and also representative for the Romanian (de)glaciated mountain areas,

  DOI: 10.5775/fg.2067-4635.2011.015.i

because it preserves considerable fragments of all Carpathian erosion levels and surfaces, originally combined with relict glacial landforms. The north-west mountain basin shows a typical alpine landscape (glacial landscape of Făgăraş type): alpine ridges and sharp peaks that form two distinct gipfelflur levels, separated by large glacial cirques and valleys, of great complexity dictated by aspect, structure and lithology. To the east and south, there is gradual passing to the glacial landscape of Borăscu type, with a large extent of the Carpathian pediplaine, fragmented from place to place by smaller glacial cirques.

This paper intends to explain some theoretical and practical aspects regarding the correct definition and identification of glacial cirques, and to provide a glacial typology that includes morphological, genetic and topographic criteria. Large glacial complexes, with well developed or mature cirques (large sizes, large floors of low gradient, evident headwalls, impressive glacial thresholds) developed under the main ridge (corresponding to the studied basin) of the Făgăraş Mountains. Under the secondary ridges (cut in the fragments of the Borăscu erosion surface, or on sheltered slopes), there are either valley-side (often hanging), or isolated glacial cirques; in both cases, these cirques have less developed elements (smaller sizes, small floors with higher gradients, smaller thresholds) and therefore belong to the immature cirque category.

The glacial cirques decrease in altitude (lowest, medium and maximum floor altitudes, medium cirque altitudes) and sizes (length, width, area) from west to east and from north to south, as the altitude, massiveness and landform energy of this part of the Făgăraş Mountains (corresponding to the Doamnei River basin) decrease. The number, distribution, size and shape of the glacial cirques are generally influenced by their location – altitude, distance to the main ridge, and aspect – on a mountain side.

The morphometric analysis of the glacial cirques in Doamnei River basin provided interesting conclusions regarding the distribution, genesis, form and size of cirque population. All types of glacial cirques developed here, from the point of view of form in plan (simple, elongated, complex, cirque in cirque), shape of long profile (simple, twined/ with steps), location in relation to the major glacial valley (valley-head, valley-side), affiliation to a glacial valley (glacial complexes/ cirque complexes, isolated cirques). From the point of view of cirque sizes (length, width, perimeter, area, volume/ main size), all cirque categories (large, medium/ common – lightly more numerous, and small) are equally represented in the studied basin.

The geomorphologic map (the result of a more extensive analysis) of Doamnei River mountain basin shows a synthesis of the glacial landforms (with 7 glacial complexes, isolated glacial cirques, glacio-nival cirques), as well as the periglacial landforms and the Borăscu erosion surface.

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Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume 10, Issue 1 / June 2011, pp. 50-57
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.016.i

The Landforms of the Făgărăș Mountains (The Argeș Mountain Catchment): Analysis of the Related Dynamic Processes

Alexandru NEDELEA[1], Răzvan OPREA[1], Laura COMĂNESCU[1], Gheorghe CURCAN[2]

[1] University of Bucharest, Faculty of Geography
[2] University of Craiova, Geography Department, gil.curcan@yahoo.com

Received on <December 25, 2010>, revised on <February 5, 2011>, accepted on <April 9, 2011>

Abstract

The present configuration of the Făgăraş Mountains is a snapshot of the long-term evolution that brought about significant alterations of the landscape, and especially of the relief, which has acquired different features depending on the intensity of the relationship between the exogenous and endogenous agents. Relief shaping in the study area is controlled by the orographic and climatic features. However, the climate of the high and middle-height mountains is the main cause that determines the mechanism, the intensity and the spatial distribution of the shaping processes. The massiveness and the considerable height of the Făgăraş Mountains, which exceed 2500 m altitude (Moldoveanu peak 2544 m, Negoiu peak 2535 m, Lespezi peak 2522 m, Vanatoarea lui Buteanu peak 2507 m, etc.), are responsible for the vertical zonation of climate and vegetation. The study area lies in the middle of the Southern Carpathians range, on the southern slope of the Făgăraş Mountains (the Arges mountain catchment). The scale of investigated phenomena and the frequency of their occurrence allow us to distinguish two types of different phenomena on the basis of their geological or geomorphological origin. Each slope section was analyzed by using a series of parameters considered as being stable from the morphodynamic point of view.

Keywords: *the Făgăraş Mountains, morphodynamic processes, landform dynamics, slope materials*

Rezumat. Formele din Munții Făgăraș (bazinul montan al Argeșului): analiza proceselor dinamice asociate

Configuraţia actuală a reliefului făgărăşean reprezintă un moment din îndelungată evoluţie a acestui lanţ care a suferit importante modificări în decursul timpului. Relieful a căpătat aspecte diferite în funcţie de variaţia raporturilor dintre agenţii exogeni şi endogeni. Modelarea reliefului în arealul investigat se exercită în moduri variate, fiind condiţionată de particularităţile orografice şi climatice. O cauză esenţială care determină mecanismul, intensitatea şi distribuţia spaţială a acestor procese o constituie climatul specific zonelor de munţi înalţi şi mijlocii. Masivitatea şi înălţimea apreciabilă a munţilor Făgăraş, care trec de 2500 m (vf. Moldoveanu 2544 m, vf. Negoiu 2535 m, vf. Lespezi 2522 m, vf. Vânătoarea lui Buteanu 2507 m etc.) impun variaţia altitudinală a climei, în etaje (climatice şi de vegetaţie).Teritoriul cercetat se află pe versantul sudic al Munţilor Făgăraş (bazinul montan al Argeşului). Procesele analizate şi amploarea lor au condus la distingerea a două tipuri diferite de fenomene în funcţie de originea lor geologică sau geomorfologică. Pentru a evidenţia frecvenţa lor, fiecare versant a fost analizat cu ajutorul unor parametri consideraţi stabili în morfodinamică.

Cuvinte-cheie: *Munţii Făgăraş, procese morfodinamice, dinamica formelor de relief, depozite de versant*

INTRODUCTION

The study area lies in the central-southern part of Romania, in the middle of the Southern Carpathians range, on the southern slope of the Făgăraş Mountains (Fig. 1). Its western and eastern borderlines follow the water dividing the Capra and the Buda catchments, two streams developing at the headwaters of the Argeş river. Within this territory, the high steps of the mountains, usually lying above 1800 m altitude, make up a morphosculptural level with specific features. This level develops in a region of plateaus, high peaks, cirques, glacial troughs and ridges. The climate is characterized by low mean annual temperatures (0^0C) (INMH, 1980-2009), which often record negative values in the area of the high peaks (around -2.5^{0}C). The thermal regime shows the existence of 6 – 7 months with negative mean daily values and 4 – 6 months with good conditions for gelivation (October – November; March – May). Precipitations do not exceed 1200 mm per year (INMH, 1980-2009), 50% of these being solid.

The scale of investigated phenomena and the frequency of their occurrence allow us to distinguish two types of different phenomena based on their geological or geomorphological origin (Fig. 2).

Landform dynamics induced by geological factors is not something happening by accident, but a normal feature of lithosphere development. It is certain that the gravitational movements can influence the adjacent areas even when their intensity is low and the consequences are minor or even absent. What is really important, however, is that they unleash considerable forces and reduce the relative altitudes. Such phenomena can bring about some minor natural disasters, which however cannot be overlooked: - collapses, landslides, rock falls; - torrential flows, ice and avalanches, flow alterations (through the building of dams).

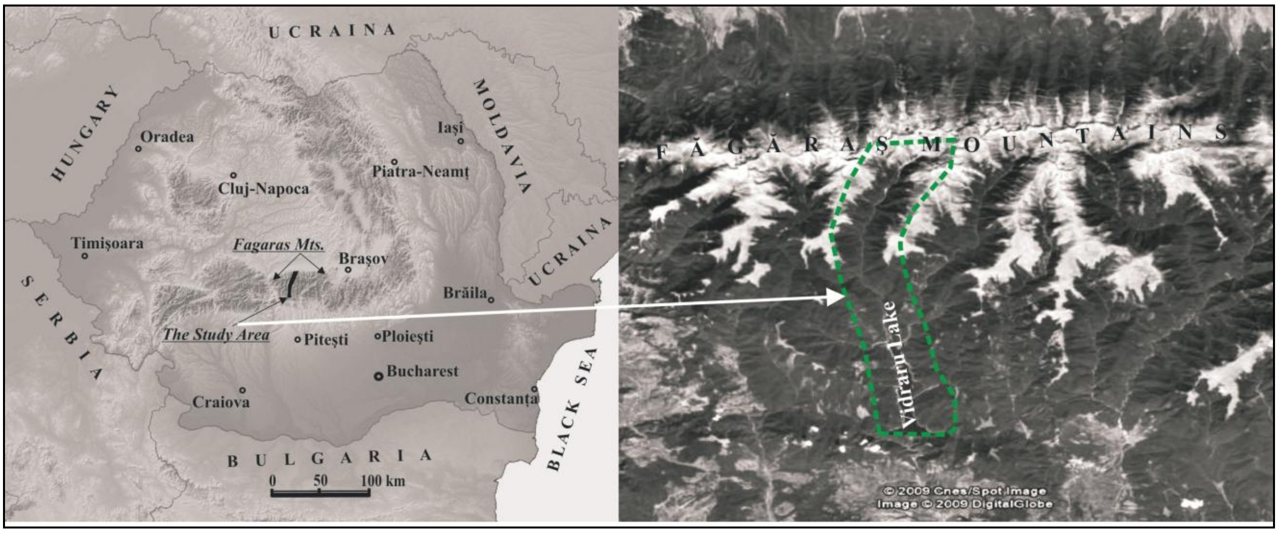

Fig. 1 The geographical location of the study area

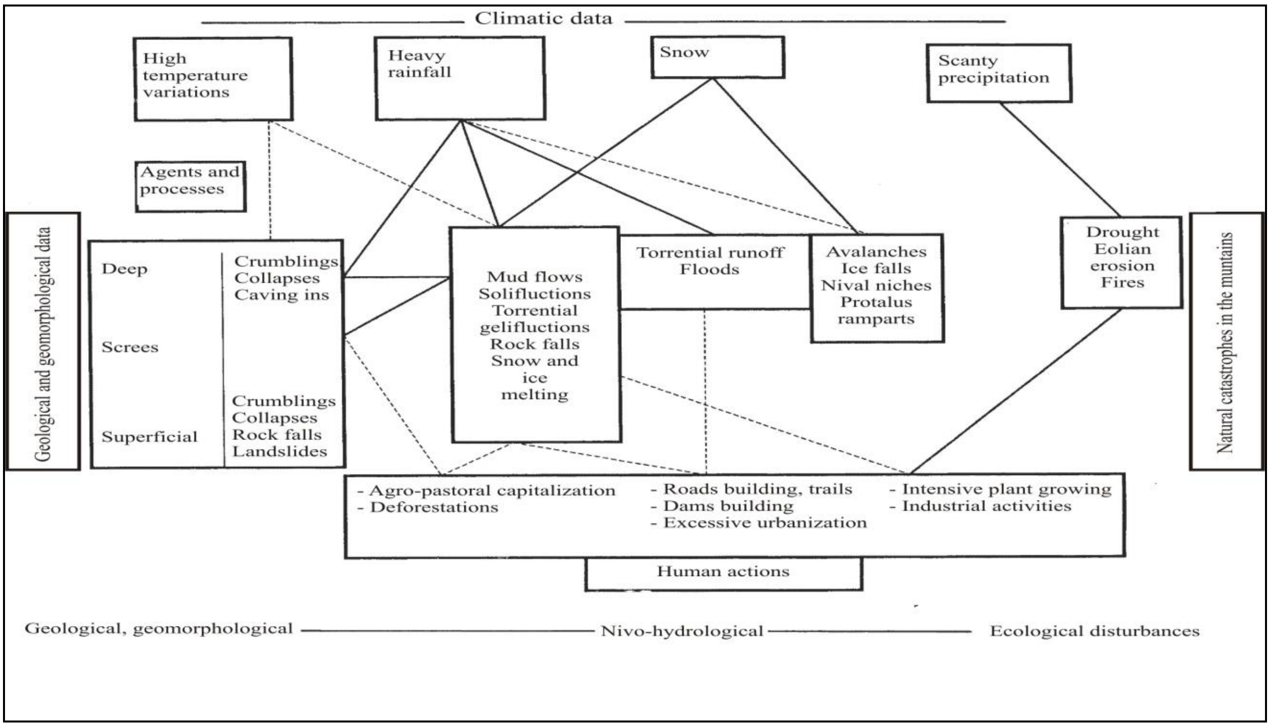

Fig. 2 Geological, geomorphological, climatic and anthropogenic factors that control terrain morphodynamics. (according to Chardon, 1990, with modifications)

Landform dynamics induced by geomorphological factors takes place in small areas. Despite the low intensity, these processes can disturb the landscape and the geosystem and sometimes can also be responsible for the loss of human lives, too. From this point of view, they have come to be considered as natural risk.

This category of processes includes rock falls, collapses and sudden and violent fall of a slope or of a significant amount of weathered material. The

DOI: 10.5775/fg.2067-4635.2011.016.i

slope processes and the rock falls of higher or lower intensity may lie at the origin of some disasters: topography alterations, changes in the courses of the rivers, alterations of ecosystems (vegetation is either destroyed through repeated fallings or it cannot develop because of land instability), loss of human lives, etc. These processes are controlled by gravity, gelifraction, moisture and temperature variations, rill erosion and torrentiality (Deline, PH., 1998; Jonasson, C., 1991; Urdea P., 1995). The crumbling of land happens continuously, but is difficult to foresee this. It affects many areas in the Făgăraş Mountains, as it is the case of those lying on both sides of the Transfăgărăşan road.

The landslides can also be accompanied by other phenomena, such as: collapses with volumes of dislodged materials ranging from a few cubic meters to hundreds of cubic meters; frequent rock falls with varying volumes of dislodged materials; rock falls with particles ranging from a few centimeters to a few decimeters; solifluctions and landslides.

The events implying rock falls raise the water level in streams, reduce the land gradient and hinder rill erosion and torrentiality. In the same time, the aforementioned processes, sometimes associated with avalanches (Bertran, P., 1996), carry and lay the dislodged materials to the base of the slopes, thus increasing the gradient.

The shaping activity alternates the paroxysmal phases with the lull periods. Its manifestation is permanent, but the intensity oscillates because of various agents that influence it: gravitation, temperature variations, diffused and organized water flow, etc. In addition, it can be aggravated or hindered by the human intervention, the nature of the vegetal cover or by the absence of it.

The landslides are movements that affect the surface formations, the bedrock, or both. Depending on the local conditions (gradient, the nature of soil and subsoil, hydrography, the intensity and duration of precipitations, human activities), the landslides affecting the weathering crust may occur in a matter of hours, days, years or centuries. If the paroxysmal phases of the collapses often result in disasters, in the case of landslides the consequences are the following: the alteration of gradients and the reactivation of erosion in the upper part of the cliffs; the disturbance of water cycle and sometimes the alteration of the river system; the destabilization of ecosystems; the disturbance of human activities, the deterioration of the settlements and roads and, sometimes, even the loss of human lives.

The landslides are triggered by a series of factors, such as gravitation, heavy rainfalls, temperature variations, the rising and falling of the water table, the amount of water in the soil, earthquakes and human activities.

METHODOLOGICAL ISSUES

Slope landforms were mapped in the field on topographic maps and aerial photographs. In the areas with bare rocks the sensitive zones were studied using maps and photographs. Every summer we identified the areas with material accumulation, undertaking the following activities: the assessment of the size of the deposits; the computation of rock volumes on several sites with an area of one square meter; the computation of the mean values of these measurements as an average for the entire area.

The spatial distribution of the processes was done using statistical techniques. Every slope was divided into equal geometrical units of one square kilometer. Each slope section was analyzed using a series of parameters considered to be stable from the morphodynamic point of view. These parameters were not selected randomly. As far as lithology is concerned, the four classes of rocks represent the main facieses that underlie the landforms. When it comes to vegetation, everybody agrees that forested areas represent a more important factor of stability than the areas where vegetation is sparse. All the parameters that had suffered the effects of current morphodynamics were analyzed and catalogued.

RESULTS AND DISCUSSIONS

The results concerning the movement of materials on slopes are not extremely accurate, inasmuch as the investigations left aside the particles smaller than two centimeters. In the same time, it was impossible to estimate the loss of the fine particles resulting from the decomposition of fissured schistose rocks, which were washed away by summer rainfalls. In case of superficial formations, were used painted marks lying 50 cm or one meter away from the edges of the cliffs and glacial walls. The following summer they allowed the computation of talus volume (L*l*h). The density of natural cracks encourages the mechanical destruction of rocks. The comparison with the gelivity indexes allowed a better understanding of the differences between the talus masses. On the Capra and the Buda valleys, at about 2000 m altitude, quartziferous micaschists and other rock layers show fissures at depths between one and three centimeters. The gelivity index of these rocks is nearly 1%, which explains why the slopes are so resistant (Nedelea, A., 2003).

  DOI: 10.5775/fg.2067-4635.2011.016.i

On the Museteica and the Raiosului valleys, the tributaries of the Buda river, at 2200 m altitude, the dolomites and crystalline limestones with fissures between 5 and 30 cm have a higher gelivity index (30%). The arrangement of the rocks natural fractures in relation with the gradient is responsible for the amount of fallen rocks. The rate of decay is higher in the case of polished micaschists and frail gneisses. During autumn, when rainfalls are heavy, and in spring, when avalanches occur, micaschists supply a great amount of fine materials and paralellipipedal blocks. Thus, the amount of materials, which depends on the fragility of the rocks, alters considerably the weathering crust. Therefore, the natural fragility of the rocks can be considered the main instability factor and the basic condition for the detachment of rock particles and boulders.

However, on the Capra and the Buda valleys, the bioclimatic controlled gradient usually plays an important part in the supply of weathered materials. Despite the fact that the two valleys are carved in almost similar rocks (micaschists, paragneisses and gneisses) the bulky materials depend on the type of gradient, on slope aspect and on the low water stages. At about 1700 m, the debris deposits piled up at the base of the slopes vary between one and three cubic meters on the northern and north-eastern slopes, covered by grasslands and shrubs (juniper trees and rose bays), and exceed five cubic meters on the weathered and concave southern slopes with gradients higher than 400. On the steep slopes, the absence of the vegetal cover explains the higher amount of weathered materials. These are removed along the torrential streams (rock streams), but on the cliffs the movements are not related to these axes. Gelifraction is very active at heights above 1800 m, where the quasi-ubiquitous screes become mobile. As the altitude increases, the rate of freeze-thaw cycles intensifies. The cryoclastic optimum occurs in winter at lower altitudes, while in springtime it is much higher. Above 1800 m altitude, one may notice two cryoclastic optimums. Here, there is also an altitudinal zone where cryoclastic optimum combines with the heavy precipitations specific to spring and autumn, while the long periods with freeze-thaw action are pushed further to the drier months. As far as the rock decay process is concerned, one can distinguish a first phase, in which materials are detached from the slopes, and a second phase, when they are removed and caried to lower altitudes (Niculescu, Gh., 1994).

The natural fissures, gelifraction, nivation and chemical decay are other factors that encourage the formation of screes. Eventually, these are removed by avalanches and torrentiality. The volume of accumulated materials is significant, inasmuch as on the bottom of some valleys it can reach several cubic meters (the Fundul Caprei, the Buda, the Podul Giurgiului, the Orzaneaua Mare, the Raiosu) (Nedelea, A., 2005). Although the boulders that make up these deposits are sometimes enormous, the frequency of gravitational fallings is rather low. Gelifraction processes develop continuously, even though the size of gelifracts is not so big. Those proceeding from glossy schists are between three and five centimeters long, but are very abundant, whereas those detached from ocular gneisses may reach 10 cm or even more, but they are less frequent. Gelifraction supplies less material than the avalanches. At altitudes of 1800 m altitude, the wet snow avalanches begin in February or March on the southern slope and in April or May on the northern one. On the adret, they correspond to the intensification of freeze-thaw weathering, while on the ubac they occur during the pluviometric maximum. From 1800 m upwards and in the periglacial realm the amount of removed materials depends on several factors, such as the nature of the bedrock, the slope aspect, the inclination of land and the altitude. The materials carried down by avalanches usually pile up at the end of the torrential valleys in the form of cones of debris. The avalanche deposits consist of fragments of litter, particles of humic horizons, coarse materials (screes) and sometimes wood, which are mixed up on a depth of 0.5-3 m. Occasionally, the snow has the power to remove significant amounts of material. For instance, on the Orzaneaua valley, an avalanche was able to carry a boulder exceeding one cubic meter down a chute longer than 300 m and with a mean gradient lower than 300.

Field investigations have revealed that the rate of slope retreat ranges from 16 to 20 mm/yr on the sunny and semi-sunny slopes lying between 1780 and 1840 m and from 5 to 16 mm/yr on the shadow and semi-shadow slopes lying at altitudes between 1700 and 1800 m. However, besides the altitude, the studies must also take into account some other parameters as well, as for instance the nature of the bedrock and the inclination of the land. The recession coefficient was taken into account only after the investigation of the accumulated materials.

In conclusion, the weathering gradient and the estimation of slope ablation through statistical methods allow the computation of specific erosion. For instance, specific erosion is 16.5 mm/yr for the Capra catchment, 10.1 mm/yr for the Cumpana valley and 30 mm/yr for the Raiosu valley (where crystalline limestones are prevalent). Such values

DOI: 10.5775/fg.2067-4635.2011.016.i

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are proper only for the areas with steep grades. In the same time, one must take into account the sections that receive materials from upstream and release them gradually to downstream reaches. For a better understanding of these processes, it is worth mentioning some other features of the aforementioned areas. Thus, the Cumpana catchment, which is covered by thick forests, develops on hard rocks at altitudes that keep below 1780 m. On the Capra valley, the mean altitudes reach 2300 m, while on the Raiosu valley, where one can see superficial deposits and moraines, they often exceed 2200 m (Bălteanu D., Călin D., 1996).

CONCLUSION

By analyzing the frequency histograms for F1 (Fig. 3), we have noticed that gravitational movements are not so common on fractured gneisses and micaschists, which are far more resistant than the rocks belonging to classes I and II. Class IV (resistant gneisses) is not affected at all. These gravitational displacements are specific for the north and east-facing slopes (65%). Likewise, they occur on the slopes with gradients higher than 30%, which are covered by sparse vegetation or bare soils. Often, they are very common for the altitudinal step exceeding 2200 m (Nedelea, A., 2005; Ielenicz, M., Popescu, N., Nedelea, A., 2005).

The analysis of $\mathbf{F_2}$ frequency histogram accomplished for the solifluction movements (Fig. 4) has pointed out that most of them occur on superficial formations and Quaternary deposits, which have a low cohesion.

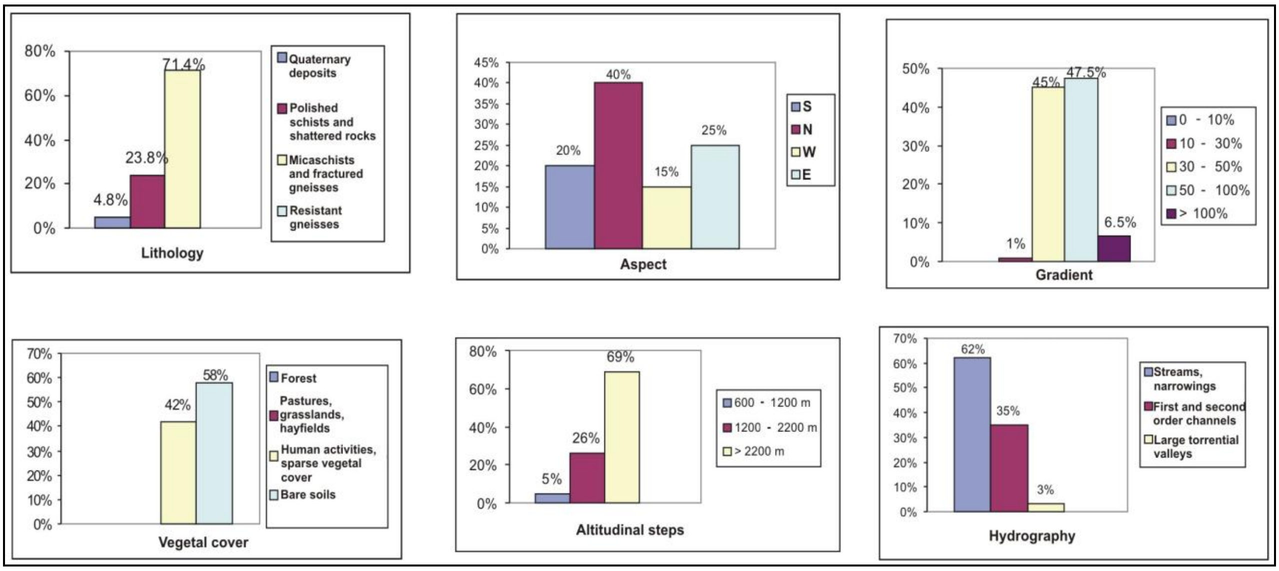

Fig. 3 The frequency of gravitational displacements (F_1)

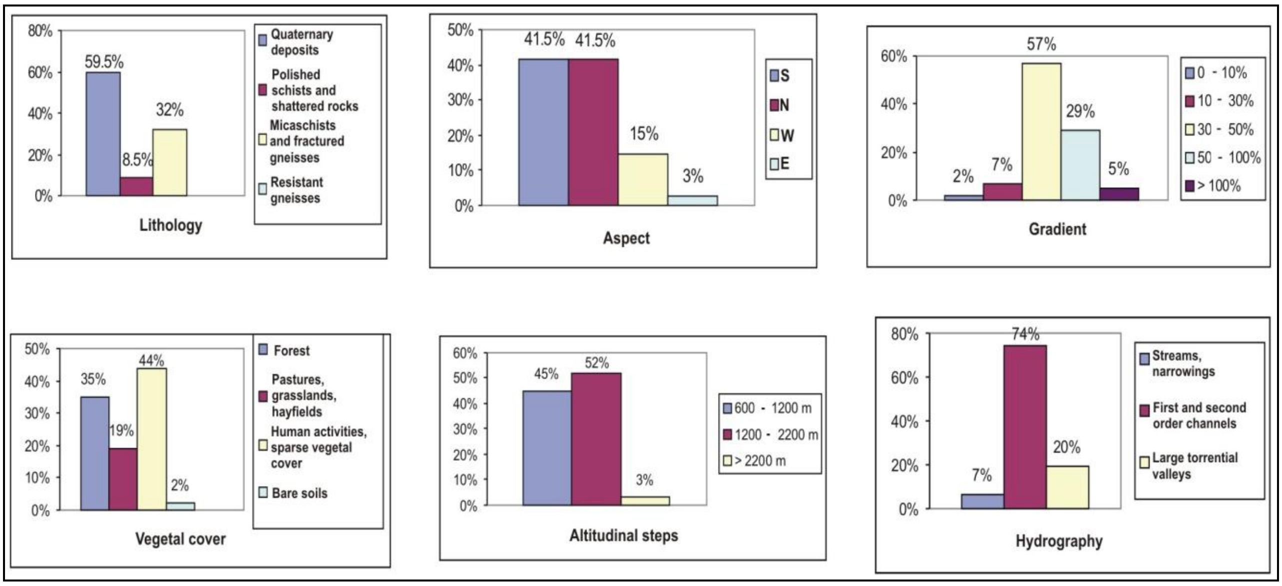

Fig. 4 The frequency of mass movements and rapid solifluctions (F_2)

  DOI: 10.5775/fg.2067-4635.2011.016.i

Such displacements can be observed both on the northern slopes (41.5%) and on the southern ones (41.5%), especially on steep grades and on the areas sparsely protected by vegetation. The mountain and subalpine vertical zones (below 2200 m) also offer good conditions for their occurrence.

According to the graphs that illustrate the $\mathbf{F_3}$ histogram for avalanches (Fig. 5), it is apparent that these processes occur frequently and with high intensities on the north and south-facing slopes, which are underlain by fractured and shattered rocks. Likewise, 95% of them occur where gradients are higher than 30%, vegetation is sparse, first and second-order torrential valleys are common and the altitudes exceed 1200 m.

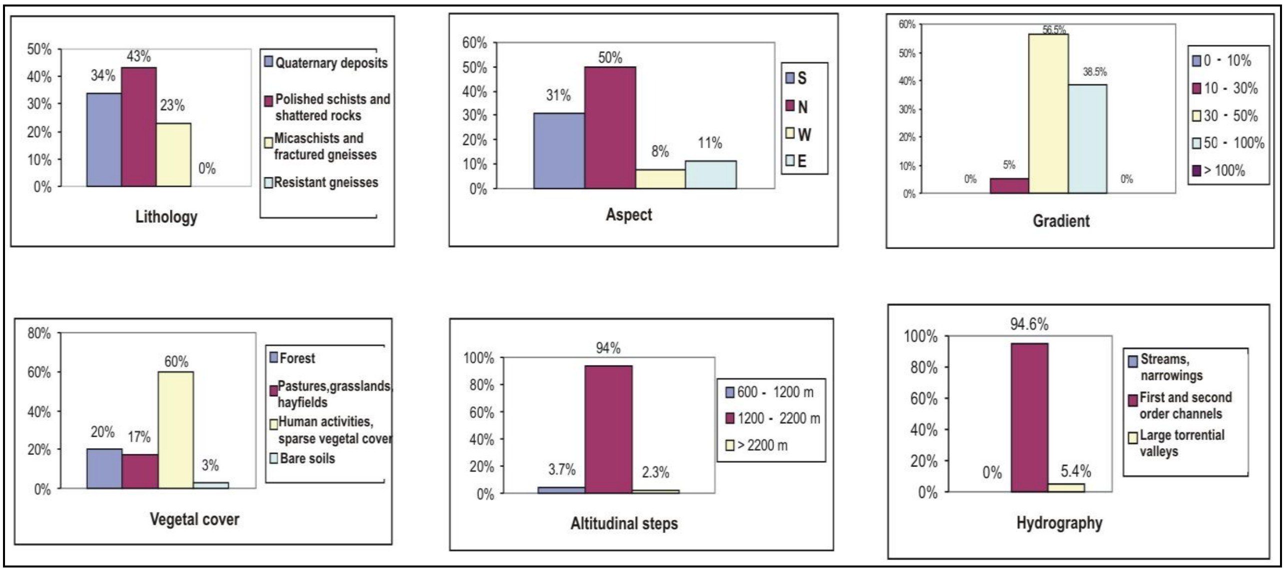

Fig. 5 The frequency of avalanches (F_3)

The $\mathbf{F_4}$ frequency histograms for the fluvio-torrential processes (gullies and torrents) (Fig. 6) are specific for the areas with fractured and shattered rocks. Usually, they prefer the north-eastern and north-western slopes, and especially those sections with medium or high gradients that lie in the mountain and subalpine levels (1200-2200 m), where the vegetal cover is sparse.

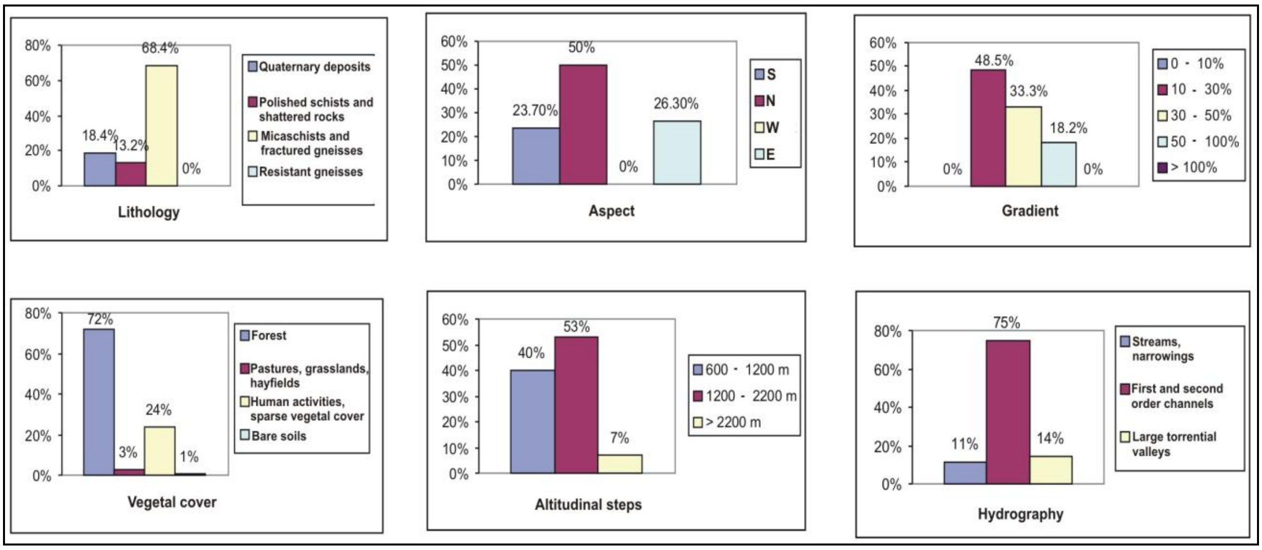

Fig. 6 The frequency of gullies and torrents (F_4)

The $\mathbf{F_5}$ histograms for slow movements (solifluctions) (Fig. 7) prove that these processes develop in the mountain levels, on thick superficial formations. The solifluctions occurring in the mountain level affect the less inclined slopes, which exhibit old channels, filled with colluvial materials. The more active dynamics of the upper part of the slopes is encouraged by the lack of protective cover of

DOI: 10.5775/fg.2067-4635.2011.016.i

vegetation, as well as by the freeze-thaw cycles and snow melting water. At low altitudes, the displacements induced by slow solifluctions usually develop under the forest. Where vegetation is missing, the dominant processes are the rapid solifluctions and torrentiality, as it happens on some northern and western slopes that develop along the Buda valley.

The $\mathbf{F_6}$ histograms for the stable slopes (Fig. 8) show that these are found below 2200 m altitude, on gently inclined surfaces covered by a thick regolith and a continuous vegetal cover. This tendency proves that the slopes lying in the mountain level are very active or can become active. The findings are confirmed by the existence of many rocks having a low cohesion index.

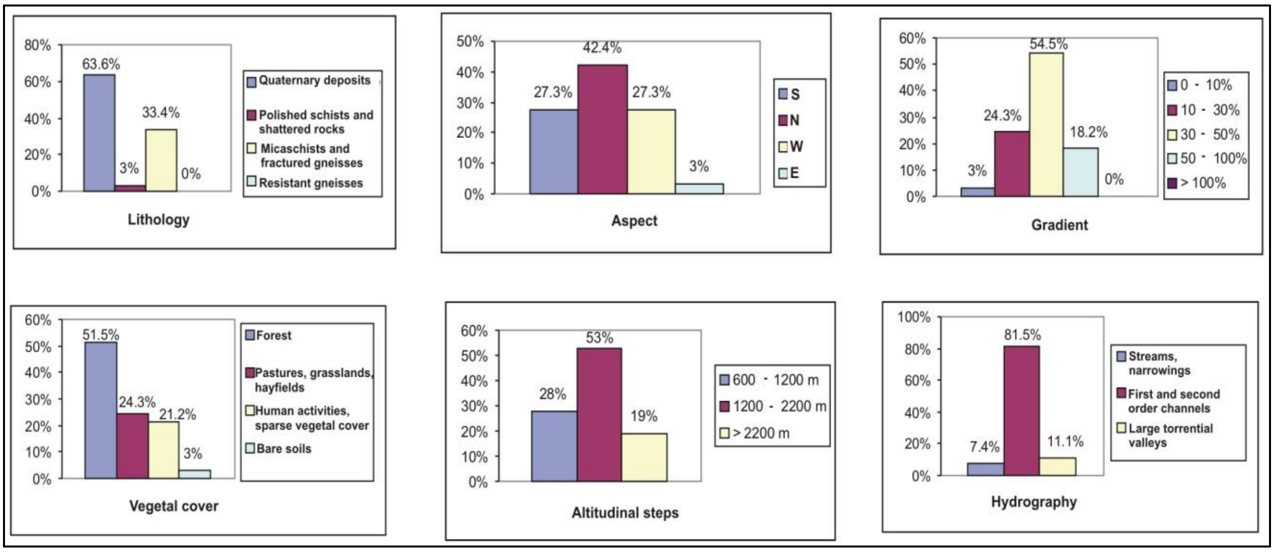

Fig. 7 The frequency of slow movements (solifluctions) (F_5)

As a matter of fact, these classes of processes highlight two zonal morphodynamic mechanisms: one corresponds to the mountain heights, where a relative stability is recorded (biostasy) and the other must be interpreted as a precarious balance of a masked or potential rhexistasy (Voiculescu M., 2002).

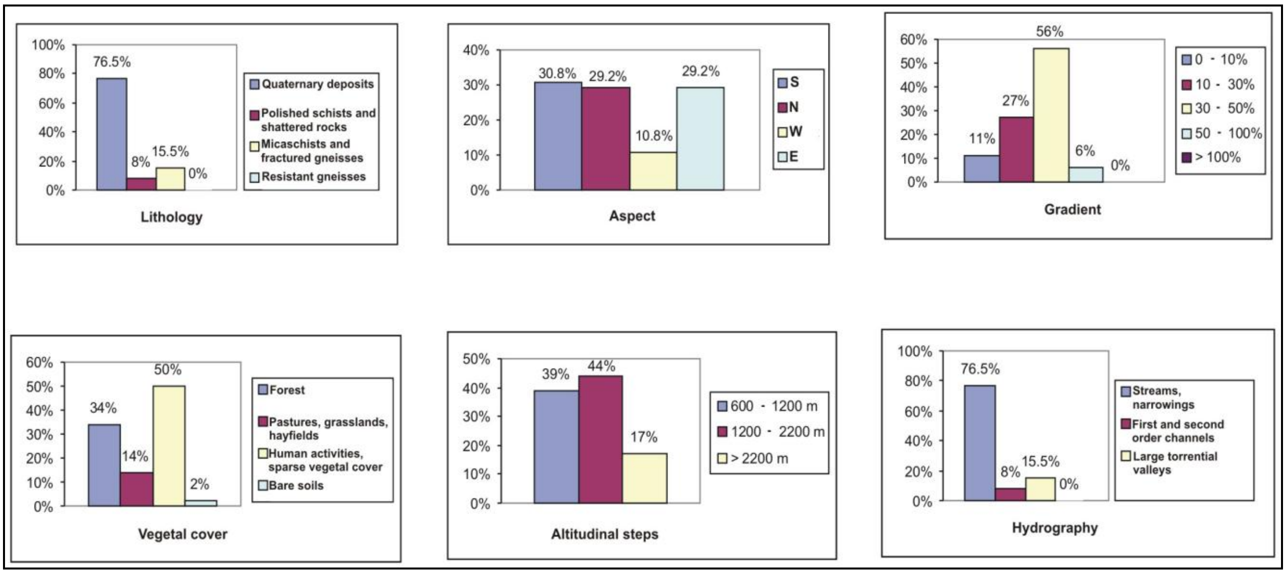

Fig. 8 The frequency of stable slopes (F_6)

ACKNOWLEDGEMENTS

The results in this article are part of the research projects PN II/Idei financed by NURC: *Evaluarea şi monitorizarea riscului la avalanşe în contextul organizarii şi amenajării spaţiului montan. Studiu de caz: Munţii Făgărăă şi Piatra Craiului*, project manager Alexandru Nedelea and *Inventarierea, evaluarea şi cartografierea geomorfositurilor. Studii de caz: Podişul Dobrogei şi Carpaţii Meridionali*, project manager Laura Comănescu.

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Volume 10, Issue 1 / June 2011, pp. 58-69
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.019.i

Features of the Ski Area from the Romanian Banat

Mircea VOICULESCU[1], Florentina POPESCU[1], Marcel TŐRŐK-OANCE[1], Martin OLARU[1], Alexandru ONACA[1]

[1] West University of Timişoara, Department of Geography, No 4 Pârvan Bv., 300223, Timişoara, Romania
Email: voicu@cbg.uvt.ro; florentina.popescu@cbg.uvt. ro; torok@cbg.uvt.ro; olaru@cbg.uvt.ro; ducuonaca@cbg.uvt.ro

Received on < December 22, 2010>, revised on < February 19, 2011>, accepted on <March 25, 2011>

Abstract

The Romanian Banat is endowed with an important mountain area composed of the Banatului Mountains and the north-western part of the Retezeat-Godeanu Range, i.e. Ţarcu – Muntele Mic. The purpose of our paper is to make an account of the features of the two important ski areas within this mountain area: Ţarcu - Muntele Mic and Semenic. Their structure evolved over time according to the local and regional interest, but also due to more recent activities of the Romanian investors. Our research concluded that both ski domains have a great natural potential to sustain winter-sports and to further develop what today are two very small resorts. They have a low capability of attraction due to the small capacity of the pistes and to the fact that each resort has only two ski-lifts. In both cases the access is rather limited and as far as accommodation is concerned in both cases it is disproportional in relation with the provisioned capacity of the ski pistes. Having these aspects in view, we conclude that these resorts do not represent as yet a major attraction, especially due to the fact that there are undercapitalized and underdeveloped for the raising demand of the regional market for winter-sports. On the other hand in both cases projects have already been blue-printed by the aforementioned investors which are waiting to be undertaken for development.

Keywords: ski domain, infrastructure, Romanian Banat, Semenic ski area, Ţarcu - Muntele Mic ski area

Rezumat. Trăsături ale domeniilor schiabile din Banatul Românesc

Banatul românesc dispune de o importantă zonă montană, compusă din Munţii Banatului şi partea de nord-vest a Grupei Retezeat-Godeanu, respectiv Munţii Ţarcu - Muntele Mic. În lucrarea de faţă ne-am propus prezentarea caracteristicilor celor două domenii schiabile din această zonă: Ţarcu - Muntele Mic şi Semenic. Structura lor a evoluat în timp, în funcţie de interesul local şi regional, dar şi datorită mai multor iniţiative, recente ale investitorilor români. Cercetările noastre au ajuns la concluzia că cele două domenii de schi dispun de un important potenţial natural pentru a susţine activităţile sportive de iarnă, respectiv de ski în cadrul a două mici staţiuni de iarnă. În prezent. Acestea au o capacitate redusă de atracţie, datorită existenţei unor pârtii mici şi a cîtorva mijloace de transport pe cablu. În ambele cazuri, accesul este destul de limitat şi datorită capacităţii de cazare disproporţionată în raport cu gradul de încărcare a pîrtiilor de ski. Având în vedere aceste aspecte, putem concluziona că aceste staţiuni nu reprezintă încă o atracţie majoră, datorită faptului că sunt insuficient utilate şi subdezvoltate în raport cu creşterea cererii pieţei regionale de sporturi de iarnă. Pe de altă parte, în ambele cazuri, au fost iniţiate la nivel local, proiecte de extindere spaţială a domeniilor schiabile şi a capacităţilor de cazare, proiecte care încă aşteaptă să fie puse în aplicare.

Cuvinte-cheie: domeniu schiabil, infrastructură, Banatul Românesc, Ţarcu - Muntele Mic, Semenic

INTRODUCTION

The skiing activity represents a very important attribute of winter tourism. At the same time the ski activity is similar to sport activity, generating an entire industry within mountain areas (Agrawala, 2007; Hudson, 2002), being one of the most spectacular forms of tourism (Booth & Cullen 2001; Heberlein et al., 2002; Jeanneret, 2001; Godde et al., 2000; Yang et al., 2009).

The Romanian ski industry is in development (Master Planul pentru Dezvoltarea Turismului Naţional 2007-2026, 2010) and is polarized by the well-known Prahova Valley ski area, which has indeed the highest density of resorts and corresponding amenities. From the total carrying capacity of the Romanian ski domains: 35,000 persons (Master Planul pentru Dezvoltarea Turismului Naţional 2007-2026, 2010), up to 20,000 can be sustained by the resorts of the Prahova Valley (Master plan în turism pe Valea Prahovei şi Zona Braşov-Râşnov, Faza I - Analiza zonei Valea Prahovei şi Braşov - Râşnov, 2009). On the other hand, we need to consider that Romania is a country covered up to a third of its surface by the Carpathians. Therefore winter sports have developed in other regions as well, but as a consequence of the distant major demand pool, the capital city of Bucharest, these ski domains have not always evolved into proper resorts and as a general characteristic they are undercapitalized when compared to their true potential. More important than the amenities the resorts are endowed with, are the natural factors and conditions, of which the major role is played by the characteristics of snow. So that the largest quantities of snow are registered towards the western part of the country rather than the central part where the area aforementioned is located and where the continental influences play an important role. In the south - western part of Romania, in the Banat Region, there are two resorts of regional importance, which even though they pertain to two different mountain-ranges they bare, more or less the same features.

Study area

This study is focusing on two ski resorts in western of Southern Carpathians, Ţarcu - Muntele Mic and Semenic. The Ţarcu - Muntele Mic ski area is located in the Ţarcu Mountains within the western-most range of the Southern Carpathians called the Retezat - Godeanu Range. And the other ski area, Semenic, is located in the massif baring the same name within the Banat Mountains, the southern-most range of the Western Carpathians (fig. 1).

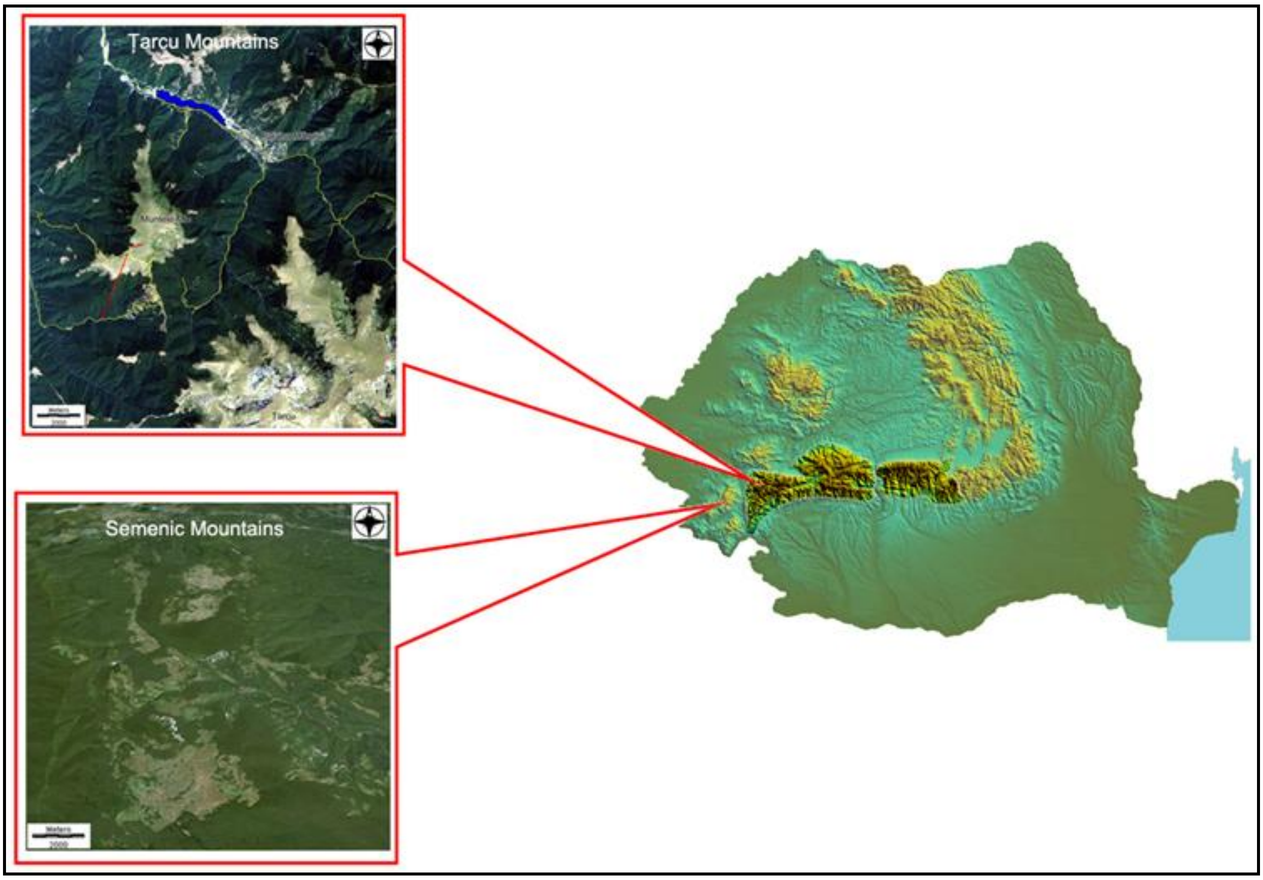

Fig. 1 Location of the Ţarcu and Semenic Mountains
(source: Aster 30m resolution DEM and 30m resolution spot images - Google Earth)

Ţarcu - Muntele Mic ski area is in the north-eastern part of the Ţarcu Mountains. It is characterized by the lowest altitudes within the massif, with a large planation surface located at 1800 m (reaching the highest altitude in the Muntele Mic Peak, 1802 m). This characteristic denotes lean to moderate slopes, adequate for the average Romania skier. On the other hand, towards the south - east, in the Ţarcu-Căleanu division, the slopes are steeper, and there are no resorts or marked ski - pistes, only freeride skiing, snowboarding, skiboarding, skitouring and back-country skiing being practiced like in other mountain areas of the world (Hudson, 2004; Pickering et al., 2003). On the other hand, the Semenic Mountains, located just across the Caransebeş basin to the west, are characterized as having the highest altitudes of the Banat Mountains reaching the top altitude in Gozna Peak - 1447 m, but with the same plantation surface as in the Ţarcu

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- Muntele Mic Mountains, present at lower altitudes, between 1250 - 1400 m (Geografia României, vol. III, Carpaţii Româneşti şi Depresiunea Transilvaniei, 1987).

MATERIALS AND METHODS

The main features of mountain resorts to be analyzed and compared are the natural factors, especially the ones related to terrain and to the climatic factors, having the major concern directed onto snow – duration of the snow layer, depth and the economic conditions related to infrastructure and capitalization of winter-sport produce. Therefore, we have used a 30 meter resolution Aster DEM to depict the thematic maps concerning the terrain analysis important for ski resorts: altitude, slope and aspect (Török-Oance, 2001-2002). As for the analysis of the climatic factors we have used the data provided by the Ţarcu and the Semenic weather stations. We have also used a Lansat image to extract the forested/ non forested areas in order to use it together with the slope, aspect, and altitude maps and with the average snow-depth map to estimate the avalanche risk in the Ţarcu - Muntele Mic ski area (for the Semenic Mountains, due to their physical characteristics such a map was not reclaimed). On the other hand we have used terrain gathered data for the ski domain metrics: length, width of ski pistes and type and condition of the cable transportation devices. And for the correlation of the ski domains caring capacity and the resorts carrying capacity we have used data regarding the accommodation found in the Zonal Urbanism Plans of the two ski area.

RESULTS

Terrain features

The terrain factor is an essential element serving the principle of providing high quality natural background for the winter - sport tourism (Jamieson and Johnson 1998; McClung and Schweizer 1999; Schweizer and Jamieson 2001; Ţigu, 2001).

The most important factors that need to be studied within the terrain analysis are: altitude, slope, and aspect, to which we can add plane and profile curvature as well. Altitude bares two connotations: absolute attitude (of the domain) and vertical drop. High altitude resorts are not characteristic for the Romanian ski area landscape, but with a few exceptions (Sinaia being one of them, the ski area here rises up to 2000 m). In terms of vertical drop, to be able to consider a ski area for a future or existing resort the vertical drop has to integrate within these values: 400 - 1600 m (Peterson, 2005). The importance of the slopes' aspect rises with the drop in altitude. The most favorable slope aspect is the northern one. It becomes almost imperative at altitudes below 1800 m (for moderate latitudes) and is usually chosen to insure the maxim persistence possible of the snow layer.

There are of course degrees of favorable to unfavorable slopes, with northern orientation considered to be most favorable and the southern-east favorable. Slope is a defining parameter for ski domains for it separates the type of ski pistes for different category skiers. Penniman (1999, pp. 36) separates the skiers into two large categories: skiers who are users of skies or snowboards or other gravity propelled recreational devices whose design and function allow users a significant degree of control over speed and direction on snow and beginners, whom he categorizes as: those individuals whom use one or another of these devices for the first time or who possess marginal abilities to turn or stop on slopes with an incline greater than 20%. It is fair to say that these are quite different one from the other and also use different reporting units (% and °), therefore, today, there are accepted different classifications. There are numerous classifications of ski pistes and of skiers alike. Therefore, some researchers (Borgersen, 1977, quoted by Penniman, 1999; Gaylor and Rombold, 1964; Tremper, 2001) separated the skiers into 3 large categories and allocated very tight classes of declivity for them: beginners or novice, intermediates, advanced or expert (table 1) or according to Blanchère scale (Tremper, 2001), moderate skiers, good skiers and very good skiers (table 2). Directing our attention towards our areas of interest we can realize that from the altitudes' point of view, the Ţarcu - Muntele Mic ski area is located within the range of 1800 m and 800 m, measuring a vertical drop higher than 1000 m (fig. 2), being very well integrated into Petterson's principle (2005).

In terms of aspect, the slopes used for skiing are northern (fig. 2), almost exclusively, and the newly designed ski pistes, which are following the chair-lift line are mostly southern and south-western, likely to denote a short season for these ones.

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Table 1. Slope gradient criteria

Erickson, 1992 (quoted by Penniman, 1999)			Borgersen, 1977 (quoted by Penniman, 1999)			Gaylor and Rombold, 1964		
Trail Code	**Skier Ability**	**Grade Max**	**Trail Code**	**Skier Ability**	**Grade Max**	**Trail Code**	**Skier Ability**	**Grade Max**
Easier	Basic beginner	15% (8.5^{o})	(No code)	Beginner	20% (11.5^{o})	(No code)	Novice	20% (11.5^{o})
More Difficult	Basic intermediate	24% (13.5^{o})	(No code)	Intermediate	35% (19^{o})	(No code)	Intermediate	34% (18^{o})
Most Difficult	(No description)	50% (26.5^{o})	(No code)	Advanced	55% (29^{o})	(No code)	Expert	35% (8.5^{o})
Extreme	(No description)	(no value)	(No code)	Expert	80% (39^{o})			>35% (>19^{o})

Table 2. Blanchère scale (Tremper, 2001)

Skier Ability	**Characteristics**
Moderate skier	A skier of moderate ability capable of secure stem turns, off-piste, in all condition, on slope of 25^{o}-30^{o}
Good skier	Able to make controlled turns of snow on slopes of 30^{o}-35^{o}. Able to descend short steeper pitches and handle difficult snow
Very good skier	Able to ascend and descend on skis sustained and exposed slopes that most people can only climb up with axe and crampons. These are slopes in excess of 45^{o} requiring a high level of skill and experience, to say nothing of courage.

These is why the future project of development for the Muntele - Mic ski area (Bocicai, 2006) is actually aiming for the northern slopes, towards the resort of Poiana Mărului. As a result the two resorts will become connected and will exchange tourists, making Poiana Mărului an auxiliary pillar on terms of accommodation for the Ţarcu - Muntele Mic ski area. In terms of declivity (see fig. 2) we notice the prevalence of light to medium-steep slopes, particularly favorable to winter-sport activities (skiing, snowboarding, backcountry skiing), and which can be associated with the average Romanian skier whose expertise ranges from beginner to advanced.

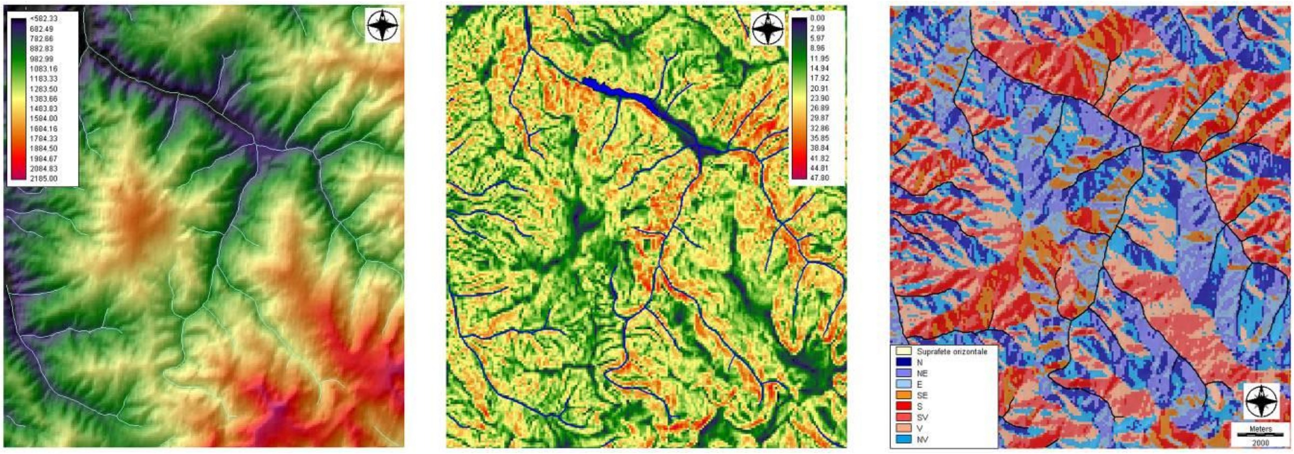

Fig. 2 Thematic maps of the Muntele Mic - Ţarcu area (with the location of the cable transportation): altitude (in the left side), aspect (in the centre) and declivity (in the right side) (Török-Oance et al., 2010)

Only the slopes of Ţarcu ski area are steeper where there are no ski pistes, where is the realm of more advanced to expert skiers practicing free-riding and backcountry skiing.

Turning our attention to the Semenic ski area, from altitude point of view, the existing ski pistes are located at the top of the massif, stating at 1440 m, and descending not lower than 1250 m (fig. 3). If we are to consider the vertical drop it cannot even be included in the proper resorts which need to have a vertical drop of at least 400 m (Petterson, 2005). There is however a plan to develop this resort in three stages and the lowest point of the projected resort would be located at 600 m in altitude by Văliug Lake, reaching an 800 m vertical drop, which is almost 4 times bigger than the present one. We need also to consider that these plans were blue - printed in 2007 and to this day (November, 2010) no action was undertaken in fulfilling the project. From the aspect point of view, both existing ski pistes have northern, north-eastern and north-western orientation (fig. 3). Having in view also the future development, those ski pistes as well are of the majority provisioned to have the same aspect as the already existing two, except a couple of the ski pistes designed to appear in the third phase of construction, which have a western orientation and do not cover more that 20% of the future ski area.

DOI: 10.5775/fg.2067-4635.2011.019.i

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Volume 10, Issue 1 / June 2011, pp. 58-69

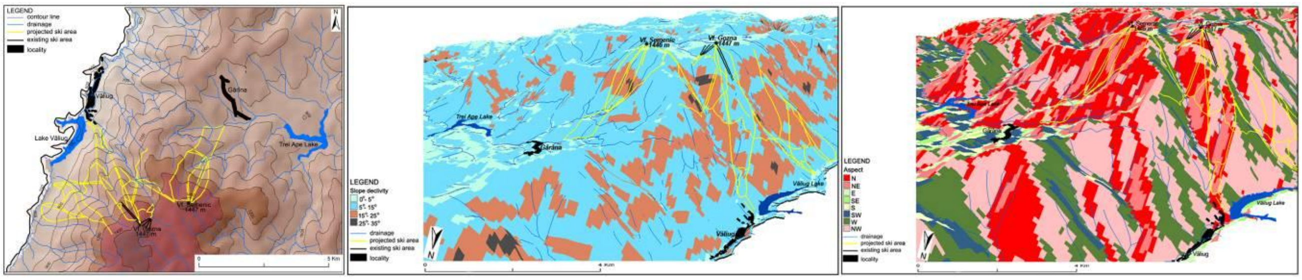

Fig. 3 Thematic maps of the Semenic ski area (with the location of existing and projected cable transportation): altitude (in the left side), declivity (in the centre) and aspect (in the right side) (source: Aster 30m resolution DEM)

In terms of slope (fig. 3), the two existing ski pistes are designed for medium skiers, having their average slope within the 5°-15°. The projected ski domain will build a ski area that is comprised of 70% ski pistes for advanced skiers (with average slopes within 15°-25°), 18% for medium skiers and around 12% to the very good skiers. We need therefore to notice the disproportion between the projected resort and the average Romanian skier whom is either beginner or a medium skier.

Climatic analysis

The other fundamental natural factors are the climatic ones with a major focus on snow (Jamieson and Johnson 1998; McClung and Schweizer 1999; Schweizer and Jamieson 2001; Ţigu, 2001), where literature states that in order to have an economic efficient resort, it is necessary to have 120 days of snow - covered ski area (Ţigu, 2001), or other researchers have the opinion that if in seven out of ten winters there is snow covering of at least 30 cm on at least 100 days between 1 December and 15 April (Becken, Hay, 2007, pp. 38; Besancenot 1990; Freitas 2005; Hall and Higham, 2005) it is the place of a safe investment.

Temperature plays an essential role because it denotes the type of precipitations. Analyzing the temperature graph for the Ţarcu weather station (2180 m), we can conclude that temperature, on average favors the solid precipitation from the month of December until April when these are negative (fig. 4). Literature and common practice suggest that in order to undergo an exploitation process of the ski domain a 30 cm layer needs to be present. Therefore, when comparing snow cover and snow depth (fig. 4) we can make a note of the fact that in the area of the Ţarcu area weather station (close to the Ţarcu - Muntele Mic ski area) there are around 135 days that meet this requirement. Consequently, there is no need for artificial snow production.

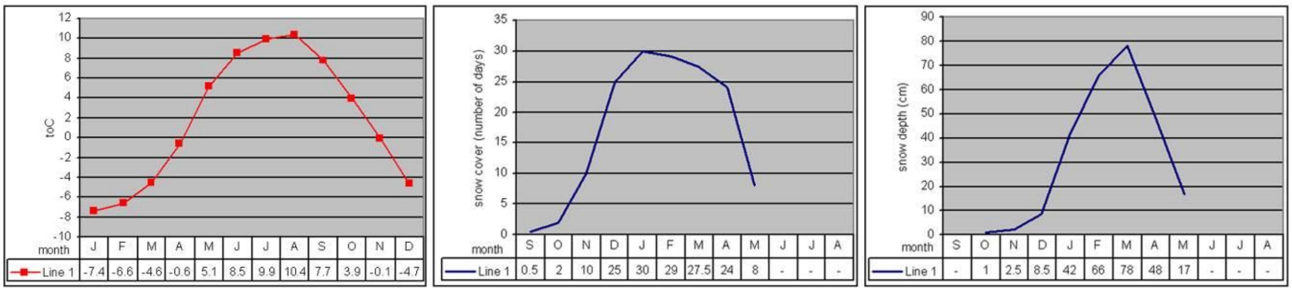

Fig. 4 Temperature (^{o}C) on the left, snow cover (days) in the centre and snow depth (cm) variation on the right, at the Ţarcu weather station (average monthly values)

Analyzing the data from the Semenic weather station, which is located at a considerably lower altitude (at 1440 m), we can notice that the average temperatures are characteristically negative until March (fig. 5), approximately a month less than in the previous case. But, when turning our attention to the number of days with snowfall (fig. 5), we notice that, even for April there are characteristic more than 6 days with snowfall, which could guarantee prolonging the season, should those days be closely distributed. Looking closer to the distribution of the snow depth on the decades of the winter months we came to realize that on average, the necessary conditions for winter-sports are met from mid – December, when there are more than 30 cm of snow available, until the second decade of April, when there still are a few centimeters over 30 that insure the good conditions for skiing (fig. 5). To support

  DOI: 10.5775/fg.2067-4635.2011.019.i

the climatic data, we mention the Snow Celebrations of the Semenic resort which are usually held the week-end that proceeds the 1st of May.

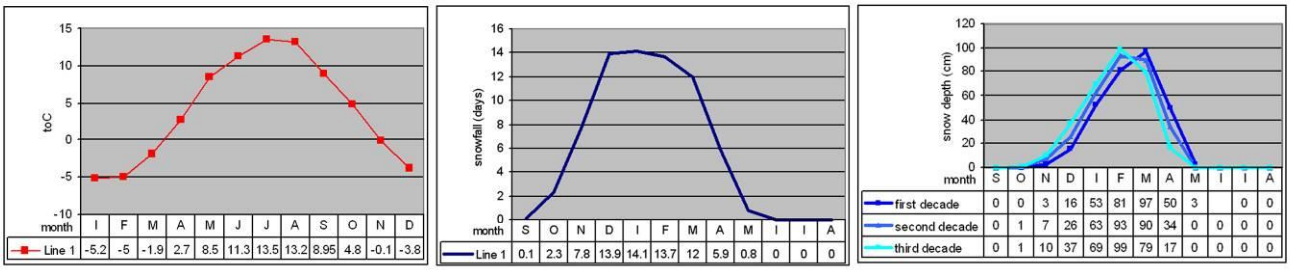

Fig. 5 Temperature (°C), snow fall (days) and snow depth (cm) variation at the Semenic weather station (average monthly values)

Therefore we can estimate that for the Semenic ski area, at the same altitude as the weather station, there are around 130 days with snow cover, but from terrain observations, we could realize that towards the end of the season, under the limit of 1300 m, the snow was present only as patches and there was no management as to insure the proper distribution of snow onto the patches of grass. Furthermore, if we consider that the lowest point of the provisioned ski resort will be 600 m, than snow data should be gathered at lower altitudes as well to determine the running time of each ski pistes, each type of cable transportation as to realize if the provisioned extension of the resort is feasible. To conclude our terrain and climatic analysis we have developed an avalanche risk map (fig. 6) for the Ţarcu - Muntele Mic ski area, with the help of the ArcGis Raster Calculator, where we have overlapped the following maps: slope, aspect, snow depth and a Boolean map with forest - nonforest areas depicted from the Lansat satellite image. The study of snow avalanches is necessary and very important because many snow avalanches are triggered by skiers (Grímsdóttir and McClung, 2006; Pfeifer, 2009; Tremper, 2001; Schweizer and Camponovo 2001; Schweizer and Lütschg, 2001). In this context we should mention that snow avalanche accidents were defined as incidents where skiers were totally or partially buried by snow avalanches. Also, snow avalanches related deaths occurring directly as a result of burial or crushing (Burtscher, Nachbauer, 1999, pp. 46). Snow avalanches have a particularly high incidence in the higher part of the Ţarcu - Muntele Mic ski area where the slopes are steeper. There have been recorded some tragic events, when freestyle and freeride skiers triggered snow avalanches. Between steepness and avalanche danger there is a very good relationship. In table 3 (Tremper, 2001) we can find some typical situations for our study area.

Table 3. Relationship between steepness and avalanche danger (Tremper, 2001)

Steepness	Slope Rating at a Ski Area	Avalanche Activity
10°-25°	Beginner to intermediate slopes	Slush flows in arctic climatic. Infrequent wet avalanche runouts. Dry slabs in extremely unusual situations.
25°-30°	Intermediate slope	Infrequent slabs in unstable conditions. Those that do occur tend to be large.
30°-35°	Advanced slope	Slabs increasing rapidly in frequency as you approach 35 degrees. Usually requires fairly unstable conditions.
35°-45°	Expert slope	This is prime avalanche terrain with the bulls-eye around 38 degrees. Frequent slab avalanches, some large.
45°-55°	Extreme terrain (couloirs in cliffs-usually roped off)	Frequent smaller slabs and sluffs reduce the number of larger slabs.
55°-90°	Alpine climbing terrain (cliffs and very steep couloirs)	Frequent sluffs and small slabs dramatically reduce the number of larger slabs.

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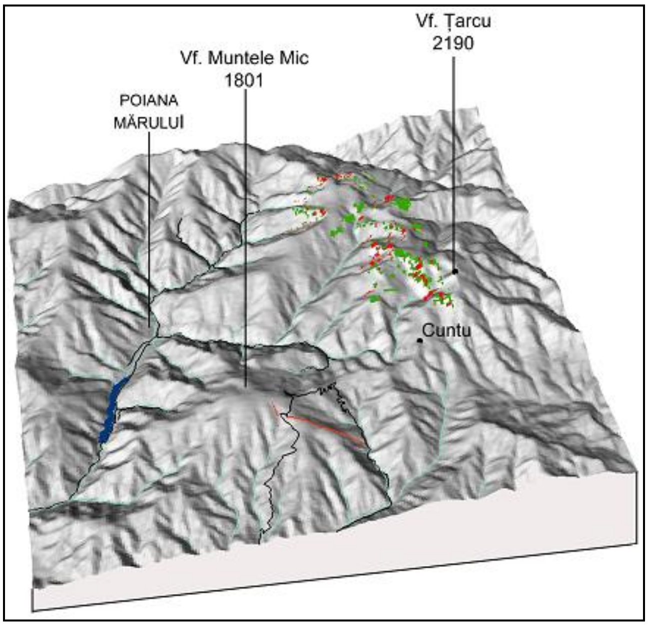

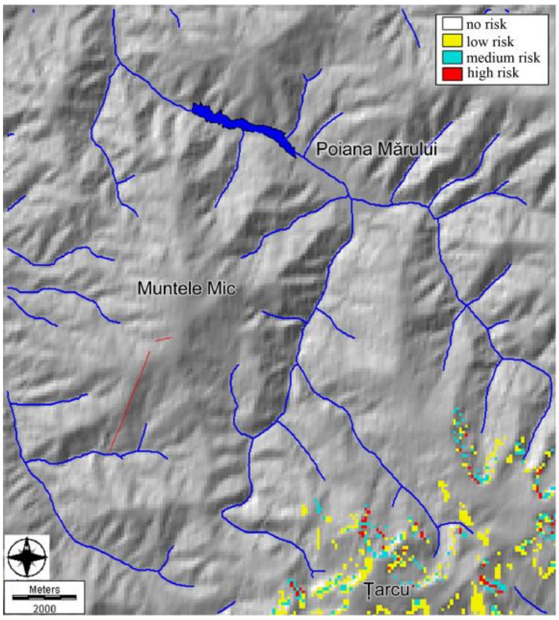

Fig. 6 Avalanche risk map of the Țarcu - Muntele Mic ski area

The results were as expected, with no risks for the Muntele Mic area, but with different degrees of risk for the Țarcu area, where the fragmentation of the landscape is higher due to their geomorphologic past regarding the Quaternary Ice Age. The areas of high and moderate risk are consistent with the high slopes and lack of forested vegetation depicted from the thematic maps (fig. 2).

Infrastructure and ski pistes

For the ski area of Muntele Mic, there are two ski lifts and only one chair lift that are taking skiers up the slope. There are in fact six pistes (table 4, fig. 7):

Table 4. The features of infrastructure ski pistes of skis area Muntele Mic

Name	Dificulty level	Length (m)	Departure elevation (m)	Arrival elevation (m)	Vertical drop (m)	Type of cable-way	Facility
Valea Soarelui	beginner skiers	1500	1700	1520	180	ski-lift	-
Sub teleschi	for medium skiers	800	1700	1520	180	ski-lift	-
Mâloasa	beginner skiers	16000	1780	800	980	chairlift	-
Valea Craiului	for medium skiers	4500	1780	1150	630	chairlift	-
Raindor	for medium skiers	2500	1620	1150	470	chairlift	-
Pârtia Nordică	for medium skiers	1200	1780	1520	260	ski-lift	night skiing

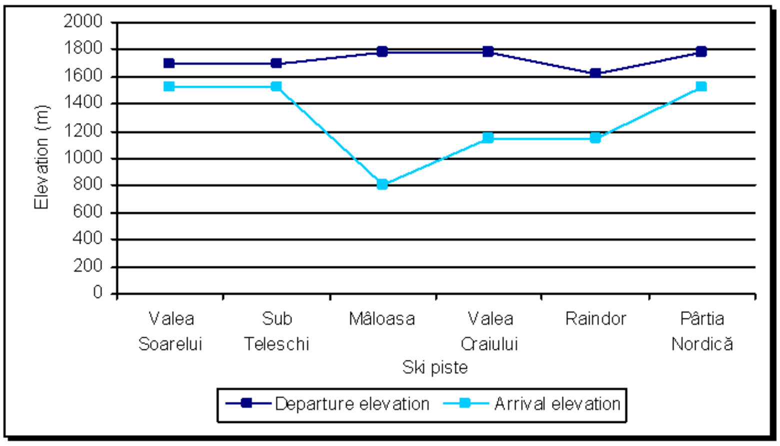

Fig. 7 The departure and arrival elevation of Muntele Mic ski area

Valea Soarelui and Mâloasa pistes are for beginner skiers, Valea Craiului, Raindor and Pârtia Nordică (fig. 8) are for medium skiers, which offer the possibility of night skiing as well.

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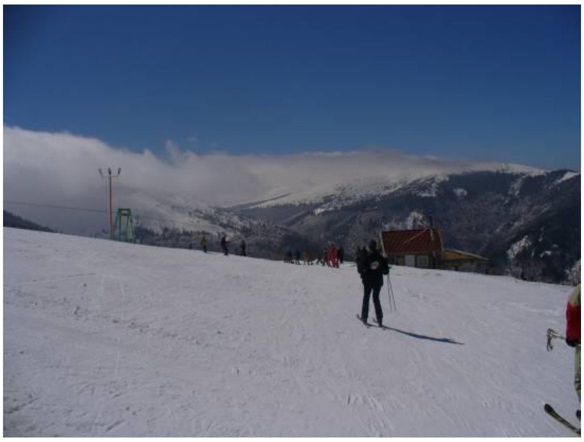

Fig. 8 Ski pistes on the Muntele Mic ski area (photos by Török - Oance, 2008)

In between the two ski lifts there is one piste called Sub Teleschi, which is not groomed at all and where off-piste skiing and snowboarding is practiced. This is the proper ski area, to which there are added other three pistes, which can be accessed by means of the chair-lift (the same that insures access to the resort); but these are seldom used due to the fact that they are not groomed or managed in any manner, for that matter. They can be used by very good skiers, who know the area quite well because there are large rocks, fallen trees and other obstacles on these so-called ski pistes. Still, we are considering them in the following index calculation because in time, with proper management they could sustain the number of skiers resulted in the following calculus.

Any resort can be as big as the carrying capacity of its ski domain; therefore we have calculated the optimum capacity for these ski pistes from the Muntele Mic ski area, following the formula (according to Ţigu, 2001):

Q= D×L/Z/H, where

Q - optimum capacity

D - average flow calculated in accordance with the skier's speed and distance in between the skiers on the ski piste in accordance with the difficulty of the ski piste

L - width coefficient

Z - average length that a skier of that particular category descends within a day

H - vertical drop

1. $Q_{Valea\ Soarelui}$ = D×L/Z/H=(D×L×H)\Z = 850×1,67×180/1400=180 skiers
2. $Q_{Nordica}$=1750×2,5×260/2700= 420 skiers
3. $Q_{Sub\ teleschi}$=1000×1,67×180/2700=111 skiers
4. $Q_{Raindor}$=1750×1,67×470/2700=508 skiers
5. $Q_{Mâloasa}$=1750×1,67×980/2700=1,060 skiers
6. $Q_{Valea\ Craiului}$ =1750×1.67×630/27000=682 skiers

$Q_{actuel\ total}$ =2,961 skiers

The actual carrying capacity is of 711 skiers, but if we were to add the rest of the three trails supposedly served by the chairlift, then the total number of skiers that could be present at one time on the Muntele Mic would be 2,962. The total number of accommodation places within the Muntele Mic resort is around 600 (Bocicai, 2006). Having in view that the accommodation capacity needs to be 20% larger that the carrying capacity of the ski domain, there would be a shortage of about 180 places, which in the last 4 years it is highly likely it has already been covered. Considering the last three trails, we mention that there is no real infrastructure support for their economic efficiency, and therefore this is one of the reasons why they are not managed in any way. On the other hand, the ski pistes provisioned by the mentioned Bocicai (2006), which would connect the Muntele Mic Resort with the Poiana Mărului Resort, would allow 2,260 skiers on the slopes connecting the two resorts (fig. 9).

Then the need of accommodation places would go up to 2,860, which the planners suggest to divide between the two corresponding resorts, in order not to overcrowd the mountain area and to over urbanize it, but rather to offer the chance of development for the Poiana Mărului as well; so that within the mountain area, there will not be more than 1,400 accommodation places, the others being located at Poiana Mărului. Like the Ţarcu - Muntele Mic ski area, the Semenic ski area has only two ski lifts as well, but in this particular case there are no other alternatives at the present moment. The existing ski pistes are Gozna, which offers actually two versions of descend - on the left and on the right side of the ski lift, and the Slalom ski piste (table 5, fig. 10). Calculating the same index for the two ski pistes of the Semenic ski area, we have reached the following results:

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1. Q_{Gozna}=D×L/Z/H=(D×L×H)\Z= 1000×3.53×103/1400=260 skiers

2. Q_{Slalom}=D*L/Z/H=(D×L×H)\Z =1750×1.67×252/2700 =273 skiers

$Q_{actuel\ total}$=533 skiers

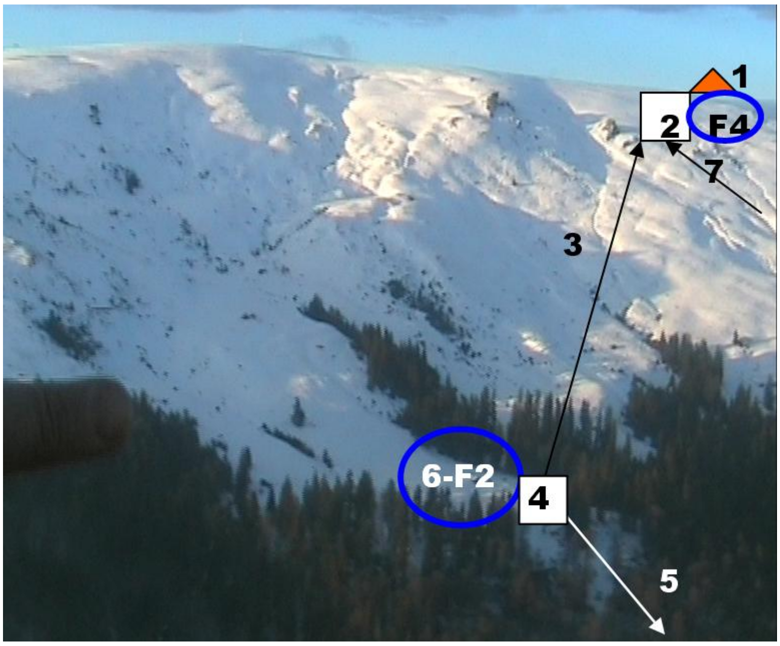

Fig. 9 Expansion plan of the ski area Muntele Mic - Poiana Mărului resort (Bocicai, 2006)

Table 5. The features of infrastructure ski pistes of Semenic ski area

Name	Dificulty level	Length (m)	Departure elevation (m)	Arrival elevation (m)	Vertical drop (m)	Type of cable-way	Capacity (pers/h)
Gozna	for medium skiers	400	1421	1318	103	ski-lift	500
Slalom uriaș	for medium skiers	1200	1432	1252	180	ski-lift	1000
Idioții	beginner skiers	225	-	-	-	babyschi	-

Fig. 10 Gozna ski piste (on the left) and Slalom Uriaş ski piste (on the right) (photo by Popescu, 2009)

The total number of the accommodation places on the Semenic plateau is very small, around 200, but if we consider all the small resorts around it (Văliug - Crivaia, Gărâna, Trei Ape) the number goes up to 820. This is the only way we could reach a reasonable correlation index. The whole area is actually providing a little over 100 accommodation places for the existing ski domain. If we are to consider the project of development for this area, the provisioned optimum capacity, when all the three phases of construction would be complete would sum up to 4,456 skiers, making the exiting carrying capacity accounting for only 12% of the provisioned one, consequently this would mean, enhancing the accommodation capacity with 32,000 accommodation places. This seems rather unrealistic if we consider the existing accommodation capacity and the existing road

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network, which would not be able to support the traffic generated by this network of resorts. The Semenic ski area is managed by a successful businessman, which today represents only a fraction of the plan which he has commissioned. According to Caraş County Council, the development plan (fig. 11) is built on the basis of a feasibility study underwent by an Austrian contractor. The future resort will be endowed with up-to-date cable transportation, snow-making facilities and proper maintenance equipment. Upon completion it will become an important ski destination for much of the western part of Romania and furthermore a proper ski area for regional scale competitions.

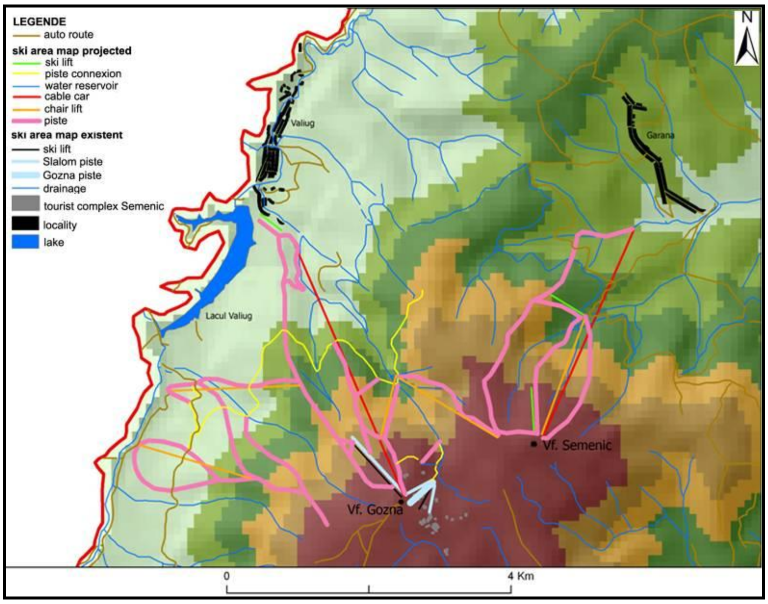

Fig. 11 The development plan of ski area Semenic (according to Caraş County Council)

DISCUSSIONS

Both ski areas as mentioned have provisioned bold plans of development, but apart from the already analyzed terrain parameters, it is recommended that plane and profile curvature analyses are performed in order to have ski pistes with smooth surfaces and with correct orientation down the slope. More importantly, it is advisable to make an account of the number of vehicles, which can drive to the destination in order to see if the dimensions of the resorts are in accordance with the access index; otherwise alternative means of access need to be delineated in order to have an acceptable traffic charge. Furthermore, market research needs to be undertaken with regard to the closest market pools, which do not need to be confined within the borders. The major advantage in this case it is given by the location of the two resorts close to the border with Serbia (120 km from Semenic to Vršac). The study needs to focus on the size of the winter-sports tourism market and on the right marketing strategies to make these resorts appealing to the target market. These studies and strategies could be joint ones for both resorts due to the fact that they are both within the limits of Caraş - Severin County and could make use of regional development structural funds.

CONCLUSION

The two resorts have an enormous advantage with regard to their location. Just within the country, close to these resorts there is a market larger than these two resorts could polarize (mentioning just the larger towns: Timişoara, Lugoj, Caransebeş, Reşiţa), and also being close to the Serbian border, the target market could enlarge tremendously; yet the resorts fail to attract tourists to their potential. The main reason is the lack of proper infrastructure: the access infrastructure is limited to an access road in both cases, which for the Semenic ski area during winter is more often than not covered with snow in the upper part due to the fact that there is no forest vegetation to shelter the road and therefore the snow is storm-swept onto to the road even immediately after the road was ploughed; and in the case of Ţarcu - Muntele Mic ski area, a new access road was opened which can take tourists up the mountain to the resort. Unfortunately this road is rarely ploughed and when it is, they just ploughed one lane, creating traffic jams; furthermore at the end of this road there is no proper parking space. There is an alternative means to get up the mountain, on a 50-year-old chairlift, which is also expensive. This implies leaving your

DOI: 10.5775/fg.2067-4635.2011.019.i

car at the bottom of the chairlift where the parking space cannot accommodate more than 20 vehicles at time.

The skiing infrastructure for both resorts is represented by just two ski-lifts whose ski area cannot receive more than 711 skiers at the Muntele Mic ski area and 533 skiers at Semenic ski area, which make the resorts unattractive considering the long time to queue for the lifts and as a result the little time actually allocated to ski. The accommodation infrastructure for the Muntele Mic ski area can insure the necessary number of places for the existing ski domain; on the other hand, the Semenic ski area has very few accommodation places of its own, having to rely on the close tourist villages to supply the rest of the places, which means additional time to get from this villages to the Semenic ski area.

Concluding the analysis, we mention that both resorts have major access issues that need to be resolved in the beginning of the future development plans; but on the other hand, we need to mention their great potential regarding the number of snow-covered days in the first place, than the terrain parameters that respond to the typology of the Romanian ski practitioners: beginners, medium and advanced; and also their relative short distance to potential markets which they can attract through proper marketing strategies.

ACKNOWLEDGEMENTS

The research for this paper was supported by the National University Research Council (CNCSIS - UEFISCSU), Romania, project number PNII - IDEI 1066/2009, Creation of the data base and thematic maps for the ski areas in the Southern Carpathians using GIS. Analysis, up to date evaluation and prognosis within the global climatic changes perspective.

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Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume 10, Issue 1 / June 2011, pp. 70-77
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.021.i

Landslide assessment: from field mapping to risk management. A case-study in the Buzău Subcarpathians

Mihai Micu[1]

[1] Institute of Geography, Romanian Academy, Dimitrie Racovita 12, Sect.2, Bucharest; e-mail: mikkutu@yahoo.com

Received on <December 30, 2010>, revised on <February 12, 2011>, accepted on <April 25, 2011>

Abstract

Landslide risk management represent the final steps within a long process of evaluation that starts with detailed field observation. Based on geomorphological field mapping and the additional support offered by other methods and devices (aerial photos or remote sensing images, GPS and total station surveys, statistical analysis, numerical modelling etc.), landslide susceptibility and hazard assessments offers compulsory information for risk mapping. Unfortunately, there are still papers and even legislative initiatives which skip these important steps, offering results which can be at least severely arguable. The present paper is focusing on highlighting a proper methodology for landslide risk management, having as a case-study a small catchment typical for the Romanian Curvature Carpathians-Subcarpathians contact (Muscel Valley). Within this space of 19.6 km^2, the risk management assessment started with detailed geomorphological mapping, providing information for landslide inventory. Based on this inventory, statistical analysis allowed the susceptibility assessment, and through additional information like landslide frequency and magnitude, triggering threshold and its recurrence interval, landslide hazard assessment and mapping were performed. Finally, risk analysis, assessment and management, outlined by a risk map, finished the procedure, aiming to provide useful information for risk governance.

Keywords: *landslide risk, mapping, small catchment, the Subcarpathians.*

Rezumat. Evaluarea alunecărilor de teren: de la cartarea pe teren la managementul riscului. Studiu de caz în Subcarpații Buzăului

Managementul riscului la alunecări de teren reprezintă etapa finală a unui proces de evaluare de lungă durată, care începe cu observaţii de teren detaliate. Pe baza cartărilor geomorfologice de teren şi a suportului adiţional oferit de alte metode şi mijloace tehnice (aerofotograme şi imagini satelitare, ridicări GPS sau cu staţii totale, modelare numerică etc.), evaluarea susceptibilităţii şi hazardului la alunecări de teren oferă informaţii obligatorii pentru cartarea riscului. Din nefericire, încă mai există lucrări şi chiar iniţiative legislative care fac abstracţie de aceste etape importante, oferind rezultate care pot fi considerate cel puţin discutabile. Lucrarea de faţă urmăreşte să descrie o metodologie adecvată managementului riscului la alunecări de teren, având ca studiu de caz un bazin hidrografic mic, tipic pentru contactul Carpaţilor şi Subcarpaţilor de la Curbură (bazinul Muscelului). În cadrul acestui spaţiu de 19.6 km^2, managementul riscului a debutat printr-o cartare geomorfologică de detaliu care a furnizat informaţii pentru realizarea unei inventarieri a acestora. Pe baza acestei inventarieri, analiza statistică a permis evaluarea susceptibilităţii iar cu ajutorul informaţiilor precum corelaţia frecvenţă-magnitudine, praguri de declanşare şi interval de recurenţă, s-a realizat evaluarea şi reprezentarea grafică a hazardului la alunecări. În final, analiza, evaluarea şi managementul riscului au dus la schiţarea hărţii de risc, care a finalizat procedura şi care urmează să furnizeze informaţii utile pentru guvernarea acestuia.

Cuvinte-cheie: *risc la alunecare, cartare, bazin mic, Subcarpaţi.*

INTRODUCTION

The Buzău Subcarpathians, as a part of the Curvature Subcarpathians, and especially their inner sector, represents an area severely affected by a wide range of landslides. Their morphological, morphometrical and morphodynamic complexity represents the combined result of numerous favouring (heterogeneous and predominantly poor-consolidated sediments), preparedness (long-lasting autumn rains, rains overlapping snowmelt, summer torrential rainfalls) and triggering (certain values within the above-mentioned rainfalls, certain earthquakes) factors.

The main purpose of this paper is to gather all the requested data for obtaining a risk map, constituting also an example of methodological approach, in which the risk is regarded as the logic product of the inventory-susceptibility-hazard assessment and mapping succession. We have considered only those landslides triggered by precipitation, the earthquakes not being taken into consideration in this application as triggering factor. The case-study is represented by Muscel, a small catchment situated on the border of the Buzău Subcarpathians and Carpathians.

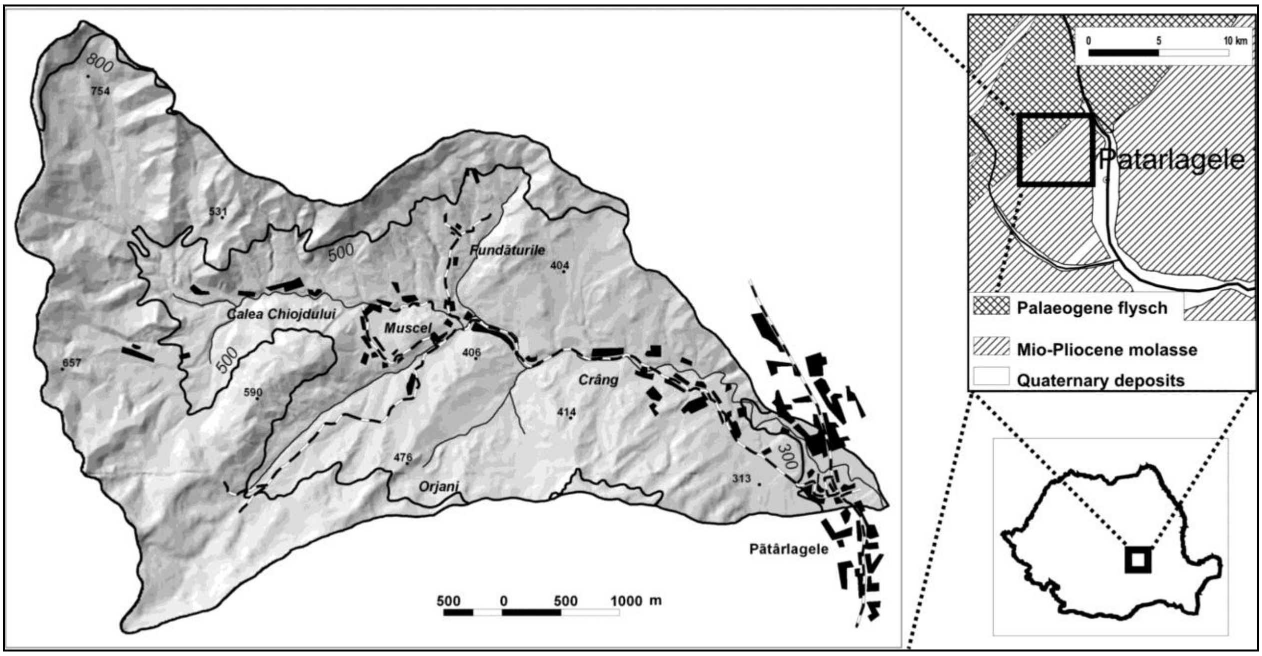

Fig. 1 Study area

STUDY AREA

The main reason for picking-up the Muscel Catchment (Fig. 1) as study area is due to the fact that it represents a typical Curvature Carpathians-Subcarpathians basin from several points of view: an almost equal distribution of Paleogene flysch - Mio-Pliocene molasse – Quaternary deposits; petrographic and structural-controlled relief morphology and morphometry; land-cover and land-use; settlements distribution and structure.

Covering an area of 19.6 km^2, Muscel Catchment is carved in the east-facing slope of Manta-Muscel Hill and it extends on an altitude of 629 m, between Pătârlagele Peak (909 m) and the Buzău Valley (280 m). There is a clear correlation between the relief and the lithological background: the upper sector of the catchment, developed on schistose flysch formations, is characterized by steep slopes (affected mainly by sheet wash, gully erosion and rarely by rock falls), narrow valleys, high summits (Pătârlagele Peak, 909 m), 6-6.5 km/km^2 fragmentation density, 30-50° average slope and a 300-350 m relief energy. The middle sector, corresponding to Mio-Pliocene schistose and marly-clay formations, features rounded ridges, slopes affected by superficial slides and flows, wider valleys, lower values of fragmentation density (3-4 km/km^2) and depth (50-100 m) and average slopes of 5-30°. The lower sector, built on the Quaternary terrace deposits of the Buzău river, shows depleted slopes (under 5°) and lower values of fragmentation density (2-2.5 km/km^2) and depth (10-20 m) (Bălteanu & Micu, 2009).

Among the climatic features, the rainfalls are showing maximum implications in slope modeling, either as long-lasting autumn rains or concentrated episodes of summer heavy rains (177,8 mm in 24 hours, on the 2nd of July, 1975). The temperatures may be considered as landslide preparing factors only in spring, when the snowmelt may be overlapped by spring showers. The annual precipitation regime registers means of 630-700 mm, with a minimum of 350 mm and a maximum of 1 200 mm.

The main land cover class is represented by forests (41.5%); 33% is covered by grasslands and pastures and 12.3% by old, almost destroyed orchards, which are used in present mainly as hayfields, resulting large areas prone to landslides.

DATA AND METHODS

In order to obtain a landslide risk map, several steps should be followed, always taking into consideration the quantity and especially the quality of the input data on one hand, and the working scale-adapted methodology, on the other hand. The methodologies for obtaining such maps are largely described in the actual international literature (ALARM FP5, MountainRISKS FP6 - related). Among some of the (many) new examples are: Castellanos Abella & vanWesten (2008), Gulla et al. (2008), Melchiorre et. al. (2008), vanWesten et al. (2008) (susceptibility); Brunettil et al. (2010),

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Crozier (2005), Holub & Fuchs (2009), Hungr et al. (2008), Pasuto et al. (2004)(hazard); Castellanos Abella & vanWesten, (2007), Chung and Fabri (2008), Remondo et al. (2008), Zezere et al. (2008).

The risk map is based on the hazard map, which is realized taking into account the susceptibility map (Glade et al, 2005, Lee & Jones, 2004). On each step, one may take into consideration the above-mentioned relationship. Based on that, a certain approach, either qualitative or quantitative (Micu, 2008) should be used for reliable results. If a transition from a quantitative method to a qualitative one may be used based on data depletion, the other way around (from qualitative to quantitative) may induce a lot of potentially propagating uncertainties, especially if used at the beginning of the process.

Therefore, adapted for a data-scarce environment, employed a combination of approaches, starting with quantitative methods but finishing with a qualitative one, transition conditioned by the quality of the available data.

The GIS, built under ArcView 3.2, contains topographical maps 1:10000, geological map 1:100000, improved with terrain-based geological sketches (i.e. superficial formations map, Institute of Geography archive) and aerial photos from 2005, based on which it was developed a 10x10 m/pixel DEM and also the land-cover map. The landslide inventory was based on field mapping, aerial photo interpretation, DGPS measurements (Thales Mobile Mapper) and total station surveys (Sokkia E 610).

The landslide susceptibility map was based on bivariate statistical analysis (*joint conditional probability*) and completed with a frequency-magnitude relationship analysis, was useful for a quantitative hazard map.

Vulnerability and risk were assessed in a qualitative manner, based on an expert judgment analysis.

RESULTS AND DISCUSSIONS

Landslide inventory

In Muscel catchment, the landslides are very well represented, and their typology (age, movement type, depth, structure, form, direction) is the result of the lithological favourability combined with poor-quality forest coverage.

The majority of the landslides are being single-patterned, shallow and translational. Along the main rivers (Muscel, Balosin, Saramura, Maloteasa) are characteristic rotational displacement, superficial (1-2 m deep) caused by river erosion (slope undercut). They are showing 20-500 m lengths, rarely exceeding 20-30 m in width. Their displacement rates (from 3 mm/min to 13 m/month) rank them as moderate to rapid (Cruden and Varnes, 1996). Generally, the shallow slides with an elongated profile (length/width ratio above unity) characterize steep slopes (>15°), while an ellipsoidal shape (length/width ratio under unity) is characteristic of more gentle slopes (<15°) (Bălteanu & Micu, 2009).

The landslide inventory (Fig. 2) includes (2008) 147 cases of active landslides (79 ha total surface) and also very large areas (31.5% of the entire catchment) corresponding to dormant landslides (605 ha). Their seasonal and annual dynamics are showing an increased activity interval between March-July (0.20-1.50 m retreats of main scarps), caused by spring showers sometimes overlapping snow-melt. Subsequently, the slides become almost generally covered by grass, but keep a reactivation potential over the following years.

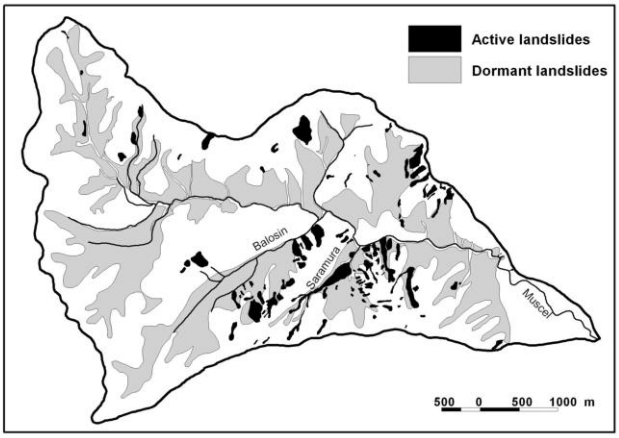

Fig. 2 Landslide inventory

Landslide susceptibility

Based on the previously-obtained inventory, landslide susceptibility, defined as the space component of occurrence probability, was assessed using a quantitative approach, based on bivariate statistical analysis.

The method, applied and described in detail by Bălteanu and Micu in 2009, followed several major steps:

- defining independent variables: simple data, rather easy to obtain like slope, aspect, lithology, land cover;
- determining landslide distribution on each class of each previously-considered parameter and each parameter;
- obtaining a non-classified susceptibility map (values from 0 to 1, representing a future landslide occurrence probability based on the prior probability for each variable and on all of their conditional probabilities) (Fig. 3);

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- classifying the previous map (splitting the data-set into training/ estimation and validation landslides);
- obtaining the classified landslide susceptibility map (Fig. 3), based on the prediction/ validation curves (Fig. 4);
- susceptibility map validation, using 2005 landslides, not included in the initial landslide inventory.

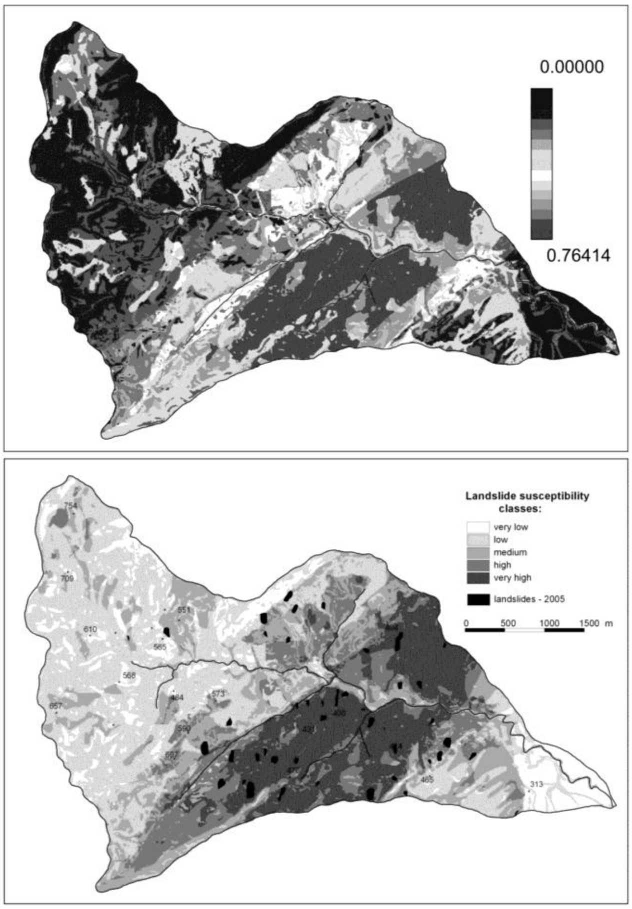

Fig. 3 Landslide susceptibility map (unclassified - above, classified - below)

The landslide susceptibility map shows clearly the mid sector of the catchment, corresponding to loose formations belonging to Mio-Pliocene molasse formations, as being the most landslide- prone from the point of view of space occurrence probability.

Landslide hazard

The first information concerning landslide hazard, regarded as the probability of occurrence in space and time, was given by the first morphodynamic maps (Bălteanu, 1975; Bălteanu & Micu, 2009). Along 4 years (1969-1972), an area of 10.12 km^2 situated in the middle catchment, was mapped periodically, the result being an assessment of spring and summer as the seasons marked by the most intense landslide activity.

Based on that assumption, a further and more detailed assessment of the most landslide-prone months was done using Angot Pluvial Index (Dragotă et. al., 2008; Bălteanu & Micu, 2009). Based on this assessment, the summer proved to be the season showing the highest favourability for landslide, while June represents the month marked by most landslides occurrence, followed by May and September.

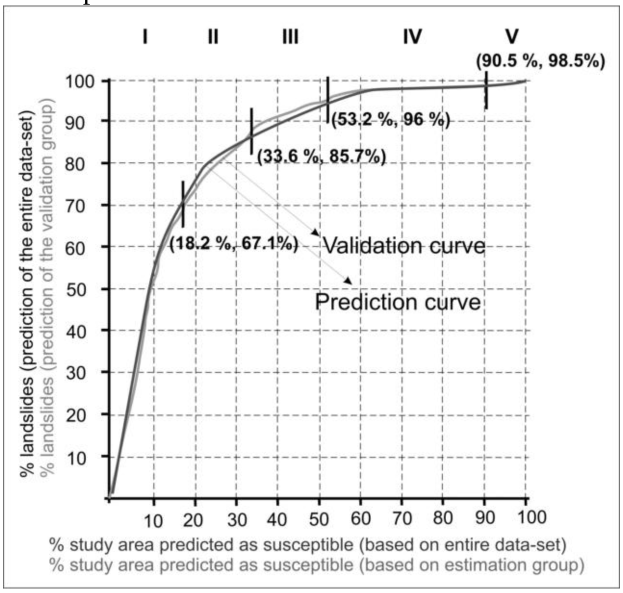

Fig. 4 Prediction-validation curves

A quantitative hazard assessment should mean the completion of the susceptibility map with information concerning: landslide frequency-magnitude relationship, typology of existing landslides, presumed landslides typology, occurrence factor and occurrence threshold, and also the recurrence interval of that particular threshold. Hazard assessment is based on the following assumption: a certain combination of precipitation quantity-duration, evaluated in present as producing landslides of a certain magnitude (a certain scenario), will have the same effect (from the point of view of landslide typology and affected surface), each time it will occur in the future. Knowing the recurrence interval of that particular threshold (determined using Gumble function), one can model corresponding scenarios.

The probability that a pixel can be affected by a landslide, within each scenario, is given by the formula (Zezere, 2004):

$$P = 1 - \left(1 - \frac{S_T}{S_{Sc}} \times \text{pred}\right)$$

where:

S_T – total surface affected by landslides within a certain scenario; S_{Sc} – total surface of a particular susceptibility class; Pred – prediction value of that particular susceptibility class.

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During 2005, a year of maximum rain activity (the second ever recorded, after 1975, with four months - May, July, September and October - marked by mean monthly values above 130 mm), the landslides occurred in Muscel Catchment (mainly shallow, between 0.3 – 1.5 ha) were mapped after each rainy episodes. This helped, on one hand, on validating the landslide susceptibility map (near values of occurred and predicted landslides; Bălteanu & Micu, 2009) and on the other hand, outlined several landslide-generating rainfall thresholds. Combined with the subsequent field mappings (2006-2009), at least two thresholds may be taken into account: 30 mm in 24h and 50 mm in 48h. For Pătârlagele weather station (very close to the confluence of Muscel and Buzău, therefore considered representative), the recurrence interval for maximum precipitation in 24 and 48 hours are 52.4 and 63.3 mm (for 20% probability) (Micu et al, 2010), and values of 30 mm/24 h and 50 mm/48 h may occur annually. Taking into consideration the landslides caused by 30 mm/24 h, a landslide hazard map, based on the previous formula, was obtained (Fig. 5). This is the way in which, fulfilling all the previous requirements, one may model all the scenarios needed.

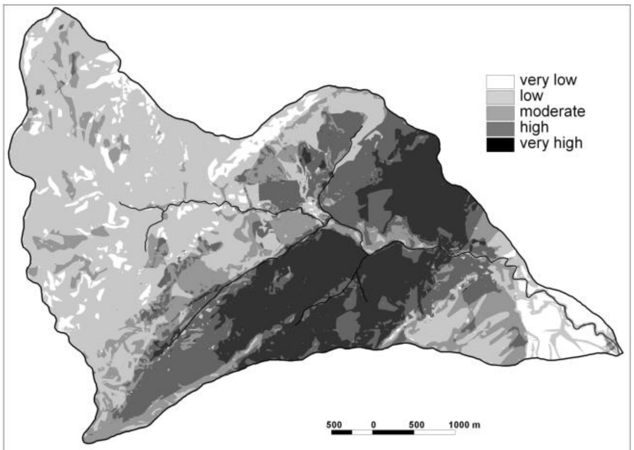

Fig.5. Landslide hazard map for 30mm/24h scenario

Landslide risk

Based on the information provided by susceptibility and hazard, one may go one step forward and obtain a landslide risk map. In order to do that, it is required a vulnerability assessment.

Vulnerability and its components represent a rather delicate problem, especially due to the social, economical and political framework of today's Romania, and subsequently, of our study-area.

An objective assessment of vulnerability should contain (Weichselgartner, 2001) exposure, preparedness, prevention and response analysis. If exposure, regarded as identifying, inventory and assessment of infrastructure, properties or individuals through direct or indirect consequences, may be rather easily achieved, the vulnerability assessment gets complicated when dealing with preparedness, prevention and their means, and also with the measures for coping or mitigating the potential social or economical losses.

For today's Romania, some elements on which vulnerability assessment should be based on are quite difficult to quantify. Issus like Government or EU subventions, insurance market trends are often considered as highly confidential. This aspect may be related with resilience, as the society's (on all its levels) response capacity in the framework of EU joining (regarded as a "risk" by a lot of people).

This is the moment in which a change from a quantitative assessment to a qualitative one has been done. The attempt to quantify a maximum loss potential through monetary units (humans being excluded as elements at risk due to the absence of previous victims and landslide typology) proved to be difficult, caused by the lack of information derived from the confidential status of the insurance policies and submitted subvention files.

Therefore, it was considered more reliable a qualitative risk assessment, the elements at risk and vulnerability being ranked through attributes varying from "*no damages/interruptions*" to "*quas-itotal damage/interruption*", reflecting a particular potential damage level. Through primarily estimations of the presence/absence of insurances or subventions and a parallel analysis of building/maintenance and salary/income, seven classes of elements at risk have been established (some with sub-classes), each one with its correspondent vulnerability class (Table 1).

The result was a vulnerability map (Fig.6) showing that the majority of Muscel Catchment corresponds to medium vulnerability class, followed by high vulnerability. Very low and low values are corresponding to the reinforced concrete houses or facilities built in the lower sector of the catchment, on Buzau River terraces. Also, in these classes were included the insured orchards who benefits also by governmental and EU subventions.

The next step is the risk map (Fig. 7) which is represented by the overlay of hazard and vulnerability maps, through the combination of the specific classes (Table 2).

Risk analysis – highlights the level of threat; landslide magnitude (very low-to-medium) compensates their high frequency (yearly in case of shallow slides) but they cover very large areas, including the entire catchment in medium-high risk.

  DOI: 10.5775/fg.2067-4635.2011.021.i

Risk evaluation – regarded as a cost-benefit analysis, is rather difficult to be performed. The costs directed to prevention measurements (drainage systems, retention walls, reforestations) are considered by the local authorities as subsidiary to more pressing problems, like transportation infrastructure improvement, water supply, domestic waste disposal, educational infrastructure improvement. Within acceptable risk may be included those areas for which the owner considers that potential damages are not important and therefore the damages are accepted without almost any interventions.

This category includes the pastures and grasslands situated at long distance to households and the forests from the upper catchment. Tolerable risk (meaning that the owner is aware of the potential damages but considers them inexpensive compared with the income and easy to mitigate with a certain cost that is willing to assume) includes the pastures and meadows situated in the villages vicinity, old orchards (more than 20-30 years old) or the shelters in the upper-middle catchment used for seasonal harvesting (Orjani, Fundături, Maloteasa, Balosin, Murătoarea).

Intolerable risk (the owner is well aware of the potential damages, and he is willing to invest any funds required by the coping and mitigation strategies) gathers the households (houses, annexes, gardens or other agricultural fields) from the Saramura-Muscel confluence or Crâng village, and also the productive, young orchards from Crâng, Muscel or Fundăturile villag*e*s.

Table 1 Elements at risk and their vulnerability

Elements at risk		Score	Vulnerability	Explanation (damage type)
Buildings	Reinforced concrete	0.1	Very low	Weakly affected structure, unaffected stability, damages at the construction joints.
	Concrete, masonry	0.3	Low	Small cracks, unaffected stability, repairs that can be postponed.
	Wood, masonry	0.5	Medium	Heavily deformed, resistance structure affected, evacuation needed.
	Wood, clay	0.8	High	Partially destruction, evacuation needed.
	Clay	0.9	Very high	Almost entire destruction, evacuation needed, full reconstruction.
Roads	Paths	0.1	Very low	Minor damages, access undisturbed.
	Stone	0.5	Medium	Repairs that implies tens-hundreds cubic meters of rough material.
	Asphalt	0.8	Large	Repairs that implies tens-hundreds cubic meters of rough and fine materials.
Electricity network		0.6	Large	Ruptures of electricity cables, pillar foundations affected, immediate repairs.
Agricult ural fields	With subventions, insured	0.2	Low	Seasonal character of potential damages can be easily covered by subventions and insurances.
	Without ubvention, not insured	0.5	Medium	Seasonal character of potential damages, acceptable costs.
Orchards	With subventions, insured	0.2	Low	Production suffers seasonal losses, recovering costs are acceptable and covered by insurances.
	Without subvention, not insured	0.7	Medium	Production suffers seasonal losses; damages are transmitted from one year to another, but with acceptable repairing costs.
Pastures, grasslands	With subventions, insured	0.2	Low	Production suffers seasonal losses, recovery costs are covered and they are not urgent and don't imply the stop of other production activities.
	Without subvention, not insured	0.6	Medium	Production suffers seasonal losses, recovery costs are not covered but they are not urgent and don't imply the stop of other production activities
Forests	With subventions, insured	0.2	Low	Reduced magnitude damages, which are covered by insurance and by selling the resulted material (wood).
	Without subvention, not insured	0.4	medium	Reduced magnitude damages, which are covered only by the selling of resulted material (wood).

Risk management – represents the most difficult aspect within risk studies, because it suppose the implementation of prevention and mitigation policies based sometimes on tough, correctional

DOI: 10.5775/fg.2067-4635.2011.021.i

measurements. It is a vital moment because the entire scientific process described before should result in convincing the authorities to accept and implement certain requirements. For Muscel Catchment, such measurements should be taken in order to reduce the potential damages caused by landslides: river banks consolidation along sectors affected by lateral erosion, causing retrogressive slides (Saramura - Muscel confluence); reducing flowing speed by building thalweg steps (Muscel, Calea Chiojdului); gabion reconstructions; stop the remove of buckthorn bushes for fence-building; rejuvenation of plum orchards; stop the construction of buildings in very high risk areas and adapt the destination of land-use in high risk areas.

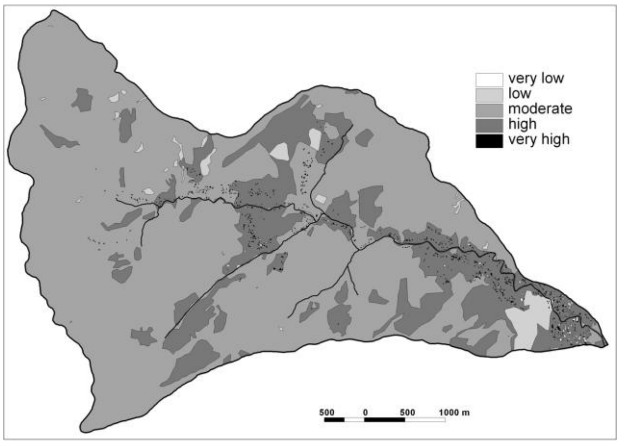

Fig. 6 Vulnerability map

Table 2 Risk matrix

Hazard	Vulnerability				
	Very low	Low	Medium	High	Very high
V. low					
Low					
Medium					
High					
V. high					

Source: after Bell, 2007

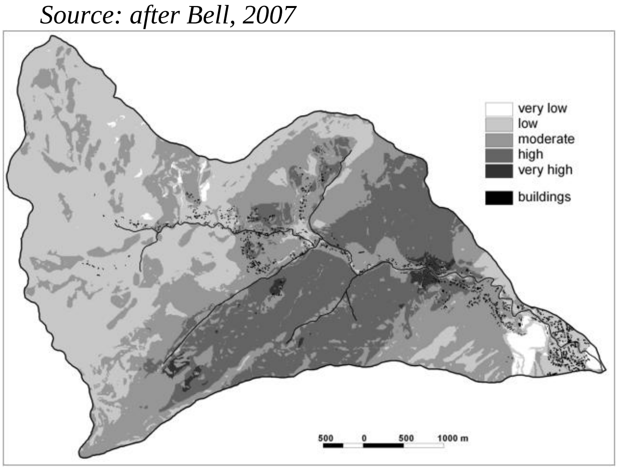

Fig. 7 Landslide risk map

CONCLUSION

The risk assessment and mapping is the final step of a complex procedure, which starts with susceptibility and hazard assessment (and for sure, not the other way around). Along this succession of activities, one may realize the importance of making a correlation of the working scale with the proper methodology. Likewise, it is strongly required a correlation between the quantity and especially the quality of the data and the proper methodology. The two approaches have both advantages and draw-backs: a quantitative approach gives indeed good and objective results, but it requires a lot of data, maybe not all the time available; qualitative approach requires more easy to obtain data, but due to their more general content, it may give good results only if carefully handled, because its rather subjective estimations, based on the expert's knowledge or judgement.

As for Muscel Catchment, taking into account the presence of large areas belonging to high risk classes, it implies a more active involvement of local authorities in realizing a common landslide data set used for a proper risk assessment, vital in establishing local development plans.

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DOI: 10.5775/fg.2067-4635.2011.021.i

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1/ June 2011, pp. 78-90
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.00008.i

Downstream Variation in the Pebble Morphometry of the Trotuş River, Eastern Carpathians (Romania)

Dan DUMITRIU[1], Mihai NICULIŢĂ[1], Daniel CONDORACHI[1]

[1]University Al. I. Cuza, Iaşi, Bld. Carol I, no 11, 700506, Iaşi, Romania, email: dndumitriu@yahoo.com

Received on <November 21, 2010>, revised on <February 1, 2011>, accepted on <April 29, 2011>

Abstract

Riverbed sediments morphometrical analysis can offer, along granulometric and petrographic analysis, relevant information on sediment source origin, transport environment and sedimentation process. Today, there are numerous descriptive indices for clasts shape and size, each one trying to evidence the influence of dynamic conditions and clasts petrography that are mobilized in certain transport environment, their shape at certain moments. Among these, this analysis focused on only 10 morphometric indices. The obtained data, either from direct measurements on 5,027 clasts or after index calculations, were processed and obtained a set of statistical parameter (average, median, standard deviation, etc.). Based on these data was assessed „*optimal shape*” for Trotuş riverbed gravels. Some parameters (like average value) were used to create frequency histograms for some morphometrical indices in sampling points and to make some mathematical modeling.

Keywords: *particle morphology, shape index, roundness, sphericity, optimal shape*

Rezumat. Variaţia unor parametri morfometrici ai pietrişurilor în lungul râului Trotuş, Carpaţii Orientali (Romania).

Analiza morfometrică a materialelor de albie poate să ofere, alături de analizele de granulometrie şi petrografie, informaţii asupra provenienţei aluviunilor, mediului de transport şi asupra modului de depunere a particulelor sedimentare. În prezent, există o mare varietate de indici descriptivi ai formei şi dimensiunii particulelor sedimentare, fiecare încercând să cuantifice cât mai fidel influenţa condiţiilor dinamice şi a constituţiei petrografice a materialelor supuse transportului în anumite medii, asupra aspectului acestora la un moment dat. Din multitudinea acestora noi ne-am concentrat atenţia doar asupra a 10 indici. Datele obţinute, fie din măsurători directe asupra a 5027 galeţi, fie în urma calculării indicilor, au fost prelucrate, obţinându-se o serie de parametri statistici (media, mediana, deviaţia standard etc.). Pe baza acestor indici s-a realizat şi o evaluare a “*formei optime*” a pietrişurilor din albia râului Trotuş. Unii parametri statistici (de exemplu, media) au fost utilizaţi pentru obţinerea histogramelor de frecvenţă a indicilor morfometrici în punctele de eşantionare şi a modelărilor cu ajutorul funcţiilor matematice.

Cuvinte-cheie: *pietrişuri, parametri morfometrici, indici de formă, rotunjime, sfericitate, forma optimă*

INTRODUCTION

Particle morphology, or form, refers to the sum of the surface characteristics of sedimentary grains. Processes of weathering, erosion, and transport may all leave distinctive imprints on particles, in the form of fractures, worn surfaces, and particular surface textures (Benn, 2010). In this way, morphometrical analysis can offer, along granulometric and petrographic analysis, relevant information on sediment source origin, transport environment and sedimentation process (Krumbein, 1941b; Pettijohn, 1949; Knighton, 1982; Bridgland, 1986; Howard, 1992; Illenberger and Reddering, 1993; Huddart, 1994; Ichim et al., 1998; Graham and Midgley, 2000; Moussavi-Harami et al., 2004; Demïr and Walsh, 2005; Attal and Lavé, 2006; Stanley and So, 2006; Lindsey et al., 2007; Ehlmann et al., 2008; Tamrakar and Shrestha, 2008; Mureşan, 2009; Hurst et al., 2010). Shape identification is also a key element in the study of transport. Sorting of sedimentary particles by size, shape, and density is of fundamental importance in the development of graded sediment beds in both space and time (Goede, 1975; Ueki, 1999; Milana et al., 1999; Domokos et al., 2010). The methods and schemes used to present/ of presenting primary particle shape data have been the subject of lively discussions, with a variety of schemes being advocated, a comprehensive summary is provided by Illenberger (1991), Graham and Midgley (2000) (Domokos et al., 2010). Each of these descriptive indices for particle size and shape try to quantify, as precise as possible, the influence of dynamic conditions and particle petrographic composition that were transported in certain environments and their appearance at a certain time. Many parameters for characterizing particle form were developed in the 1930s to 1960s because it was realized that particle form affects the area exposed to forces of flow, drag forces, lift forces, and therefore particle entrainment, transport, and deposition. Thus, two particles of the same weight or the same *b*-axis size but with different shapes can respond quite differently to water flow (Bunte and Abt, 2001). Three types of characteristics may be defined: *shape*, or the relative dimensions of the particle; *roundness*, or the overall smoothness of the particle outline and *texture*, or small-scale surface features (Benn, 2010). Among these, this analysis focused on only 10 indices as follows: *Cailleux roundness index* (R_c), *Cailleux flatness index* (A_p), *Cailleux asymmetry index* (A_s), *oblat – prolat index (OP), disc – rod index (DRI), maximum projection sphericity (MPS), Corey Shape Index (CSI), elongation index c/a, elongation index b/a, elongation index c/b*. The obtained data, either from direct measurements on 5,027 clasts, or after index calculations were processed and were obtained a set of statistical parameter (average, median, standard deviation, etc.).

STUDY AREA

The Trotuş drainage basin is located in central-eastern part of Eastern Carpathians and Moldova Subcarpathians and has about 4,350 km^2 and a length of about 160 km (Fig. 1). Between headwaters and the Siret confluence, the altitude difference is about 1,290 meters (from 1,360 meters altitude at headwaters to 70 meters altitude at confluence). The Trotuş river is of VIIIth order in Strahler classification. The catchment area lies on four distinct structural and lithological units: the marginal syncline, the carpathian flysch, the pericarpathian molasse and the platform.

Petrographically, in the four litho-stratigraphical units dominate the following lithology: 40% clayey silty rocks; 35% sandstones of different types; 18% Quaternary deposits (gravels, sands, loams, clays); 5% crystaline schysts, limestones and dolomites; 2% menilites, disodiles, etc. (Dinu, 1985; Grasu et al., 1988, 1995, 1996, 1999, 2004).

Average annual rainwater spans from 722 mm/year in the Trotuş Valley and almost 1,000 mm/year in higher mountains. These values drop down about 100 mm/year in central part of Dărmăneşti Depression and towards the subcarpathian limit. Average annual discharge for the Trotuş river, recorded at Vrânceni hydrometric station, is of 33 m^3/s while the maximum was of 3,720 m^3/s, recorded on the 29th of July 1991. Between July 12 and 13, 2005 for the Trotus river, the increased water levels were caused by the extreme flow rates that surpassed the average multiannual discharge for the month of July. For example, a maximum discharge of 2,800 m^3/s was recorded at Vrânceni, comparing with 41.3 m^3/s. At several other Trotus River watershed, the discharge were large and reached the exceeding probabilities of 1–2% (Romanescu and Nistor, 2010).

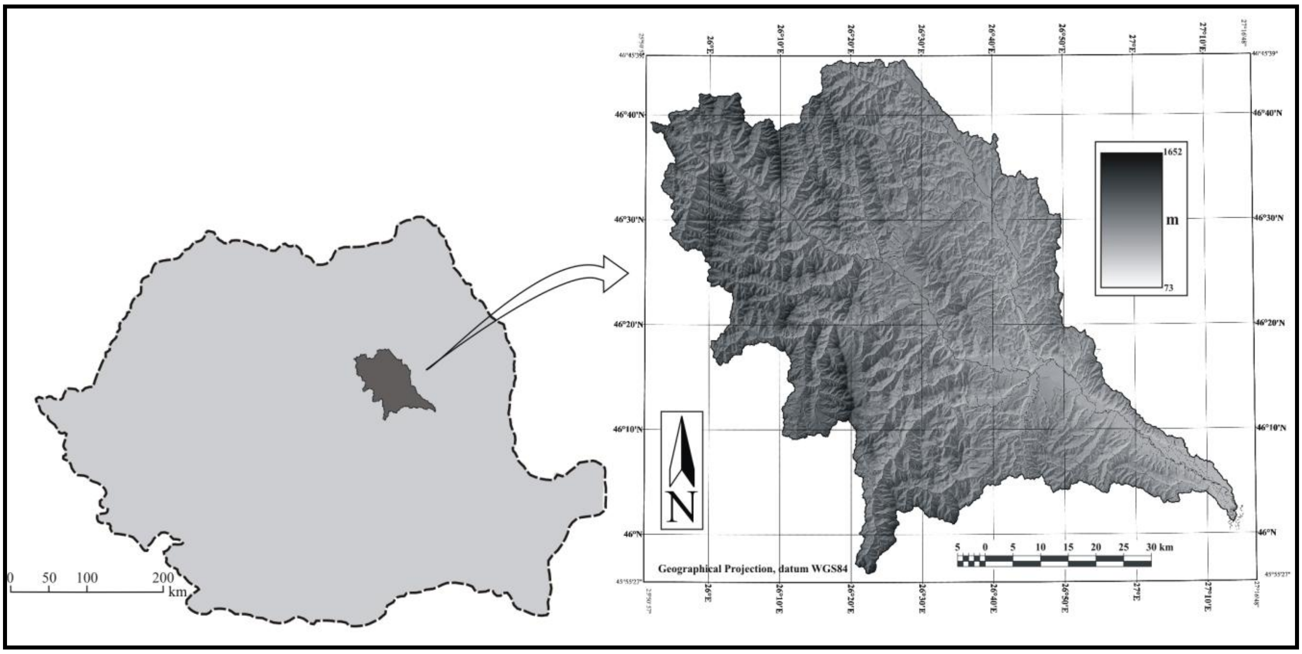

Fig. 1 Study area location

DOI: 10.5775/fg.2067-4635.2011.00008.i

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MATERIALS AND METHODS

Riverbed sediments sampling

At first, it was started by sampling material from riverbed. In this study was used volumetric sampling for river channel sediments that uses sampling for surface layers or pavement layer and subsurface layer or subpavement layer (Mosley and Tindale, 1985; Church et al., 1987; Ichim et al., 1992). This sampling method consists in drawing of three sampling categories: *surface sample* (from the layer called hydraulic layer of which thickness is equal with the diameter of the largest clast; *subsurface sample* (or material located under hydraulic layer); *a global sample* (obtained by summing up the previous sampling categories). After setting up the sampling method and sampling points (21 channel sections at a distance of 7 km of each other – Fig. 2) topometric measurements were made, for each sampling point, to precisely assess the slope of the river channel and flood plain. Then, using the method proposed by Mosley and Tindale (1985), that states that the weight of the largest clast from sampled area is 5% from total weight of the sample, the clast with the largest diameter was identified. This was weighted to know the quantity of the sampled probe area. One square meter area was chosen as being representative for the entire section, out of which were collected surface and subsurface gravel. Some of granulometric fractions were sieved directly in the field using a set of sieves with holes having diameters according to the Wentworth scale. Sieving holes were of 64 mm (-6 phi), 32 mm (-5 phi), 16 mm (-4 phi), 8 mm (-3 phi). The clasts with diameters between 128-256 mm were measured and weighted using a special calliper. For the ones larger than 256 mm, more difficult to be weighted in the field, a diameter-weight scale conversion was used (Church et al., 1987; Ichim et al., 1992) built on the basis of the river clasts that were investigated by evaluating the weight of the biggest clasts on the basis of the *b* axis.

After all the sampled material was weighted, and grouped in classes (piles of gravel were made for them) sample clasts were taken from each class. It was randomly picked 100 clasts from classes of 16-32 mm and 32-64 mm for morphometrical and petrographical lab analysis. For the material smaller than 8 mm, sieving was continued in the lab using sieves of smaller diameter (6; 5; 2; 1; 0.5; 0.2; 0.1 mm). From the obtained results there were made assessments on differences from pavement and subpavement, on median diameter of riverbed deposits, on the percentage of each granulometric fractions, clasts morphometry, lithology, etc. Global samples (by summing pavement and subpavement samples) were separated in 14 granulometric classes, at 1 phi interval, on five dimensional steps, according with Wentworth scale (Church et al., 1987), as follows: *i) silt + clay* (< 4 *phi* or 0,063 mm); *ii) sand* (between 4 *phi* or 0,063 mm and - 1 *phi* or 2 mm); *iii) gravel* (between - 1 *phi* or 2 mm and - 6 *phi* or 64 mm); *iv) cobble* (between - 6 *phi* or 64 mm and - 8 *phi* or 256 mm); *v) boulder* (over - 8 *phi* or 256 mm). For morphometric and petrographic analysis were randomly selected 100 clasts (were analysed 5,207 clasts) from 16-32 mm (*coarse pebble*) class and 32-64 mm (*very coarse pebble*) class.

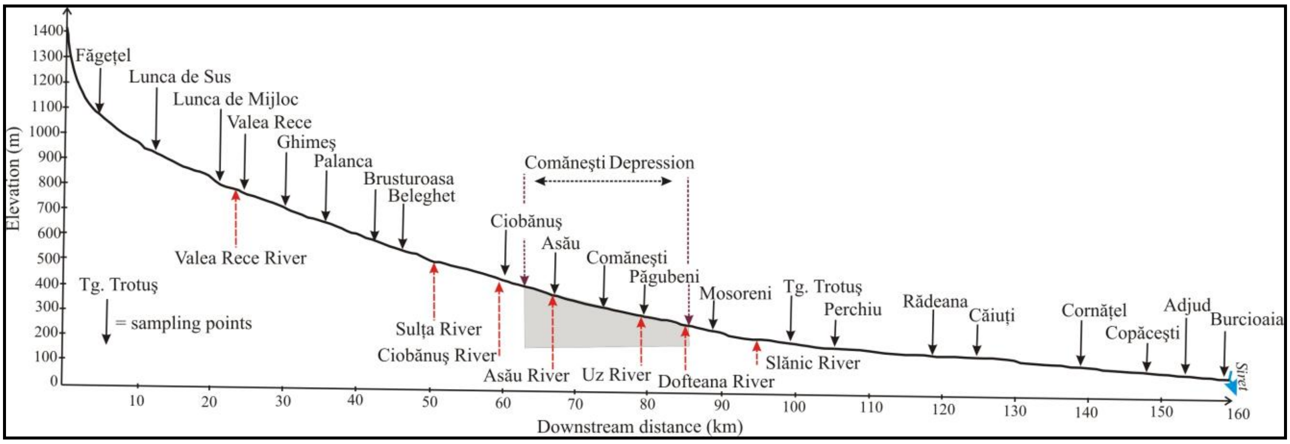

Fig. 2. Sediment sample points distribution

The analysis of gravel morphometry

The particles shape and roundness indices are calculated using formulas that contain a set of parameters. Basic parameters are represented by the values of the three axes (*a*, *b*, *c*), which, in our case were obtained by direct particle measurements using sliding callipers and the value of the ray of the sharpest corner (r_1) from particle maximum

DOI: 10.5775/fg.2067-4635.2011.00008.i

projection plane (*ab* plane). Plane shape of the particle was obtained by using an instrument whose working principle consists in creating a light beam plan-parallel using a concave mirror and in its focal point was put a source of light. Particle to be measured is placed on a flat glass piece in front of the light beam and its shadow is drawn on paper. Knowing *a*, *b*, *c* axe values and curvature rays a whole set of indices can be computed, among these, the ones proposed by Zingg (1935), Cailleux (1945, 1947, 1952), Sneed and Folk (1958), Dobkins and Folk (1970), Krumbein (1941), Corey (1949), with which it can be assessed the precise shape of the particle (Fig. 3 and Table 1).

Other calculation methods were proposed by Hockey (1970), Ballantyne (1982), Benn and Ballantyne (1993), Blott and Pye (2008). These have the advantage of the ease of computation for individual ratios.

Table 1 Used morphometric indices

Index	Formula	Author
Cailleux roundness index	$R_0 = 2r_1 / a$	Cailleux (1947)
Cailleux flatness index	100 (a +b) / 2c = FI	Cailleux (1945)
Cailleux asymmetry index	A_s = AC / A	Cailleux (1952)
Sneed & Folk (1958) elongation index	c / a b / a c / b	Sneed & Folk (1958) Zingg (1935) Zingg (1935)
Disc-Rod Index (DRI)	(a - b) / (a - c) = DRI	Sneed & Folk (1958)
Oblate-Prolate Index (OPI)	OPI = 10 (((a - b) / (a - c) - 0,5) / C / a)	Dobkins & Folk (1970)
Maximum projection sphericity (MPS)	$^3\sqrt{}$ (c^2 /ab) = MPS	Sneed & Folk (1958)
Corey Shape Index (CSI)	CSI = c / $^2\sqrt{}$ (ab)	Corey (1949)

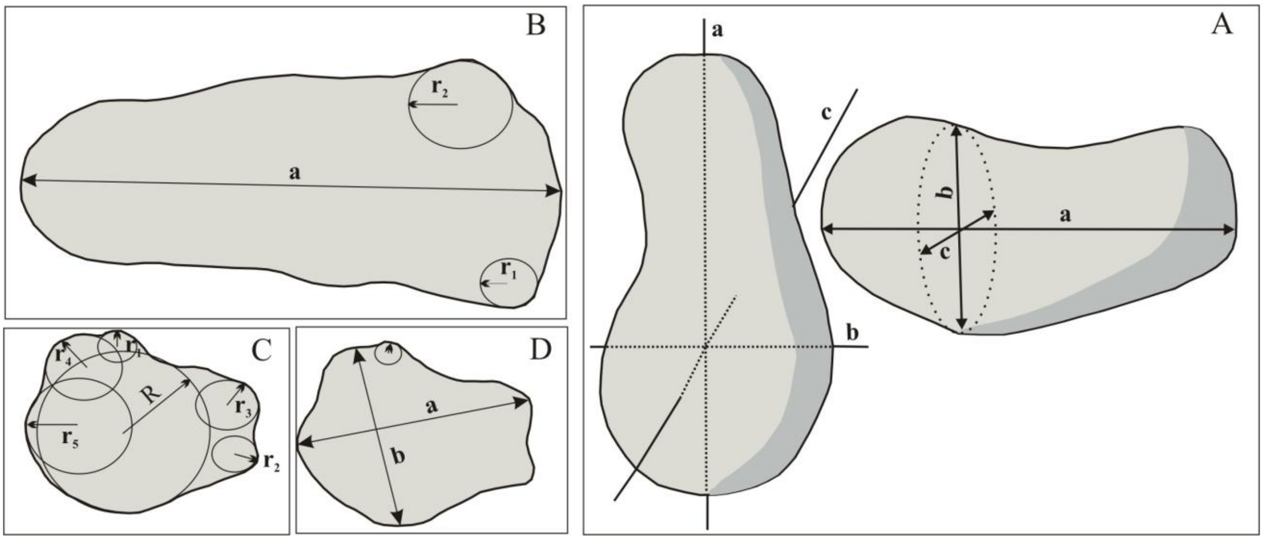

Fig. 3 A. The measurement of a, b, c particle axes after Cailleux (1947) method; B. Particle roundness measurement after Cailleux (1947) method; C. Particle roundness measurement after Wadell method; D. Particle roundness measurement after Wentworth method

RESULTS AND DISCUSSION

Variation tendency of morphologic indices along the Trotuş river were assessed by using mathematical functions as follows (Maria Rădoane et al., 1996, Ichim et al., 1998): *linear* - $y = a + bx$; *exponential* - $y = a\ e^{bx}$; *power* - $y = ax^b$; *logarithmic* - $y = a + b\ lgx$; *hyperbolic* - $y = a + b\ 1/x$; *polynomial* - $y = a + bx + cx^2 + dx^3$, in which: *y* – is the analysed morphometric parameter ; *x* – transport distance from headwaters, in km ; *a, b, c, d* – regression coefficients. Obtained results allowed us to confirm some general reports made by Miclăuş et al., (1995) and Ichim et al., (1996) according which: *(i)* particle shape is strongly controlled by *transport distance*; *(ii) the value and the sign of regression coefficients (b, c, d,* e) reflects the way in each morphometric index is influenced by the increase of transport distance.

Cailleux roundness index

Coarse pebble roundness (16 – 32 mm) is growing, between the two extreme sampling point (Făgeţel, located at 7.1 km from headwaters and Burcioaia, at 159 km), from 0.170 to 0.365.

DOI: 10.5775/fg.2067-4635.2011.00008.i

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Considering these values we can say that we are almost in an ideal situation, in which roundness index doubles from headwaters to the outflow. Between the two extreme points there are some sectors in which roundness index grows up to 0.300, and after each important confluence a decrease is reported, mostly influenced by materials inputs which were transported on much shorter distances.

In this way, particle roundness becomes greater, in general, down to the Ciobănuş confluence, then is reduced to 0.231. Between the Asău and Oneşti, the coarse gravel roundness index is above 0.300, after the confluence of Trotuş with Oituz, Caşin and Tazlău rivers, it drops to 0.273, then downstream of Rădeana is reported a small increase of this index. Smaller value of this index for the gravels sampled in sections located closer to headwaters reflects, on one hand shorter transport distances, and the Sinaia sandstones dominance in the riverbed deposits petrographic spectra which start their travel with a strong flatness index, on the other hand.

For very coarse gravels, the roundness index grows from 0.136 in Făgeţel section, to 0.360 upstream the confluence of the Trotuş river with the Siret river (Fig. 4). Compared with the values reported for the previous class, the very coarse gravel displays a much more uniform variation of this index along the river longitudinal profile. Some variations, generally specific along large rivers, like fast change on short distance for roundness index in high energy environments and its decrease along the transport distance, were reported in many studies (Mills, 1979; Richards, 1982; Ichim et al., 1998; Rengers and Wohl, 2007; Miao et al., 2010).

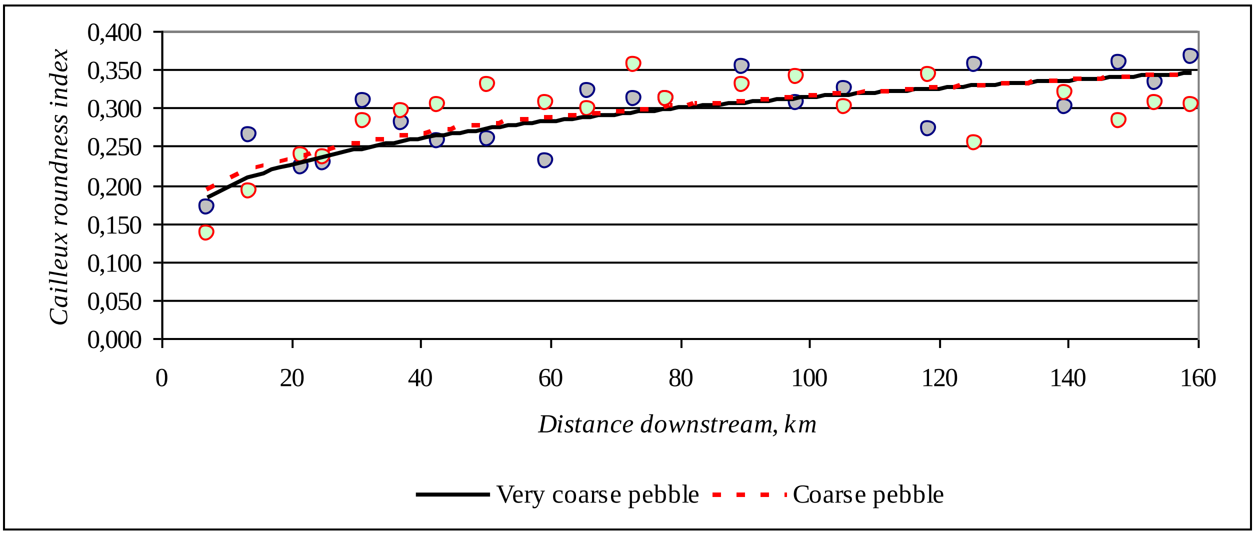

Fig. 4 Cailleux roundness index variations for gravels along the Trotuş river

Cailleux flatness index

Coarse pebble flatness (16-32 mm) within the Trotuş riverbed deposits is best described by second polynomial function. Dal Cin (1967), reported for the Piave river, in Italy, that the flatness is a very good indicator for hydro-dynamic conditions by the fact that in the river upper course very flat pebbles have many chances to break perpendicularly on *ab* plane, due to stream turbulence, while in mid course, with less transport competence, coarse particles rest longer in riverbed and are polished by the sand transported at low level waters. While flatness variations in upper and mid courses received reasonable explanations, the increase of this index in lower course, for most studied rivers, still lack sound explanations. Dal Cin (1967) considered that lower course saltation phenomenon can explain pebble flattening along the entire length of the river. The trends reported by Dal Cin (1967) were confirmed, for some Romanian rivers by Ichim et al., (1990) and (1998).

Coarse pebble flatness from the Trotuş riverbed tends to have a certain increase downstream, but as it can be noticed in Fig. 5 still has a constant slight decrease in the same direction. Theoretically, this situation is normal – roundness is increasing downstream and the flatness is decreasing in the same direction.

As for roundness index, this general tendency does not reflect in field situations. From one river sector to another, there are large variations for flatness index. For example, within only 8 km, flatness index increase from 227.946 (in Lunca de Sus section, which has almost the minimal value) to 316.818 (in Lunca de Mijloc section, which is the maximum value). We consider that pebble petrography has a more important role in pebble flatness and roundness than hydro-dynamic

DOI: 10.5775/fg.2067-4635.2011.00008.i

conditions, at least in this case. Flattened sandstones (Sinaia sandstone, convoluted sandstones, Podu Secu-Plopu sandstones, etc.) dominant in pebble petrographic spectra, for many river sectors, have an important effect on shape and size of coarse particles. For example, it was reported that pebble flatness index is over 240 for sampling sections in which the Sinaia sandstone clasts is over 50% from global sample (Ghimeş, Palanca, Brusturoasa). Another reason that might lead to our results partial uncorrelation, with the ones reported in other studies, is that statistical processing was made on global samples and not on certain lithologies. However, we can draw the following conclusion: the smaller the pebble size, the greater is the roundness index and the smaller is the flatness index.

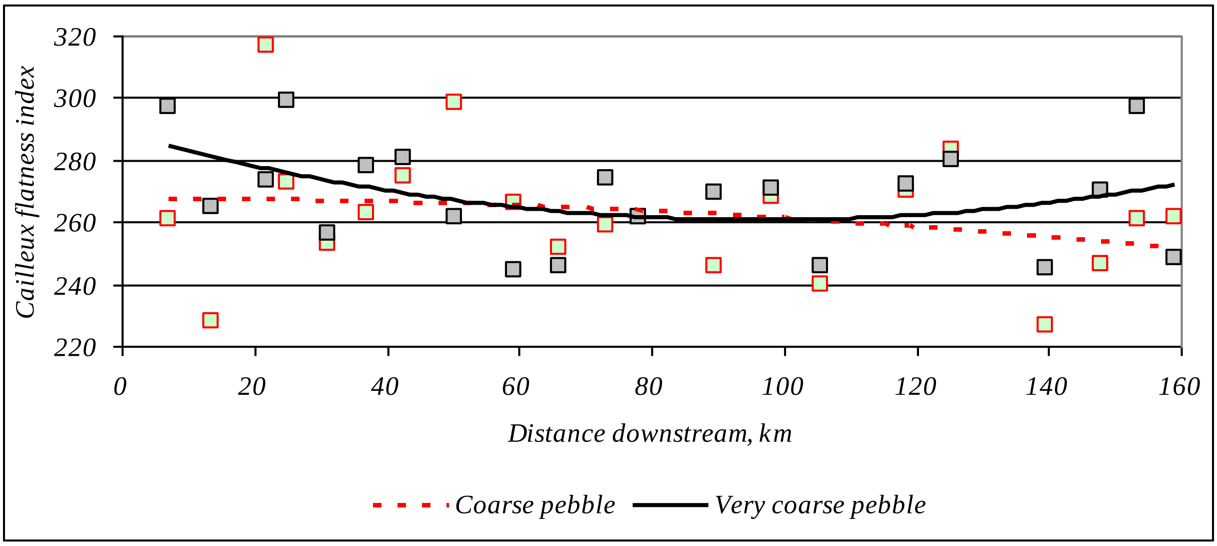

Fig. 5. Pebble flatness index variation along the Trotuş river

Very coarse pebble (32 - 64 mm) flatness index generally comply the tendency reported in the above-mentioned rivers. There is a decrease of it from upper course to mid course and a small increase towards the end of river, with values close with the one recorded in the first 20 km of the stream (for example, at Făgeţel, flatness has a value of 297.033, and at Adjud, at 150 km distance downstream, is of 296.697).

Cailleux asymmetry index

Asymmetry index, like roundness and flatness indices have some differences between the two pebble classes. Coarse pebble asymmetry has a longitudinal profile variation with close mean values (the minimum value is 0.616 in Rădeana section, and the maximum is 0.670 at Lunca de Mijloc section) which correlate well enough with the data recorded for roundness and flatness values. The maximum value for asymmetry index correlates well with the greatest value of flatness and with the second average minima for roundness (all reported at Lunca de Mijloc section). Except some anomalies recorded downstream important confluences or where the slope materials reach directly in the channel, general tendency of coarse pebble asymmetry index is a slight decrease towards the Siret confluence (Fig. 6).

Ichim et al. (1998) stated that asymmetry index, records, for most studied rivers, a tendency of exponential decrease. For coarse pebble, the tendency confirms the one reported by the above-mentioned authors, but not for very coarse pebbles, where some anomalies were recorded. In this case the difference between average minimum value and average maximum value is much higher. On 125 km distance, very coarse pebble asymmetry records a visible decrease (from 0.690 at Făgeţel section, to 0.621 at Căiuţi section, there being the average extreme values) then, downstream towards the Siret confluence, a small increase is recorded. Also, in this case, it is reported a direct correlation with the pebble asymmetry. Reports from different studies focused on pebble shapes indicated that fast and constant decrease of asymmetry, after a long fluvial transport, this index is capable to replace roundness index. This situation can be used when are made assessments for clasts decay over large transport distances (Ichim et al., 1998). In our case this replacement cannot take place, as previously stated, asymmetry decrease is constant in a certain sector, then an increase, in this way creating a better correlation with flatness and roundness indices.

DOI: 10.5775/fg.2067-4635.2011.00008.i

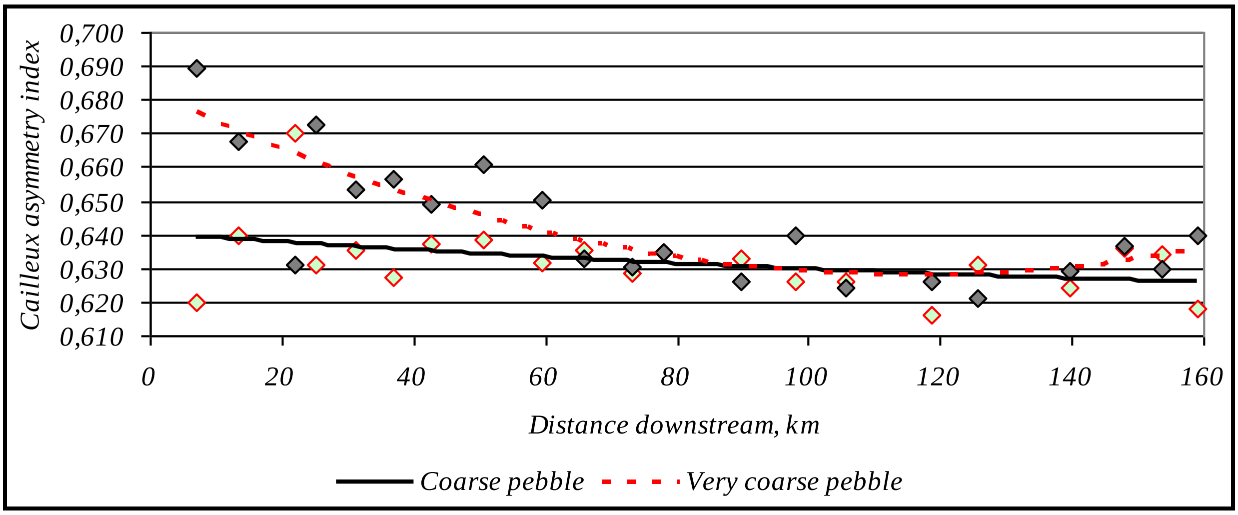

Fig. 6 Pebble asymmetry index variation along the Trotuş river

Maximum projection sphericity

Sphericity records ups and downs, among the main confluences, as this index is strongly influenced by lithology and our analysis was done on pebbles with very different petrographic spectra from one sampling section to another. Out of lithology, was reported a very good correlation between sphericity and quality class forms (rods and discs, blades and spheres) and, therefore, this index can influence sorting processes by the control made on particle mobility and ease of transport (Lane and Carlson, 1954). This authors demonstrate that low sphericity particles (disc shape ones, for example) are well anchored in the riverbed and, therefore, difficult to mobilise, but if so, are easy to be transported. According to the authors, this fact is caused by the small values recorded by vertical speed components. In the case of coarse pebble, maximum projected sphericity great values are reported in the first two sampling sections in the upper river course (Făgeţel and Lunca de Sus – 0.578 and 0.623, respectively). Lunca de Sus high value can be caused, at a certain extent, by the presence of Mesozoic limestones and Bistra sandstones whose increased sphericity is reflected in average general sphericity from the sampled point. Only at 8 km downstream, there is a very different situation. The decrease of Bistra sandstones and Mesozoic limestones share within petrographic spectra from coarse pebbles has as a result a decrease of clasts sphericity down to 0.510, which is the smallest value recorded. From this point further, with few exceptions, the sphericity index comply the rule available for most of the rivers, i.e. a slight increase towards the river mouth (Fig. 7).

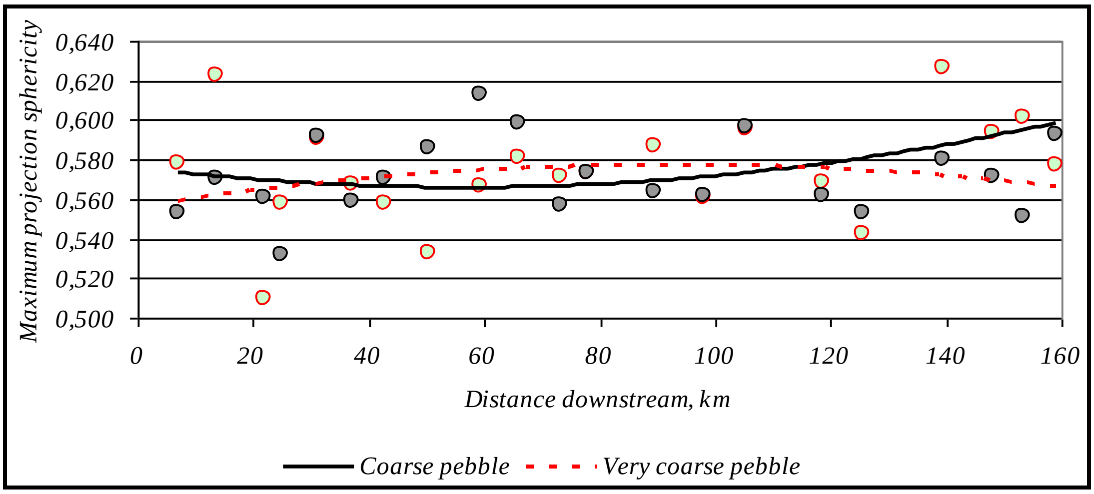

Fig. 7 Pebble maximum projected sphericity variation along the Trotuş river

DOI: 10.5775/fg.2067-4635.2011.00008.i

Exceptions appear where strong flattened rocks have over 50% from the petrographic spectra (Beleghet, Căiuţi etc.). This increase is very different compared with the results reported for other rivers (Moldova, Putna etc. - Ichim *et al*., 1994, 1998). The authors concluded that the pebble have the tendency to get a less spherical shape downstream, in order to be more resistant to the water flow. Also, in this case, we consider that the differences are given by the analysis type, for a certain lithology or for the entire pebble spectra. Moreover, we have to consider that most of the previous studies were done on very coarse pebble (32 - 64 mm) and then, were generalised for all pebble classes. As far as we can say, the behaviour is different from one petrographic class to another. Regarding sphericity index for very coarse pebble, a slight increase was reported in the first the 60 km, then the values are almost constant throughout the rest of the river.

Disc-Rod Index

The values of this index can be theoretically interpreted, as follows: if are closer to 0 value, pebbles shapes are more closer to a disc shape, and if the index value is closer to 1, clasts shape are closer to a rod/cylinder. For the Trotuş river, the average value for coarse pebble spans between 0.502 at Păgubeni (located at 78 km from headwaters) and 0.400 at Ghimeş (at 32 km from headwaters). Because 99% from the measured values are under 0.500, we can say that coarse pebble shape from the Trotuş riverbed deposits have a median position between the two extremes, much closer to disc shape, but with a slight tendency towards elongated shapes in the Trotuş lower course (Fig. 8).

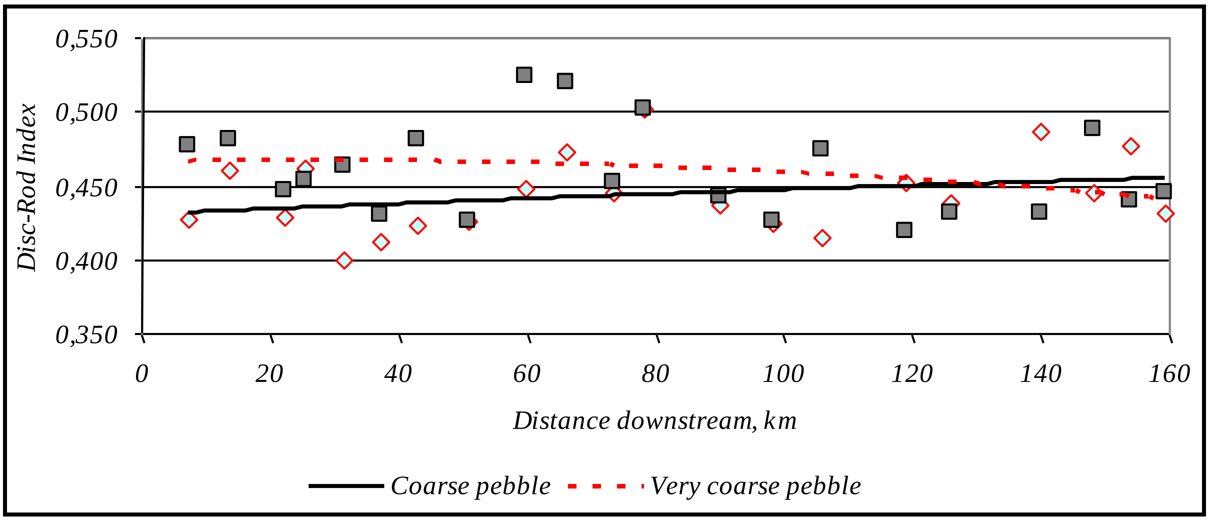

Fig. 8 Disc – rod index variation along the Trotuş river

Disc – rod index variation along the Trotuş river, specific for very coarse pebbles, seem to be much closer to the results demonstrated in scientific literature, in the way that higher values are specific for upper course, followed by a slight reduction tendency towards the mouth of the river. This behaviour seems to be reversed for coarse pebble.

Oblate-Prolate Index

Oblate - prolate index is somewhat alike with the previous one, in the way that smaller values are specific for more flat/ oblate shapes, and as these values are growing the pebble shape is much more elongated. The analysis for very coarse pebble within riverbed sediments it can be noticed a small downstream transition tendency from more advanced oblate shapes to a transitory oblate-prolate shape. Values of -2 and -3 are frequently recorded in upper and mid course, while downstream the Rădeana sampling section these values are close to 0, which indicates a certain change in the clasts shape (Fig. 9). Oblate-prolate index records a downstream general reduction tendency for very coarse pebbles which becomes flatter, but important tributaries can induce some anomalies for this index (sometimes visible enough).

DOI: 10.5775/fg.2067-4635.2011.00008.i

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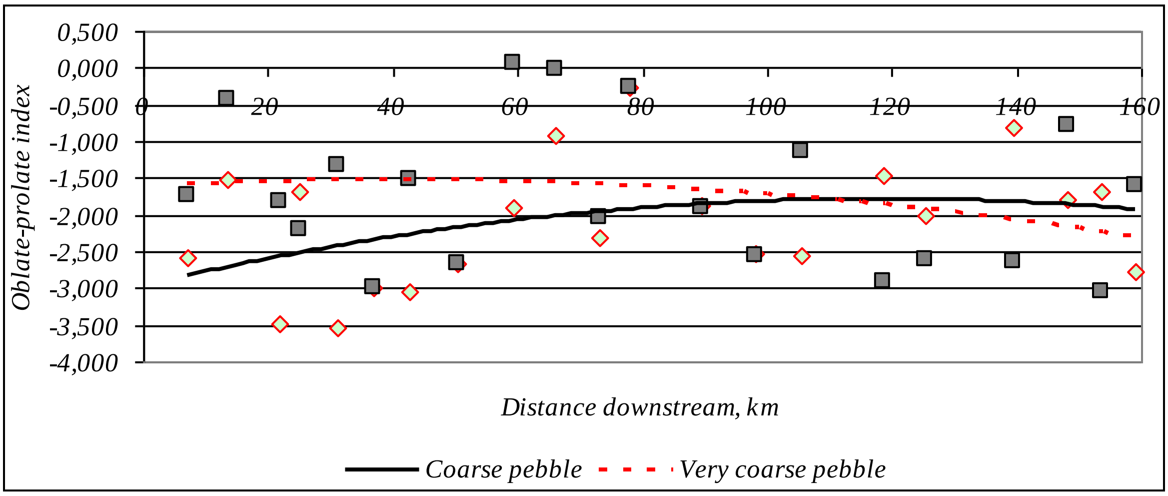

Fig. 9 Pebble oblate-prolate index variation along the Trotuş river

Corey shape Index and Sneed & Folk elongation index (*c / a*)

Both of them have almost the same variation tendency along the longitudinal profile. It was reported that in the upper and mid course (which is mostly the mountain area) average values for these indices locates the coarse pebble in plane-prismatic transition shapes class, while downstream (Subcarpathian and plateau area) are closer to the prismatic class shape (Fig. 10 and Fig. 11).

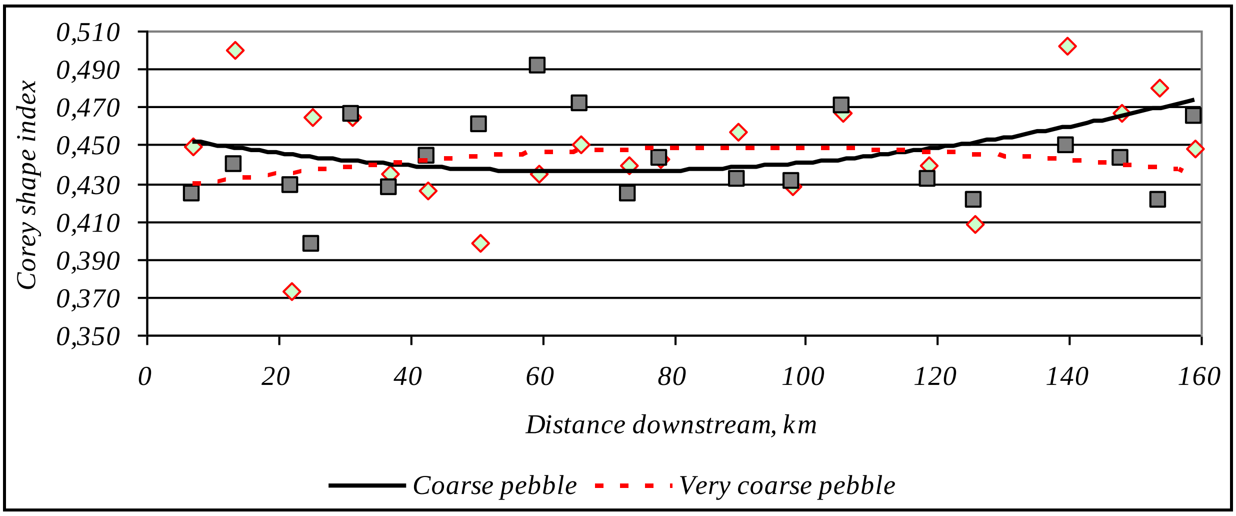

Fig. 10 Corey shape index variation along the Trotuş river

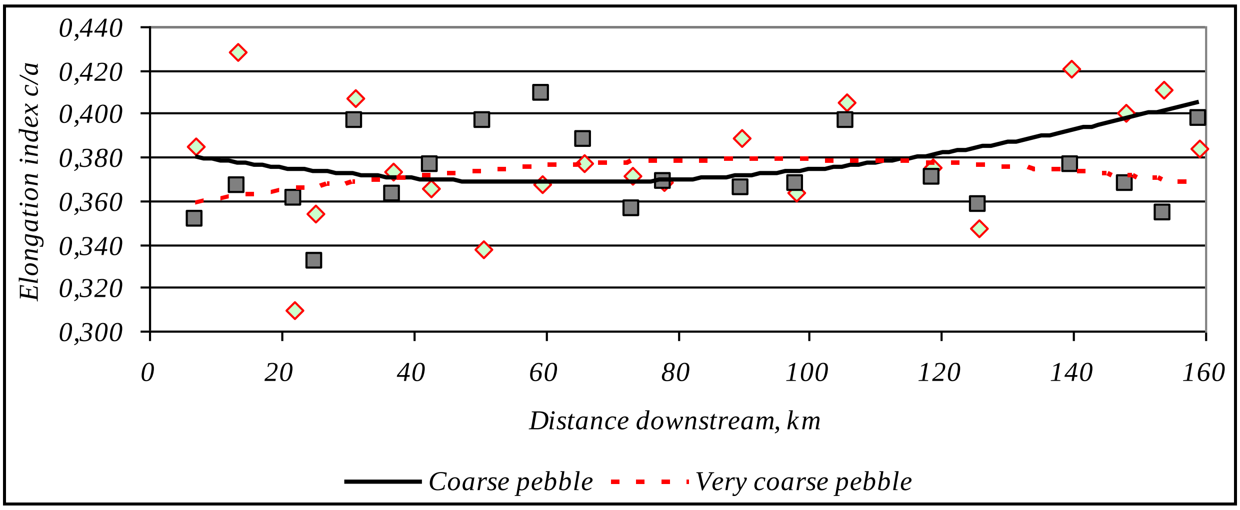

Fig. 11 Elongation index c/ a variation along the Trotuş river

DOI: 10.5775/fg.2067-4635.2011.00008.i

For very coarse pebble is reported the same downstream reduction tendency, which means that the clasts shape is more and more flat.

Ternary diagram created for five representative sampling sections (Făgeţel, Valea Rece, Comăneşti, Rădeana and Burcioaia), lead to obtaining the percentage values for some pebble morphometric indices (Dumitriu, 2007). Using Zingg (1935) classification (Fig.12 B), for example, it came out that for riverbed sediments dominates oblate class, for coarse pebble values are dominant in the upper course and for the inferior course dominate very coarse pebble values. For bladed clasts category the sectors are reversed, for both pebble classes. Oblate-prolate index classifications evidence that oblate shapes pebbles are dominant.

Pebble 'optimal shape' within the Trotuş riverbed sediments

Within Sneed and Folk diagram were delineated the areas for the following shape types: *compact, compact platy, compact bladed, compact elongated, platy, bladed, elongated, very platy, very bladed and very elongated* (Fig. 12 A).

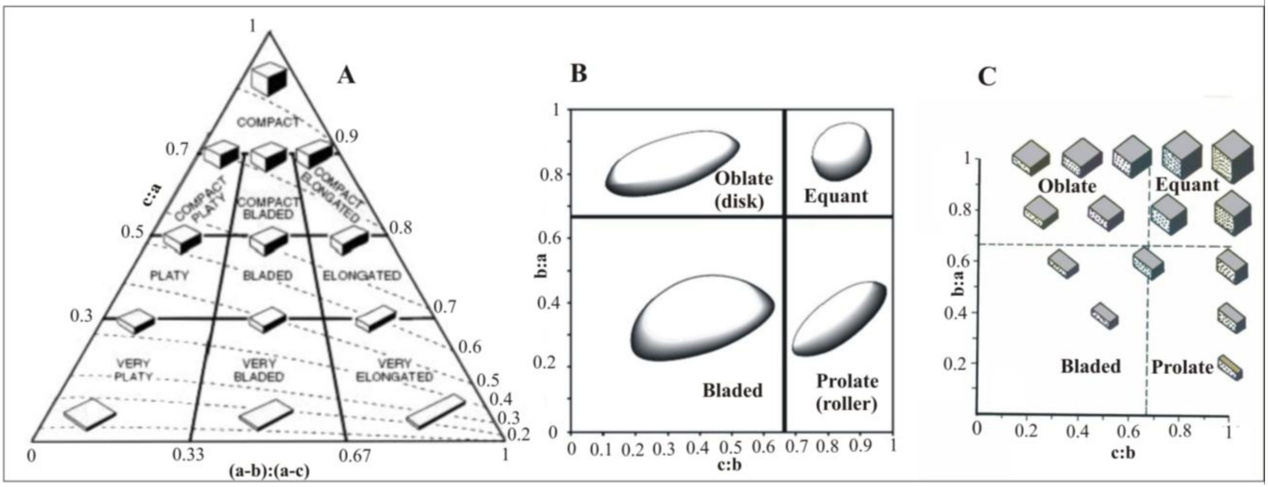

Fig. 12 A. The 10 descriptive classes defined by Sneed & Folk (1958); B. Zingg diagram. Shape classes definition; C. Zingg diagram particle distribution and shape

Based on these 10 descriptive classes it was made an assessment of the 'optimal shape' for gravel riverbed sediments within a river. The results evidenced that the cluster of values display a strong bimodality among these classes for the entire length of the river that confirms the results reported for other rivers (Ibbeken and Schleyer, 1986, for rivers in Calabria; Ichim et al.,1998 - for the Putna river). The dominating class, according with the percentage values, along the entire river length is the bladed class, within 12 out of 21 sampling sections. Cumulated percentage of the bladed class for the pebbles sampled in all 21 sections has values from 20 to 27%. Only in 4 sections (Făgeţel, Valea Rece, Brusturoasa, Mosoreni) the bladed class is not dominant for very coarse pebbles, while coarse pebbles is in minority for other 5 sections (Lunca de Mijloc, Beleghet, Păgubeni, Rădeana, Căiuţi). Very bladed class holds about 15-20% for both granulometric class pebbles, while platy and very platy classes hold 10-15% each.

CONCLUSIONS

Gravel morphometrical analysis evidenced the following conclusions:

- for *Cailleux roundness index* was reported that the two analysed granulometric classes have largely the same behaviour. In general, it was noticed a twofold increase of the index value between first and last sampling section. This index value decrease for Ciobănuş-Asău and Oneşti-Rădeana sectors can be explained by the intake of weak river processed materials (reported downstream several confluences) or of completely raw materials, when the slopes feed directly the river channel;
- in the case of *Cailleux flatness index* it was reported that for coarse pebble is a uniform slight decrease of the index value, a reverse tendency that was reported for most of the studied rivers. Very coarse pebble flattening comply, widely, the general accepted tendency i.e. a decrease of the value from lower to midcourse, followed by a new increase of the value;
- *Cailleux asymmetry index* should record an exponential decrease tendency, but this is true only for coarse pebble, while for very coarse pebble it seems to display a certain increase downstream the Căiuţi section and downward the Siret confluence;

DOI: 10.5775/fg.2067-4635.2011.00008.i

- *maximum projection sphericity* for the Trotuş riverbed gravels is closely related with lithology, which, in turn, decides the shape of the clasts. In this way, coarse gravel sphericity has the same tendency reported for most of the rivers, i.e. a certain increase downstream. For very coarse pebble it was reported a slight increase of the index value for the first 60 km of the river, then the values are almost constant throughout the rest of the drainage channel;
- for *disc-rod index* was reported that about 99% of the values are under 0.500, which can lead us to conclude that coarse pebble shapes from Trotuş riverbed have an average position between the two extremities, much closer to disc form and a slight tendency to more elongated shapes in the lower river course;
- *oblate-prolate index* has a general decrease tendency downstream, which tell us that pebbles are more and more flattened, but with certain disturbances induced by the most important tributaries;
- for *Corey shape index* and *Sneed & Folk elongation index (c/a)* was reported that in upper and midcourse average values for these indices locates the coarse pebble in plane-prismatic transition shapes class, while in lower course are closer to prismatic class shape. For very coarse pebble is reported the same downstream reduction tendency, which means that the clasts shape is more and more flat.
- estimation of the *optimal shape* of gravels was made using the Sneed and Folk's (1958) 10 descriptive classes. Their distribution points out two shape classes, namely: *bladed*, specific for 20 - 27% from the all sampled pebbles; *very bladed*, with values between 15% - 20% from the Trotuş river sampled pebbles.

ACKNOWLEDGMENT

This work was supported by CNCSIS – UEFISCSU, project PNII – IDEI number 436/2007.

We gratefully acknowledge Maria Rădoane for her pertinent opinions on fluvial geomorphology, Constantin Grasu and Crina Miclăuş for their help in understanding the Trotuş river bed deposits lithology.

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  DOI: 10.5775/fg.2067-4635.2011.00008.i

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Volume 10, Issue 1/ June 2011, pp. 91-98
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.022.i

Types of Riverbed along the Lower Course of the Buzău River

Ion FLOROIU[1]

[1] University of Bucharest, Faculty of Geography, Bucharest, email: floroiuion@yahoo.com

Received on <December 25, 2010>, revised on <January 23, 2011>, accepted on <May 25, 2011>

Abstract

In the present study there were analyzed two sectors of river bed, located along the lower course of the Buzau River: Vadu Paşii – Săgeata (sector of braided channel) and Ibrianu – Custura. Through the calculation of some indices (the braiding index, the sinuosity index), the performance of correlations between elements established through measurements (length and amplitude of the meanders, the width of the river bed) could be differentiated the types of river beds. By analyzing the Austrian maps in 1910, of the topographic maps, orthophotoplans and Landsat images from 1987, 2000, 2006 and 2007 it could be observed the spatial dynamics of the specific element of each type of river bed. For the Vadu Paşii – Săgeata sector the braiding index reduced from 3.4 in 1981 to 2.32 in 2005. In the Ibrianu –Custura sector, there took place many underpinnings at the level of the complex meanders, and the length of the river reduced from 36.4 km to 24.5 km.
Keywords: *braided channel, meander stream, Buzău river, self-capture*

Rezumat. Tipuri de albie pe cursul inferior al râului Buzău

În studiul de faţă au fost analizate două sectoare de albie de pe cursul inferior al râului Buzău: Vadu Paşii - Săgeata (sector de albie împletită) şi Ibrianu-Custura. Prin calcularea unor indici (indicele de împletire, indicele de sinuozitate), realizarea unor corelaţii între elementele determinate prin măsurători (lungimea şi amplitudinea meandrelor,lăţimea albiei) au putut să fie diferenţiate tipurile de albie. Din analiza hărţilor austriece din 1910, a hărţilor topografice, a ortofotoplanurilor şi a imaginilor Landsat din 1987, 2000, 2006 şi 2007 s-a putut observa dinamica spaţială a elementelor specifice fiecărui tip de albie. Pentru sectorul Vadu Paşii - Săgeata indicele de împletire s-a redus de la 3.4 în 1981 la 2.32 în 2005. În sectorul Ibrianu - Custura au avut loc numeroase autocaptări la nivelul meandrelor complexe, lungimea râului Buzău micşorându-se de la 36.4 km la 24.5 km.
Cuvinte-cheie: *albie impletită, curs meandrat,* *râul Buzău,* *autocaptare*

INTRODUCTION

This study proposes, besides the quantification of the elements related to each type of river bed, also to the establishment of some causal connections both at the level of the analyzed components and between them and the exterior factors.

The Buzău valley in the plain area, in the sinuous sector and especially in the sector with meander formation, was studied by Sivia Lupu (1971) who highlighted the change of the stream of the Buzău river between the localities Deduleşti and Ibrianu in July 1969, analyzing the causes and effects over the fluvial banks Câineni, Amara and Balta Albă, previously fed from the Buzău River and also over the localities located in the area of the actual abandoned stream regarding the ground-water layer. Ielenicz M. (1968), analyzing Buzău Plain, makes also a short reference about the flood plain of the Buzău in the braided channel sector (between Verneşti and Săgeata) and the sinuous one in relation to the reconstitution on the right side of the river of some old streams, which represent an evidence of the flowing of the Buzău river in the Călmatui valley.

The majority of the existing works analyze the Buzău valley in the lower course from an evolutional point of view (Vâlsan, 1915; Liteanu, 1961;Popp,1963;Vişan,1978) or in the context of the geomorphologic characterization of Râmnic Plain (Lupu et. al 1973).

The Buzău river is situated in the south-east of the country, having a total length of 302 km and a surface of 5,264 square km. The analyzed river bed sectors are in the lower stream at the contact point of Râmnic Plain, Buzău Plain and Brăila Plain.

The ground of the river bed is constituted in the sector Vadu Paşii – Săgeata by the deposits of the alluvial fan of the Buzău river. This is composed by two horizons of boulders and gravel (5-11 meters and 12-29 meters), and between them is intercalated the clay (Enea, 1964). In the sector with meander formation, according to a hydrogeological drilling performed by the Directorate of Romanian Waters Buzău – Ialomita, near the Băile locality, there were found, up to the depth of 350 m, deposits of sandy clay, clayey marls, with intercalations of grey – yellow clayey sand.

The contact between the river bed and the surface of the plain is entirely made through the terrace of 1-2 meters relative altitude (Sârbariei terrace) and 4-5 meters relative altitude (named Obor terrace in the area of city) along the alluvial fan of the Buzău river. On small sections (Vadu Paşii, Dâmbroca) where they lack, the crossing is sudden through the mountainsides of 5-8 meters.

DATA AND METHODS

In the analysis of the river beds types there were used the Austrian maps from 1910, the topographic maps from 1979-1981, orthophotoplans from 2005 and Landsat images from 1987, 2000, 2006 and 2007. These materials were georeferenced in Stereo 70 projection with the help of the programs ArcGis 9.2, Arc View 3.2 and Global Mapper.

To observe the dynamics of the liquid flow, but especially of the solid flow (daily averages for the period 1974 – 2008) we used the data for the hydrometrical posts Baniţa (located in the sinuous sector) and Racoviţa (situated in the sector with meander formation) made available by Buzău Department for Waters Household.

The morphometrical analysis of the braided channel sector (between the localities Vadu Paşii – Beilic) and of the sector with meander formation (between the localities Maraloiu – Custura) was performed by calculating the braiding index of the bed river and of the main parameters of the meanders:the amplitude of the meanders, wavelength,sinuosity coefficient (Ichim,I.,1989; Rădoane,M.,2005).In the program Microsoft Excel we made some correlations between the variations of the braiding index and the width of the river bed and between the elements which define a meander.

For the differentiation of the river bed types we used two criteria: the multiplication degree of the thalwegs (for the delimitation of the braided channel) and the sinuosity coefficient (based on which there were delimited the sinuous river bed and the river bed with meander formation). The index of the braiding of the river bed was calculated as a ratio between the sum of the length of the branches and of the main stream and the length measured in straight line between the heads of the braided part of the river bed.

The deviation of the main stream was established by overlapping the topographic maps from 1981 and the orthophotoplans from 2005 and the measurement along some transversal sections traced at a distance of 0.5 km one from another.

DISCUSSIONS

The braided channel

Analyzing the river bed type it is determined that up to Săgeata-Beilic we can find a braided channel with many secondary river beds, this being a result of the transport of alluvia and the bigger slope (the medium slope is of 1.72 m/km) along the alluvial fan of the Buzău river.

In 1981, the braiding index of the river bed of the Buzău was of 3.4 having an irregular distribution along the 12 km of the analyzed braided sector. This registers grater values (between 1.77 and 4.6) in the sectors in which the width of the braided part is greater. The dependence of the braiding index to the medium width of the braided part is shown by the correlation of these elements in figure 1. The medium width of the braiding part is 765 meters, and there are registered values between 588 meters and 1,100 meters. In 2005, this is reduced to 2.32 simultaneous with the decrease of the medium width of the braiding part to 550 meters and the disappearance of some secondary branches on the left side (especially between Vadu Paşii and Stăncesti), the general evolution being the realization of a unitary bed river with areas of local braiding (Fig.2, 3).

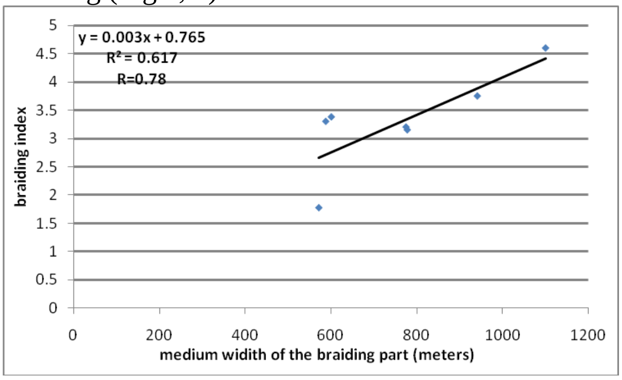

Fig. 1 Correlation between the medium width of the braiding part and the braiding index of the Buzau river (sector Vadu Paşii - Săgeata)

The tendency of the main stream is to deviate to west and south-west with average annual rhythms calculated at 4.2 m/ year (west) and 6.1 meters (south-west) in the period 1981 – 2005. This situation makes the Buzău river to sap from place to place the front of Obor terrace. Along the braided sector, there are local modifications of the stream of the main river in front of the gravel pit, as it

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happens in the south-east of Stăncesti village at the gravel pits Stăncesti I and Stăncesti II where, according to the decision regarding the issue of the environment agreement by the Environment Protection Agency Buzău, it is predicted the execution of another route for the Buzău river, deviated towards the left bank for the decrease of the erosion of the right bank.

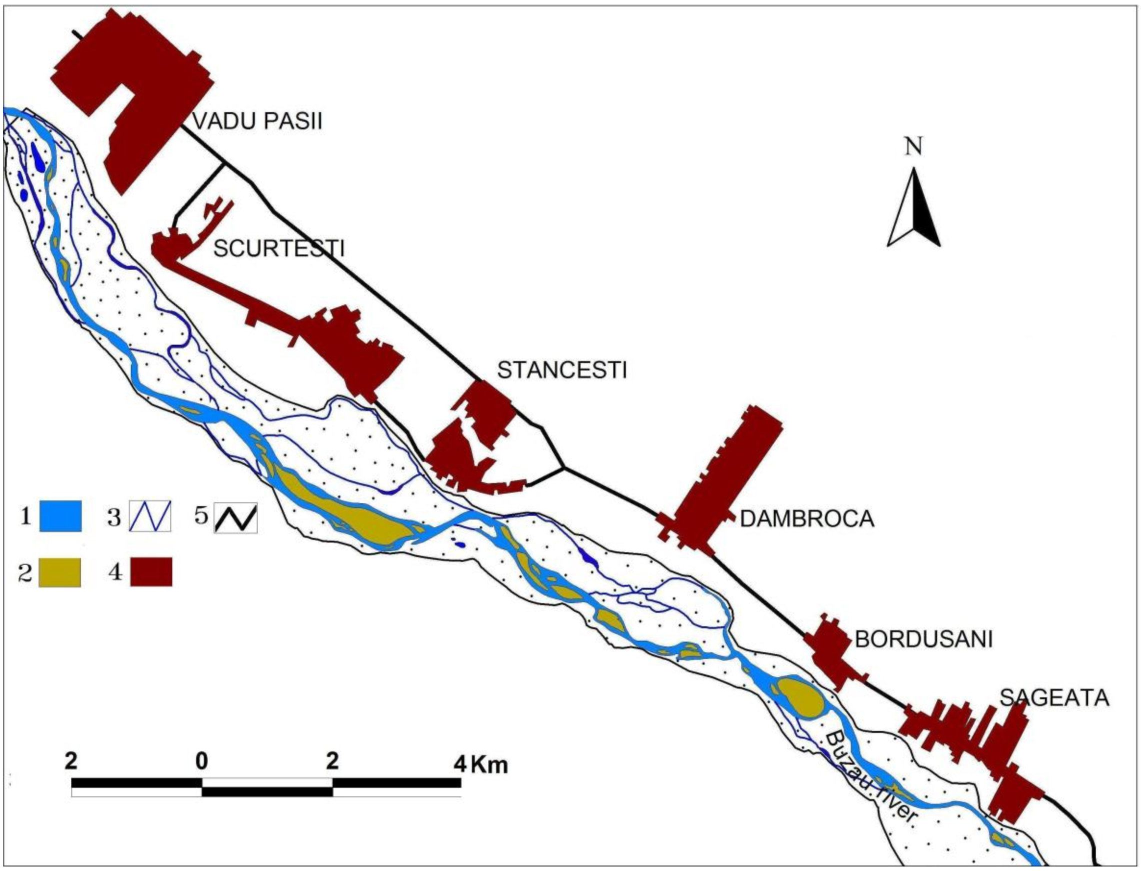

Fig. 2 The braided channel of the Buzău between Vadu Pașii and Săgeata 1981
1-main stream, 2-eyots, 3-secondary branches, 4-localities 5-roads

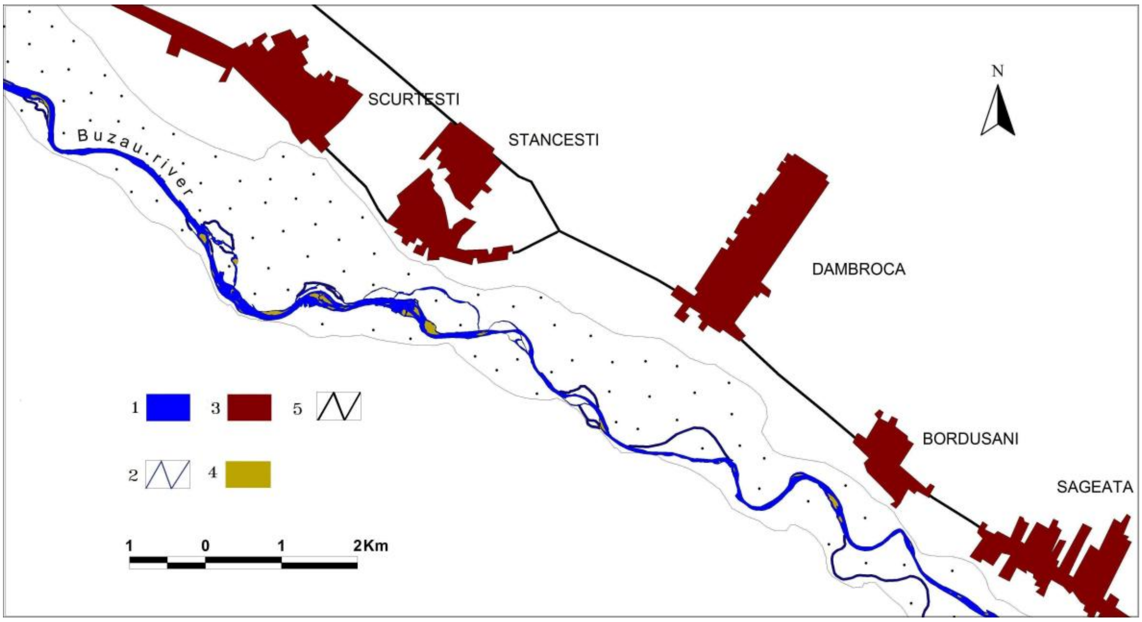

Fig. 3 The braided channel of the Buzău between Scurtesti and Săgeata 2005
1- main stream, 2-secondary branches, 3-localities, 4-eyots, 5-roads

Downstream the localities Săgeata – Beilic, the Buzău river passed from a north west – south east direction (on the braided sector Vadu Paşii – Săgeata) to a west – east direction between Săgeata and Baniţa having a sinuous river bed with eyots and a medium slope of 1.08 m/km. According to the Austrian maps from 1910 this sector could be included in the category of the river beads with meander formation. From the measurements, it is established a decrease of the sinuosity from a coefficient of 1.87 in 1910 to 1.40 in 1981, and in 2005 it decreased at 1.30. The delimitation of the braided channel from the sinuous one is done at the inferior limit of the outfall fan of the Buzău river (Fig. 4).

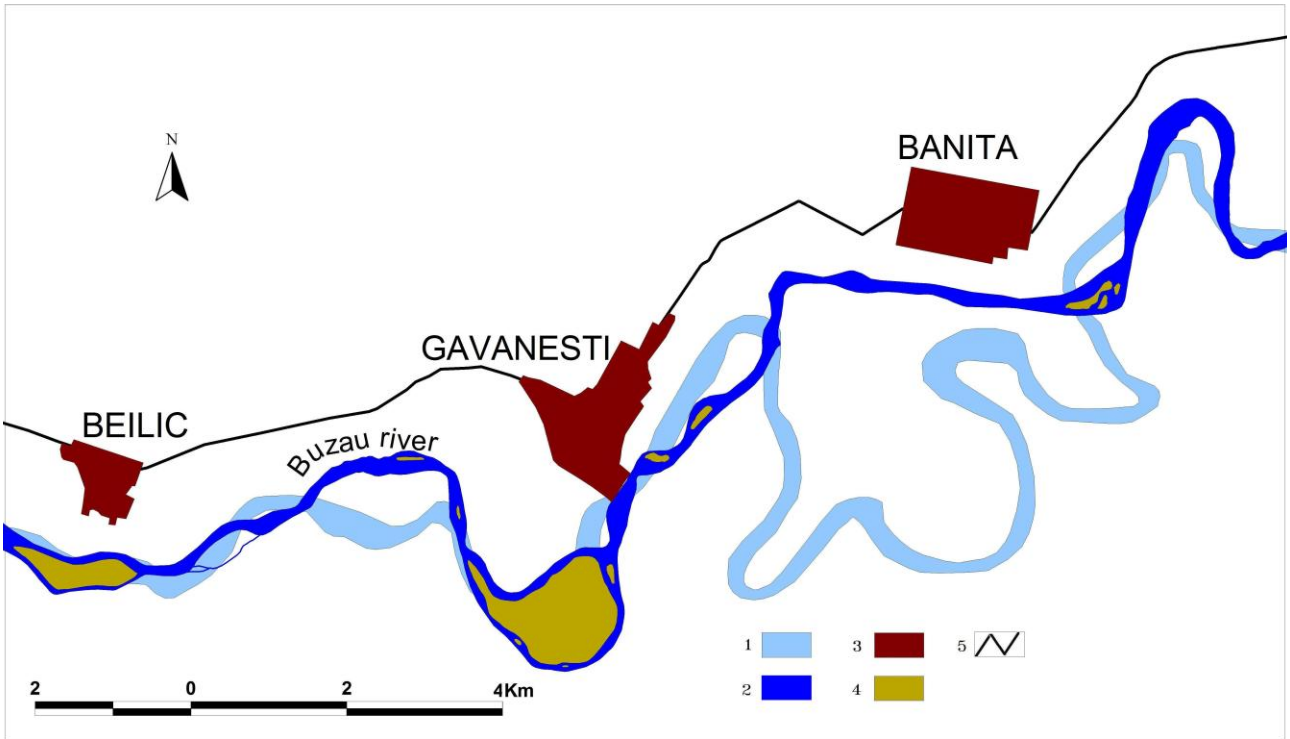

Fig. 4 The sinuous riverbed between Beilic- Baniţa
1-river bed in 1910, 2-river bed in 1981, 3-localities, 4-eyots, 5-road

The riverbed with meander formation

It is located between Ibrianu and Custura on a surface having a sinuosity index of 2.3 (2007). The passing to the surface of the field is generally made by the flood plain terrace. By comparing the situations existing in 1981 and 2005 on the topographic maps and on the orthophotoplans in the Ibrianu – Custura sector we can observe many modifications of the Buzău river stream by passing through some meanders, in the south-west of Ibrianu village, in the north – east of Suteşti village. In the north, towards Custura locality there are localized in the points Cotul Menda (situated at 25 meters altitude) and Cotul Calugărului (situated at 23 meters altitude) other abandoned meanders. According to the situation existing on the topographic maps from 1981 the complex meanders from here had a sinuosity index of 3.3 and 3.8, after the process of self-capture had the index of 2 and 2.19. The same decreasing tendency can also be noticed in the case of the length and amplitude of the complex meanders in 2005. So, the average length is reduced from 1,809 meters to 1,686 meters and the average amplitude from 1,243 meters to 1,030 meters.

The correlations between the main morphometric parameters of the complex meanders indicate through the coefficient of determination and correlation coefficient the ampleness of the reports existing at the level of the river bed with meander formation (Fig. 5, 6).

Regarding the average width of the river bed, there are no notable differences, but following the measurements performed the on the orthophotoplans from 2005, the correlation between the amplitude of the complex meanders and the average width of the river bed is weaker (the determination coefficient is 0.58 in 1981 and 0.31 in 2005) for the configuration of the stream in 2005 following the self-capture, if the width of the river bed was not modified (Fig. 7, 8).

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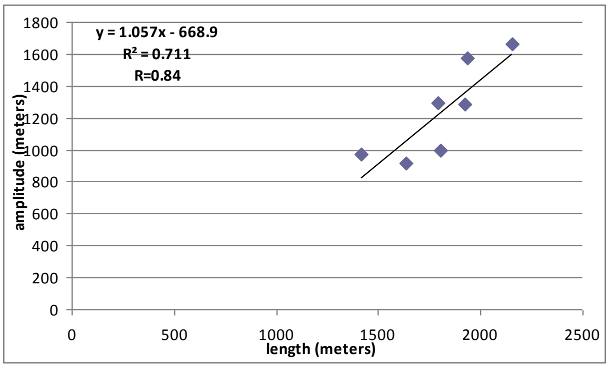

Fig. 5 Correlation between the wave length and the amplitude of the meanders (1981)

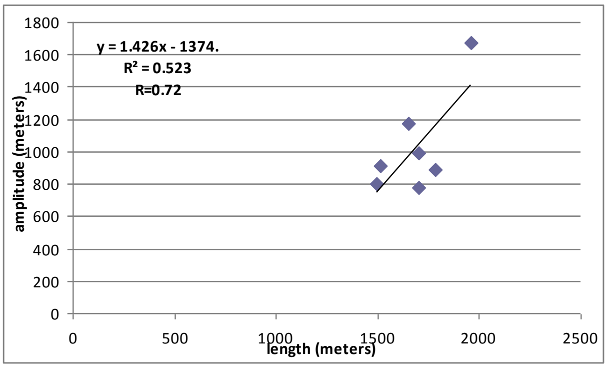

Fig. 6 Correlation between the wave length and the amplitude of the meanders (2005)

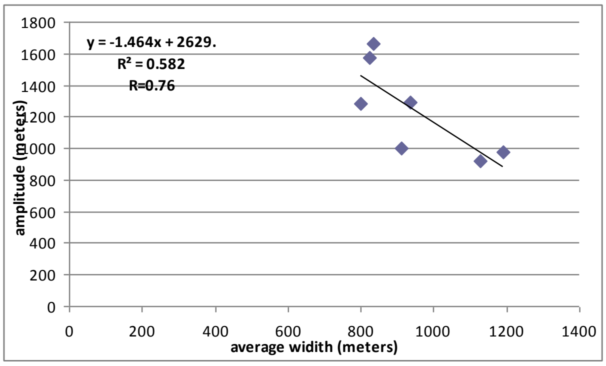

Fig. 7 Correlation between the average width and the amplitude of the meanders (1981)

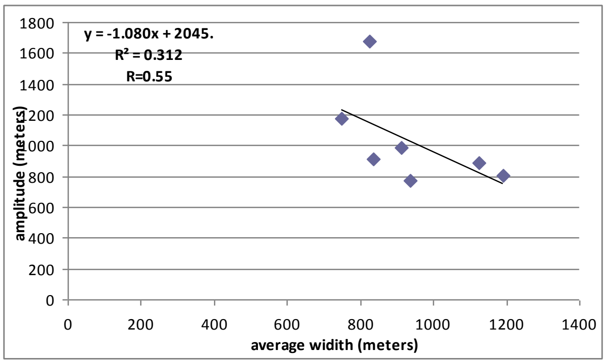

Fig. 8 Correlation between the average width and the amplitude of the meanders (2005)

A very important role in the processes which took place in the river bed with meander formation is played by the reduced slope of the river bed (0.43 m/km). From its correlation on the seven sectors of meander with the sinuosity coefficient resulted the fact that in 75% of the cases the values of the sinuosity coefficient are conditioned by the value of the slope in 1981 (Fig. 9).

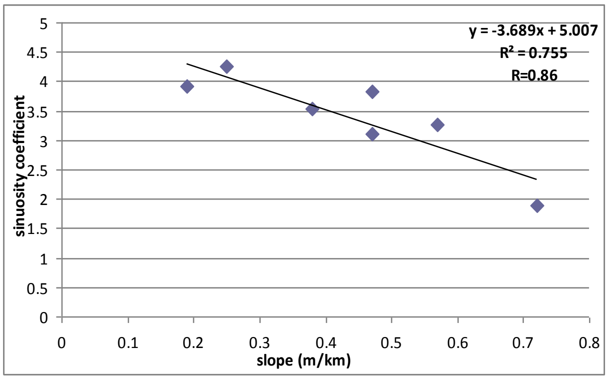

Fig. 9 Correlation between the slope and the sinuosity coefficient (1981)

The Landsat images from 2007 show other changes at the level of the river bed. In the perimeter named Lunca Suţului (situated north of Suţeşti village), the Buzău river, through self-capture, has straightened his stream and it flows on a route which rounds Movila Crestată. In the south of Movila Crestată there is an abandoned meander and a cut-off lobe on which, now, is located the Suţeşti forest (Fig. 10). The change of the stream took place between 2006 and 2007, and we obtained these information by comparing the Landsat images performed in 2006 (August 18, 2006) with the ones in 2007 (July 20, 2007). In this period, in 2006 at the hydrometrical post Racoviţa on the Buzău river the maximum flow did not exceed 50 m^3/s (48.6 m^3/s in September 4, 2006), normally having the value of 30-40m^3/s. In 2007, up to the moment when the Landsat image was made, the maximum flows were between 11.3 m^3/s and 51.6 m^3/s except March when the liquid flow reached the value of 595 m^3/s (March 25, 2007). This situation is confirmed by the information taken from the hydrometric post Baniţa located 30 km upstream on the Buzău river, where during August 2006 – July 2007 the maximum flow were between 16.7 m^3/s (December 2006) and 79.8 m^3/s (February 2007). On March 24, 2007 it was registered a maximum flow of 679 m^3/s. The difference between the crests of high flood registered at the two hydrometric posts can be explained through the taking over by the flood plain of a part of the quantity of water in the conditions of a greater width of the flood plain (1,200 meters) in the meander sector at Racoviţa. The self-capture at the level of the complex mender in the south of Movila Crestată must be related to this high flood based on the existence of sinuosity

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index of 3.19 in 2005. The length of the Buzău river suffered a decrease in the sector Ibrianu-Custura being of 24.55 km in 2007, from 28.98 km in 2005 and 36.49 km in 1981 following this event (Fig. 10, 13).

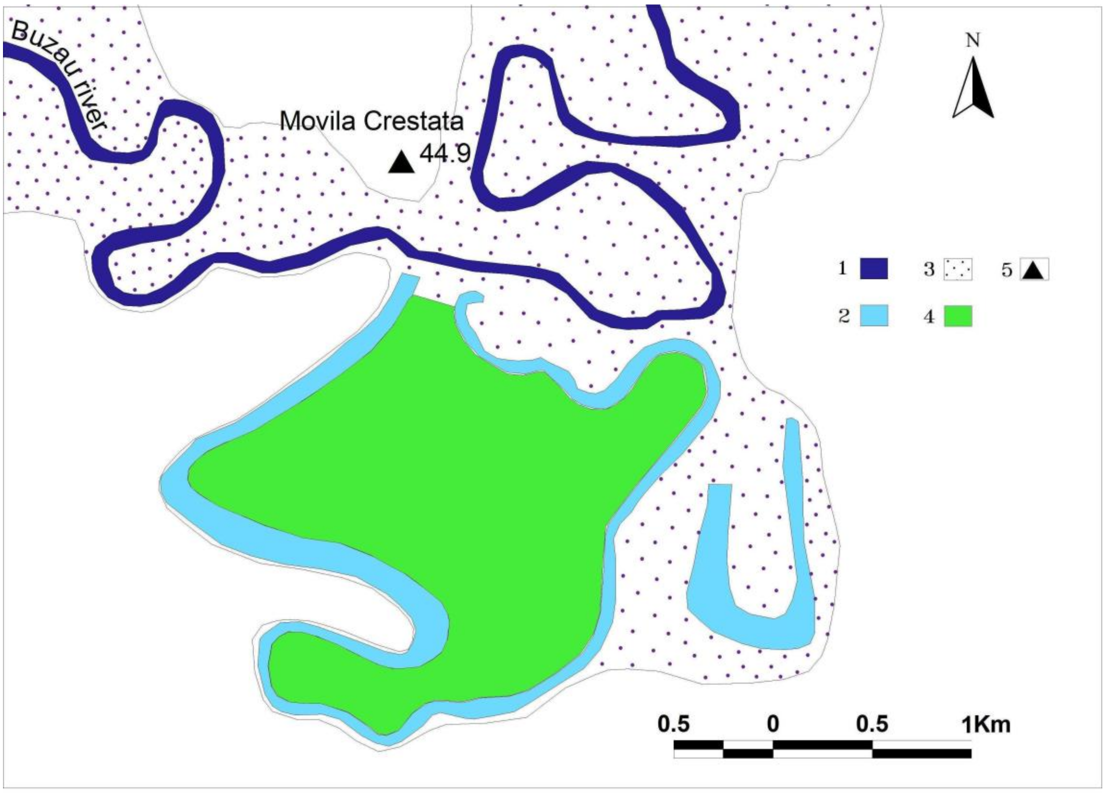

Fig. 10 The self- capture at the level of the complex mender in the south of Movila Crestată
1-The Buzău river (2007); 2-abandoned meanders; 3-delimitation of the flood plain; 4-cut off lobe; 5-altitude

The major cause for these changes for the braided channel of the Buzău, between Vadu Paşii and Săgeata, is represented by the decrease of the solid flow after 1989, following the construction of the Cândeşti barrage, situated 18 km upstream the studied perimeter. Before commissioning the barrage in 1989, at Baniţa station was registered a solid flow of 85.42 kg/sec (1974-1988), during the period 1989 – 2007 the solid flow reduced to 47.05 kg/sec. For the Racoviţa hydrometric post in the meander sector, the solid flow for the period 1989 – 2007 was 74.5 kg/sec.

The liquid flow (Baniţa station) is reduced from 28.9 m^3/s (1974-1988) to 26 m^3/s (1989-2007). Regarding the maximum annual flows registered downstream the barrage, these were reduced in the period 1990-2007, except for the years 1991 (when it was registered a flow of 1,686 m^3/sec), 2005 and 2007. For the sector with meander formation, the small influence of the liquid flow was possible in the conditions of the existence of some greater values for the sinuosity coefficient at the level of the complex menders and the occurrence of major floods on the Buzău river.

The unbalance produced at the level of the alluvia transit is presented for the hydrometric station Baniţa for the two periods in figure 11 and figure 12 by correlating the two variables and the resulted coefficient of determination and the correlation coefficient.

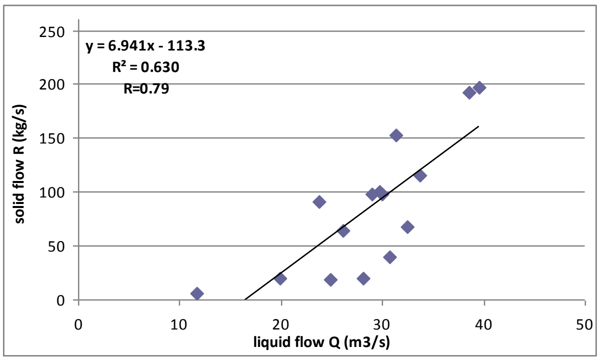

Fig. 11 Correlation between the liquid and the solid flow in the period 1974 – 1988

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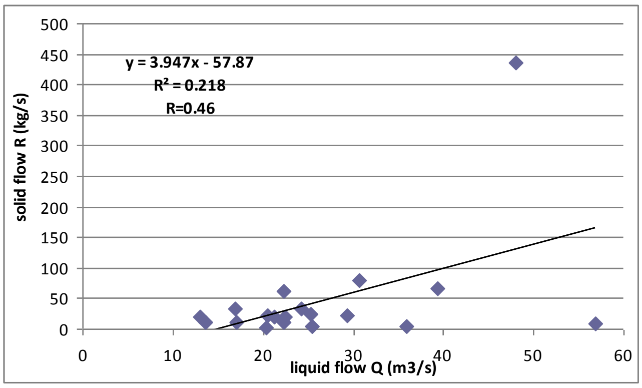

Fig. 12 Correlation between the liquid and the solid flow in the period 1989 – 2007

During the period 1980 – 2007, there were some interventions at the level of the Buzău river bed, especially over the braided sector, the ballast exploitations having a great impact on the modifications of the river bed. Along the braided sector (Stăncești I, Stănceşti II and Bentu) and also upstream there are many gravel pits which purpose, apart from the extraction of gravel and sand, is the regularization of the minor river bed and in this way the flowing section is increased.

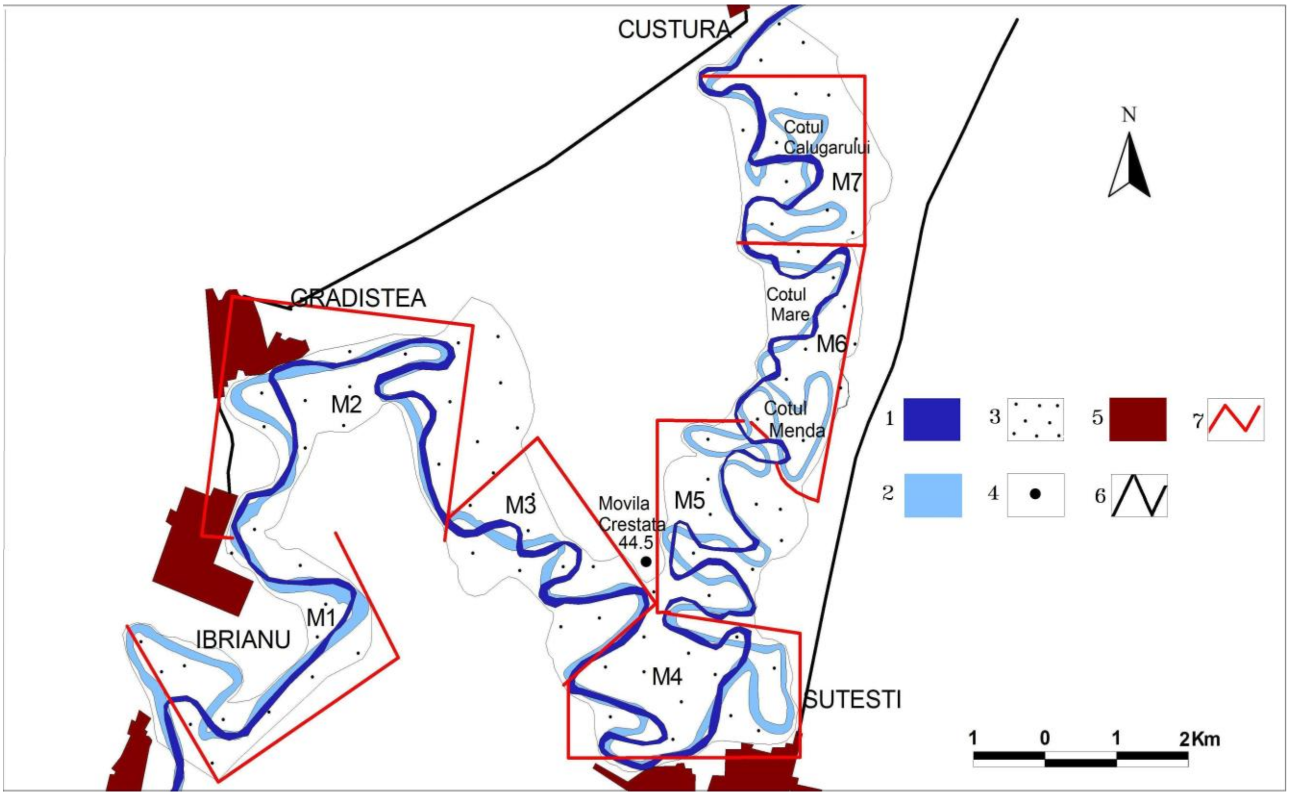

Fig. 13 River bed with meander formation between Ibrianu and Custura
1-TheBuzău river (2005); 2-The Buzău river (1981); 3-delimitation of the flood plain; 4-altitude; 5- localities; 6- roads; 7- delimitation of the complex meanders

CONCLUSION

The lower course of the Buzău river has a big diversity of river bed types, these being a result of the action of the local factors (lithology, slope, liquid and solid flow). The vulnerability is specific to each type of river bed. During the period 1981 - 2007, there took place many modifications in the analyzed braided channel sectors and in the ones with meander formation. Between Vadu Paşii and Săgeata, the changes affected the secondary branches which lengths significantly reduced. The decrease of the solid flow is one of the major causes of the decrease of the braiding together with the intervention for the extraction of the sand and gravel, simultaneously with the unsilting and deepening of some sectors, which locally modify the route of the main branch and of the secondary branches.In the same time interval, the analyzed sector with meander formation between Ibrianu and Custura, registered changes in the configuration of the stream.Many self-captures have produced,the length,the amplitude and the sinuosity coefficient of the complex meanders decrease, based on some sinuosity indices of the complex meanders which exceeded frequently 3 in 1981 and 2.4 in 2005. Based on the analysis of the maps, orthophotoplans, Landsat images and data regarding the daily

DOI: 10.5775/fg.2067-4635.2011.022.i

average flows at the hydrometric posts Baniţa and Racoviţa, we established the changes, relating them with the high floods produced on the Buzău river.

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  DOI: 10.5775/fg.2067-4635.2011.022.i

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 99-106
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.025.i

The Geological and Morphological Structural Control in the Cricovul Dulce River Basin

Veronica SĂNDULESCU[1]

[1] University of Bucharest, Faculty of Geography, Bucharest; e-mail: sandulescu_vera@yahoo.com

Received on < January 9, 2011>, revised on < February 22, 2011>, accepted on <May 5, 2011>

Abstract

This paper aims to analyze the correlations between the tectonic, structural and lithological elements in the Cricovul Dulce river Basin and their reflection in the landscape morphology.

The Cricovul Dulce river basin's position in the Curvature Subcarpathians and Cricovul piedmont plain led to different structural and lithological characteristics which favored a certain type of geomorphological landscape evolution in accordance with the physical-geographical particularities.

The faults (Câmpina, Colibaşi), the Vârfuri- Vişinesti-Draganeasa dislocation line, and the presence of anticlines (Siliştea Dealului, Gura Ocniţei- Moreni, Babanucului) and of synclines (Malurile- Valea Lungă, Ruda) in the Cricovul Dulce Basin, influence the dynamics in the morphographical development of the entire region.

The lithology, the clastic rocks (sands, marls, clays, gravels), unconsolidated sometimes, and the layers with different hardness, increase the morphodinamic processes and give rise to a structural relief specific to the Subcarpathians regions. The valleys adapt to the structure and thus, there are different types of steams: subsequent, obsequent and consequent.

The geology gets even more complicated due to the presence of some coal layers (the perimeter of Filipesti de Padure) and salt massifs (Moreni, Colibasi) in the basin. The relief of the Cricovul Dulce Basin reflects the lithological composition and structure of the region over which overlaps, resulting from this point of view a diversity of landscapes.

Keywords: *Cricovul Dulce, tectonics, faults, geological structure, morphology*

Rezumat. Controlul geologic şi morfologic în structura Bazinului Cricovul Dulce

Lucrarea își propune analiza corelațiilor dintre elementele tectonice, structurale și litologice din Bazinul Cricovului Dulce și reflectarea acestora în morfologia peisajului.

Poziţia Bazinului Cricovul Dulce în Subcarpaţii de Curbură și în Câmpia piemontană a Cricovului a determinat caracteristici litologice și structurale diverse, fapt ce a favorizat un anumit tip de evoluție a peisajului geomorfologic in concordanță cu particularitățile fizico-geografice.

Faliile (Câmpina, Colibași), linia de dislocație Vârfuri-Vișinesti- Drăgăneasa, precum și prezența anticlinalelor (Siliștea Dealului, Gura Ocniței- Moreni, Babanucului) și a sinclinalelor (Malurile-Valea Lungă, Ruda) în Bazinul Cricovului Dulce, influențeaza dinamica în evoluția morfografică a întregii regiuni.

Litologia, rocile moi (nisipuri, marne, argile, pietrisuri) uneori neconsolidate, precum și straturile cu durități diferite intensifică procesele morfodinamice și dau naștere unor reliefuri structural specific regiunilor subcarpatice. Văile se adaptează la structura și avem astfel văi de tip: subsecvent, obsecvent și consecvent.

Geologia se complică și mai mult datorită prezenței în Bazin a unor strate de cărbuni (perimetrul Filipești de Pădure) precum și datorită prezenței masivelor de sare (Moreni, Colibași). Relieful Bazinului Cricovului Dulce reflectă alcătuirea și structura litologică a regiunii peste care se suprapune, rezultând din acest punct de vedere o diversitate a peisajelor.

Cuvinte-cheie: *Cricovul Dulce, tectonica, falii, structura geologică, morfologie*

INTRODUCTION

The Cricovul Dulce River basin is located in the south central region of Romania between $25^0$28'10”-$25^0$57'26” east longitude and $44^0$44'46”- $45^0$13'43 north latitude, stretching to 577 km^2; in the Muntenia region it is situated in the central northern part.

The river has an „elongated feather” looking aspect towards the NW - SE direction with a slightly asimetric shape due to its enlargement to the West.

Geomorphologically speaking the river overlaps two great relief units: one is the Curvature Subcarpathians in the Prahova's Subcarpathians unit, the Ialomiţa's Subcarpathian sub-unit and the second is the Romanian Plain in Ialomita's Plain or Bucharest's Plain, The Cricovul Dulce Plain sub-unit (Fig. 1).

The evolution of these two morphostructural units and the tectonic and geological context have defined the Cricovul Dulce features and gave him a certain structural adaptation and a pronounced morphodynamic.

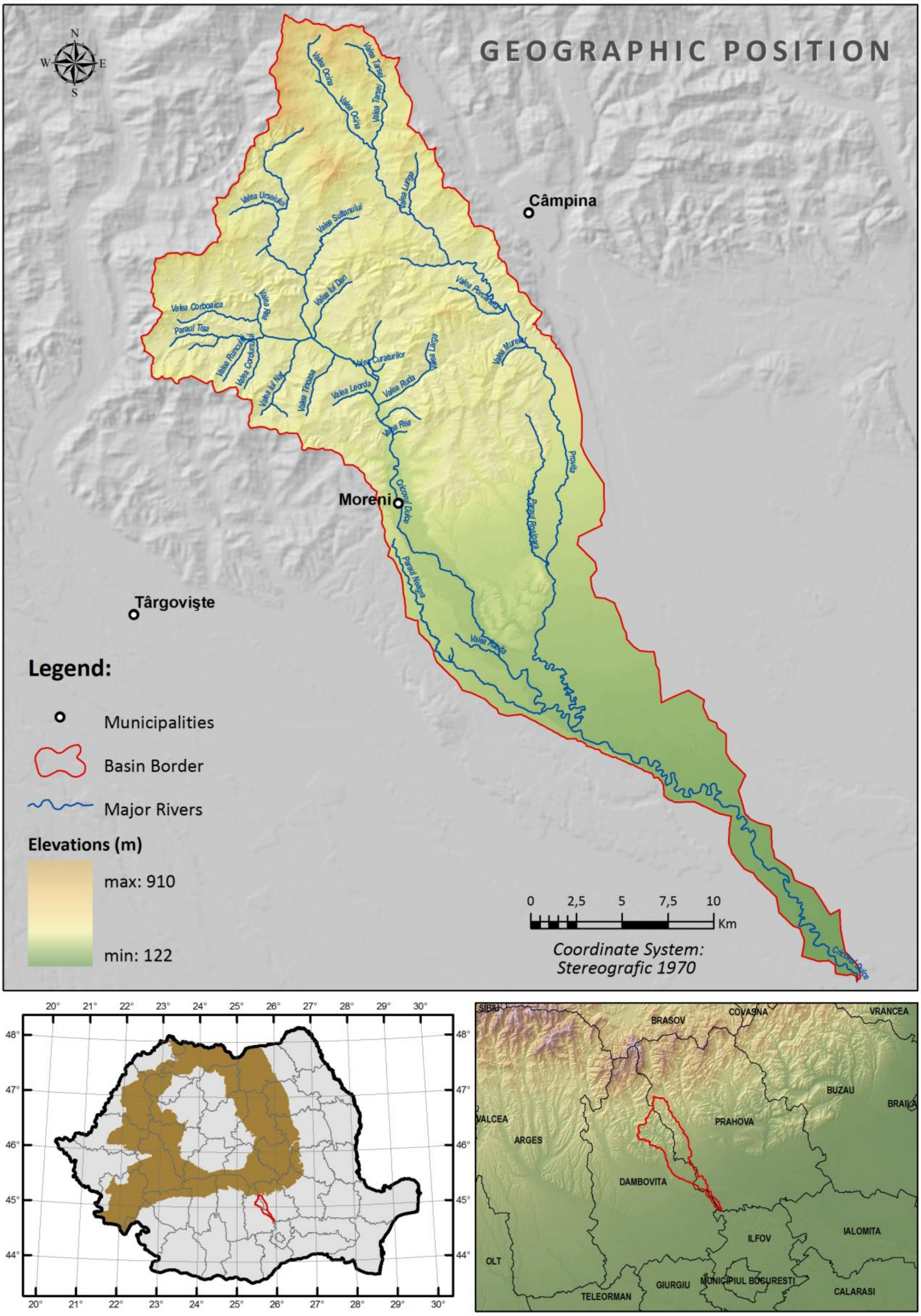

Fig. 1 Geographic position of the Cricovul Dulce Basin

  DOI: 10.5775/fg.2067-4635.2011.025.i

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DATA AND METHODS

In the present study for highlighting the implications of geological and morphological geomorphology of the Cricovul Dulce Basin, the geological map was made using data from: the 1:200,000 geological map (Sheet Targoviște published in 1968 by the Geological Institute of Romania) as well as data from the Geological Map "Higher-Quaternary Neogene deposits between Dâmbovița Valley and Prahova Valley", 1:50,000 scale, published by Răsvan Damian Geologist, in 1999. There are also used data provided by the 1:25,000 topographic maps (from 1977 and 1980, Gauss-Krüger projection) and geological maps and numerous field campaigns in 2004-2010 where the basic research of Cricovul Dulce Basin were mainly about the correlations between structure morphology and geological region.

Geological setting

The genesis and the relief evolution and geological composition are attributes that must be addressed on two major units of the Cricovul Dulce Basin: the Subcarpathians unity and the Plain unity.

In terms of structure, the Curvature Subcarpathians contain two units: an internal folded sector and a monocline external one between the Trotuş and the Dâmboviţa valleys. There is a complex structure with asymmetric faulted folds and diapir folds (Săndulescu, 1984).

The Curvature Subcarpathians belong to the Miocene-Pliocene Carpathian Orogene, Subcarpathian nappe (the flysch containing: marls, gravels, clay, sand and conglomerates). Their position at the contact of the East-European Microplate, Black Sea Microplate, Moesian Microplate and Pannonian Microplate accounts for active neotectonics. The highly faulted Curvature Subcarpathians geological structure is the result of the Moldavian and Wallachian tectogeneses (Miocene and Pleistocene). The large number of faults is due to a change in the direction of compression from NW-SE to N-S (Hippolyte and Săndulescu, 1996 quoted by Grecu Florina et al. 2009).

The tectonic movements from Miocene, Pliocene and Quaternary in the Carpathian orogen occurred in Foredeep differently in intensity from one sector to another and have created sedimentary structures that differ to one another regionally (folded, monoclinal, diapir fold). From a structural point of view we have a fragmented foundation and a sedimentary with molasses' aspect that has a high thickness due to the active subsidence between the different cycles of accumulation. Sedimentary deposits have a molasses character and were accumulated in two separate cycles by Moldavian paroxysm which they had the main source Carpathian area and partially the platform units. Miocene cycle. The lower molasse with Acvitanian deposits (under the mountain- clay, marl), Burdigalian, Badenien and Lower Sarmatian (Marne) deposits. Sarmato-Pliocene Cycle- (upper molasse) has a great variety of facies (sandstones, reef limestone, marl, clay) from the Pleistocene Meotian lower.

Uppermost Miocene-Sarmatian. Along the Provita valley, the Sarmatian deposits appear in the shape of a strip stretching towards the S-W. They uncomfortably overlay the uppermost Badenian and older deposits (Tortonian, Helvetian deposits). (Savu, Geological report 1985, quoted by Damian R., 2003). They have a thickness of 50-100 meters and are represented by greenish and purple sands between different types of yellowish calcareous sandstone. At various levels there is 2-5 meters lumachelle limestone thick that stands over the base sands.

The Meotian appears on the northern flank of the Syncline Malurile Valea Lungă, towards Pucioasa in the region Urseiu-Vişineşti and continues towards Proviţa de Jos, the Meotian deposits have a thickness of 150-200 meters (Damian, 2003). West of Colibași, it consists of marls- sandstones facies dominated by grey sand, yellow marly limestones and marls.

Between the Teleajăn and the Dâmbovița rivers, Meotian deposits have been affected by the diapir folding, and in many structures they contain oil and gas. (Patrulius et. al., 1968- Explanatory note to the geological map sheet Târgoviște).

The Pontian deposits are determined in the area between the Ialomița and the Cricovul Dulce, in the southern flank of Malurile- Valea Lungă synecline. In the west they are represented by fine clays and marls.

The Pliocene and the Dacian deposits are represented by sandy facies in the both flanks of the synecline Malurile – Valea Lungă and between Vişineşti and Pucioasa. In the area of the Cricov Valley and Proviţa valley, the Dacian sediments include the succession dominated by sands, marls, clay with coal and gravels with thickness ranging from 200-700 meters. (Patrulius D. et al., 1968- Explanatory note to the geological map of Târgoviște sheet). To the south, the Dacian deposits are determined in the Siliștea Dealului anticlinal.

The Romanian deposits are identified in the Malurile-Valea Lungă synecline, in the area between Ocnița and Provița Valley, as also in the Siliștea Dealului anticlinal. To the north of the

Cărăbuş hill, in Ruda synecline, there are cobblestones and gravels "Strate de Cândești" overlain the Middle Romanian deposits (Armaş et al., 2003).

Pleistocene. Middle and Upper Pleistocene is represented by a complex of gravels, sands, cobblestones with clay intercalations described as "Strate de Cândeşti" developed from the west part of the Cricovul Dulce, south to Moreni, to the Frasinu village (on the right side of the valley) and on the left side of the Moreni city right up to the Vlădeni locality.

The Upper Pleistocene represents another sedimentation phase characterized by an intense dynamic of erosion and transport. This process has resulted in predominantly deposits of gravel and cobblestones with sand, and subordinate types of clay and sandy clay. This evolution has taken place under a tectonic uplift instability in the region, reflected in many terrace levels. During this period the piedmont plains are formed in the northern part of the Romanian Plain: Targoviste plain on the interfluve Dambovita - Ialomita, the Pintenul Măgurii Plain from Ialomița - Cricovul Dulce interfluve, the Ploiești Plain- in the northern part.

The last stage of landscape evolution took place during Holocene period when the lower terraces and flood plains of the stream system are formed.

The tectonic evolution

The tectonic evolution of the region is linked to the Savic and the Stiric movements, which determine the avanfose formation and newer movements that have folded the Mio - Pliocene. (Damian, 2003). Savic orogenesis consists in folding the Paleogene Flysch and the attachment of this one as a new structural unity to the Eastern Carpathian and the Curvature Carpathians. The Paleogene flysch has a tectonic position of poured strips in shapes of flake folds towards east. Unlike the Cretaceous flysch the Paleogene flysch is pinching out to the subcarpathian avanfose in forms of mountain spurs.

The first folded Subcarpathian units are born during the Stiric phase. In the Acvitanian period, due to the Savic motions the molasses facies appears in all the lower Carpathian area that indicates the occurrence of the foredeep in which all the sediments of the unborn Subcarpathians will be deposed (Posea et al., 1974).

The main events that led to the Subcarpathian relief during the Rhodano-Valachian phase are: the uplifting movements of the Carpathians until they reach a mountain altitude, the folding and uplifting of the Subcarpathians and also the exudation of the entire territory. Following this morphotectonic phase there occurred a separation between the Getic Basin from the Transylvanian and the Pannonian basins. These separations determine a stop of the subsidence of the Curvature leading to a fluvial-lacustrine clogging.

The general and detailed aspect of the Subcarpathian relief is to a great extend, explained by the Wallachian tectonic phase having occurred in the Villafranchian, which had varied intensities (which reactivated the main lines of faults), determined the formation of tectonic-erosion depressions at the foot of the Carpathians, and of other structural river-denuded land forms. Indirectly, the Wallachian movements are also responsible for the diapir phenomena from (Colibași, Moreni and Siliștea Dealului- see table 1 Salt deposits).

The tectonic elements are represented by faults that are generally oriented toward an E-W direction, parallel to the Subcarpathian alignments (the Dospinești - Provița fault, the Câmpina fault, the Colibași fault, the Teiuş fault, the Ursului fault). Watercourses orientation can mark plicative alignments; the Trestia valley, the Ruda Valley, which are directed parallel to the axis of the fold or the syncline axes.

In the same way it can be seen that the anticlines axe it is represented mostly by interfluves (the anticlines: Doicești - Aninoasa, Babancului, Gura Ocniței- Moreni, Siliștea Dealului).

The contact between Orogen and Vorland is characterized by differential movements; slight uplifting movements (+1÷+2 mm/year) in the Subcarpathian area with values up to (+ 5mm/year) at the contact with Bucegi Mountains while the Vorland sector appears as a stable area marked by slightly uplifting of +1 mm/year. (Zugravescu et al, 1998).

Oil and gas deposits are related to tertiary soils (Dacian), which are found in the diapir fold region where they come directly in contact with salt deposits, especially in the Drăgăneasa area and Moreni-Gura Ocnița.

The presence of the Burdigalian salt indicates the tectonically position in diapir folds. The diapirism process begins in the Stiric movement and it is being completed due to the Valahian folding (Table 1), when the Carpathian avanfosa have risen more than the platform area (Drăgănescu, 1997). The salt deposits are found in the Cricovul Dulce Basin close to oil and coal deposits.

  DOI: 10.5775/fg.2067-4635.2011.025.i

Table 1. Burdigalian Salt deposits from the inferior saliferous formations (after Drăgănescu L., 1997)

Salt deposits	Shape	Surface km^2	Thickness km	Depth meters	NaCl %	Supplies tones
Moreni	blade	10	2	0-2.0	70-90	16.81
Silistea Dealului	blade	3.6	1	1.3	70-90	5.026
Colibasi	blade	13	0.6	0-1.5	70-90	8.475

DISCUSSION

The Subcarpathian unit occupies a 50.9% percentage from the basin area (291.9 km^2); from N to S we can observe the internal Subcarpathians who marks the transition between the Carpathians and the Subcarpathians area and the external Subcarpathians with its hilly characters.

Geomorfologically, the defining elements of the Subcarpathians are the tectonic-erosive longitudinal depressions, situated under the abrupt margins of the Carpathians, and the hills with an aspect of low mountains and folded structure, which most often close to the outer sides of the depressions.

The Subcarpathian area from the Cricovul Dulce Basin has a three different structure sectors. Near the mountain old folds are present, tight, slightly faulted (Fig. 2), and similar with the Paleogene mountain unity. In the center there is a wide range of Mio-Pliocene folds (faulted also), while on the external parts there is a monocline or diapir folds (Fig. 3, 4) (Ielenicz and Visan, 1998-1999).

The sub-mountain area represents a successive transition from the Paleogene formations (spur of Homorîciu) to the Miocene on a N-S direction, and are being succeeded in a strip form oriented NE - SW. These are different formations in terms of petrography and structure (sandstones, conglomerates, marls - Cretaceous limestone - Aptian-restore heights over 800 m, example: the Talea high peak). Also on the anticline structure, but on a much complex scale, the Miercani Hill (600-750 m) expands towards S-W, typical of Subcarpathian form, whose tectonic complexity is reflected in the expression of the morphology surface: multiple points of inflection rupture and changes slope, increased rainfall and gravitational processes, and a pronounced development of hydrographic organisms.

Valea Lungă depression is situated to the south of Miercani Hills, superimposed on the syncline Valea Lunga. The morphotectonic unit Cuveta Slanic includes in the whole area of the Ialomita Sub-Carpathians the depression alignment. Breaza-Bezdead-Râul Alb, and the syncline Valea Lungă appear in the landscape like the depression system Câmpina-Valea Lungă Pucioasa.

Fig. 2 Slope cliff in sandstones packages, Scarp Soimilor

The central area is well defined, a complex arrangement of hills with peaks interfluve on the NW-SE direction. This alignment is formed, from north to south by: the Sultan Hill (700-850 meters), the Teişului Hill (600-700 meters) and the Filipeștii Hills (420-550 meters). Morphotectonic they belong to a series of anticlines, with a normal or overthrust development. In terms of a structure-form report, for the most part we are faced with a match between the geological structures and relief stage or unit that fits over it (Fig. 5). There are also situations of relief inversion, as is the case of Urseiului depression.

Median region: it is developed on the Miocene formations in a sequence of anticlines and synclines. The main feature is the relief adaptation to the structure and lithology; it can be observed that the anticlines axe is represented mostly by interfluves (anticline Doiceşti-Aninoasa Moreni-Gura Ocniței, Colibași, Siliştea Dealului) and the synecline by the presence of the depression area: the Drăgăneasa-Meliceşti Syncline, Câmpina-Valea Lungă-Pucioasa- Syncline Valea Lungă, Iedera-Ocnița-Glodeni-syncline Ruda). The peripheral area is modeled in Mio-Pliocene sediments: the Iedera-Ochiuri-Viforata depression.

The plain unit that is situated in the central-south of the basin occupies a 49.1% of the total area of 285 km^2 and was formed as a result of the evolution of the Pleistocene and Lower Holocene. As regional units we have the Cricovul Dulce Piedmont Plain, the Ploiești Piedmont Plain and the divagation lower plain (from Băltița to the confluence of the Cricovul Dulce with the Ialomita).

The structural unit belongs to the Moessic platform (the Wallachian subunit) above which is a sedimentary layer with variable thickness (Fig. 6). At the surface we have loess and loess deposits covering sand, gravel and clay. Following the evolution of the Cricovul Dulce plain from the upper Pleistocene until the Holocene different types and forms of relief can be distinguished after genetic criterion, so that we can say that it is a high fluvial-lacustrine plain, found in an advance stage of evolution.

Fig. 3 Monocline structure (Cuestas), the Târsa and the Morii Valleys

Fig. 4 Monocline structure, Bobolia, Provița and Prahova interfluve

The lower region of the Cricovul Dulce Basin can be considered a transitional stage between the Subcarpathians tectonic-erosion unit and the Romanian Plain unit. It has developed gradually, in successive stages of erosion and accumulation of napes gravel as a result of sustained rates of river activity, imposed by climatic conditions (glacial and interglacial phases) and tectonics. Currently a number of geomorphologic processes are shaping the morphological and morphographical characteristic of the Cricovul Dulce basin.

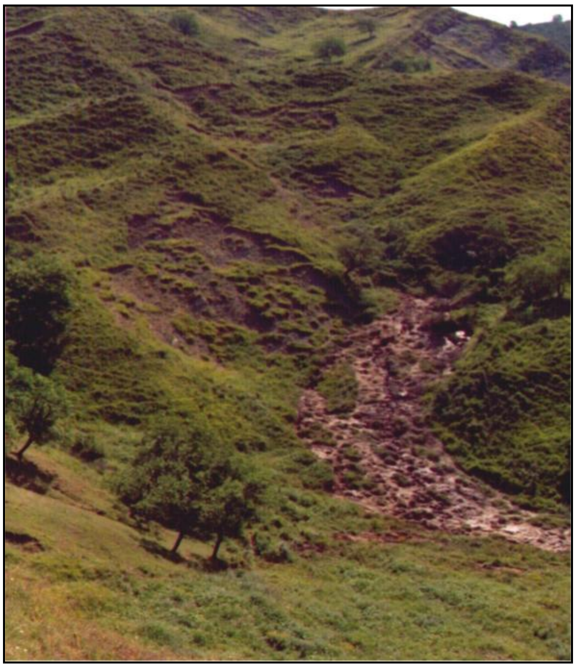

Fig. 5 Obsequent valley in the Târsa region.

CONCLUSION

The great structural complexity of the Cricovul Dulce basin is due to the avanfosa tectonic evolution from the connection between the Carpathic orogen and the others rigid units of the platforms and also the folding of the sedimentary consisting in the Mio-Pliocene molasses.

Local differences in the geological structures: anticlines, synclines, monocline, and fractures were determined by the vertical game of foundation of blocks, and by the lifting of the Miocene salt dome (diapir folds).

The general directions of evolution have been conditioned in the Cricovul Dulce Basin, primarily by the morphostructural skeleton which has developed stage after stage. Concomitant with the geological factors the morphology was also affected by the external factors of erosion and accumulation.

The tectonic usually generate major structural units, but at the same time it affects, both erosion and accumulation rate, and their area of action. The great extent and intensity of the present day denudation processes is a characteristic of the Cricovul Dulce Basin. This is because of favorable lithological, tectonic and climate conditions, expressed especially by a minute alteration of horizons with varying indurations and by the predominance of clays, marls and gypsum, by the intensity of neo-tectonic movements and the high level of seismicity in some areas, by the relatively abundant rainfall and the irrational intervention of man.

  DOI: 10.5775/fg.2067-4635.2011.025.i

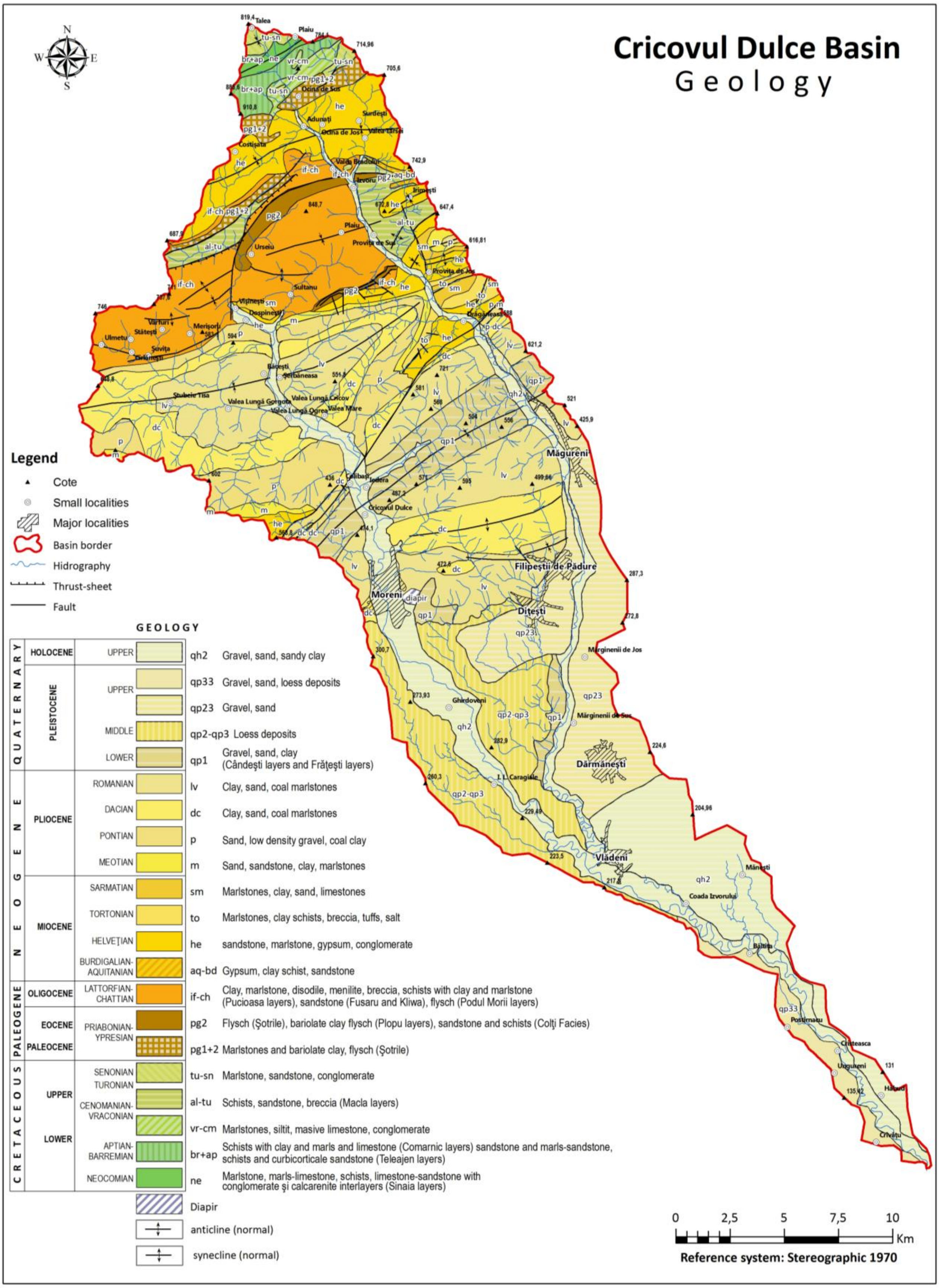

Fig. 6 The Cricovul Dulce - Geology

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  DOI: 10.5775/fg.2067-4635.2011.025.i

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1/ June 2011, pp. 107-116
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.026.i

The Impact of Solar Activity on the Greatest Forest Fires of Deliblatska peščara (Serbia)

Milan MILENKOVIĆ[1], Milan RADOVANOVIĆ[2], Vladan DUCIĆ[3]

[1] Faculty of Forestry, Kneza Višeslava 1, 11030 Beograd, Serbia, e-mail: milenkovic011@gmail.com
[2] Geographical Institute "Jovan Cvijić" of the Serbian Academy of Sciences and Arts, Djure Jakšića 9, 11000 Beograd, Serbia, e-mail: rmilan@scnet.rs
[3] Faculty of Geography, Studentski trg 3, 11000 Beograd, Serbia, e-mail: vladanducic@yahoo.com

Received on <December 21, 2010>, revised on <February 19, 2011>, accepted on <March 31, 2011>

Abstract

The subject of research refers to potential causative-effective connection between processes on the sun and the largest forest fires in Deliblatska peščara. The four greatest forest fires in Deliblatska peščara in the period 1948-2009 were in 1973, 1990, 1996 and 2007. The analysis of solar activity, especially the solar wind data and the analysis of the fire events were used in the research of the possibility of mutual connection. There are no enough data for the fire that occurred in 1973 on the basis of which the connection with processes on the sun would be determined. The fire from 1990 developed in the conditions of intensive solar activity and it was probably caused by the solar wind. There are some indications that the solar wind from energetic region 7981 caused the largest forest fire in Deliblatska peščara in 1996. For fire that occurred in 2007, the energy source (coronary hole CH279) was determined, as well as the moving of the solar wind particles. During the investigated fires the phenomena characterising fires caused by solar wind were recorded, such as frequent wind direction changes and appearance of fire on different locations at the same time. The statistical analysis of the number of fires in Deliblatska peščara and AMO also indicated the anti-phase connection between these events. Even though the obtained results have shown the signal of the connection between charged particles and initial phase of fire, the laboratory testing is necessary to prove the mentioned hypothesis.

Key words: *forest fires, solar wind, solar activity, Deliblatska peščara*

Rezumat. Impactul activităţii solare asupra marilor incendii de pădure din Deliblatska peščara (Serbia)

Subiectul cercetării se referă la potential conexiune cauză-efect dintre procesele care se produc la nivelul Soarelui şi mariile incendii de pădure din Deliblatska peščara. Cele patru mari incendii de pădure din regiune, din perioada 1948-2009, au avut loc în 1973, 1990, 1996 şi 2007. În această cercetare, s-a avut în vedere posibila legătură dinte activitatea solară, mai ales vântul solar, şi incendiile de pădure. Nu există date suficiente despre incendiul din 1973 pe bază cărora să se determine cu exactitate conexiunea cu activitatea solară. Incendiul din 1990 s-a produs în condiţiile unei activităţi solare intense şi a fost probabil cauzat de vântul solar. Există unele indicii care arată că vântul solar din regiunea energetică 7981 a determinat cel mai mare incendiu de pădure din regiunea Deliblatska peščara din 1996. În ceea ce priveşte incendiul din 2007, a fost determinate sursa de energie (gaura coroniană CH279), precum şi deplasarea particulelor din vântul solar. În timpul incendiilor investigate au fost înregistrate fenomenele caracteristice induse de vântul solar, precum schimbări frecvente ale direcţiei vântului şi apariţia incendiilor în diferite locaţii în acelaşi timp. Analiza statistică a numărului de incendii din regiunea Deliblatska peščara şi OMA indică de asemenea conexiunea anti-fază dintre aceste evenimente. Deşi rezultatele obţinute au indicat o legătură între particulele încărcate electric şi faza initial a incendiilor, sunt necesare teste de laborator pentru a susţine ipoteza menţionată.

Cuvinte cheie: *incendii de pădure, vânt solar, activitate solară, Deliblatska peščara*

INTRODUCTION

Deliblatska peščara is situated in the south-eastern part of Vojvodina (northern province of Serbia). It is also known under the name the Banat peščara. It is elliptical in the direction NW-SE. The total area of Deliblatska peščara is about 300 square kilometres and the average altitude 138 m. The mentioned area belongs to the category of special nature reserves.

There are four types of vegetation in Deliblatska peščara: sandy, steppe, marshy and forest type. The sandy type of vegetation is characteristic for bare areas, piled up places or very rarely overgrown areas. The steppe type is the most represented and a wide diapason of floral elements can be found within this type, from semi-desert to temperate steppe or meadow-steppe ones. The marshy type is least represented in this area and can be mainly seen in peripheral parts. The forest type of vegetation is represented by oak-linden forests (Stjepanović-Veseličić, 1979). However, the forests of Deliblatska peščara have been represented by a species used for afforestation in the last 200 years. Black locust prevails most (*Robinia pseudoacacia* L.), then Austrian pine (*Pinus nigra* Arn.) and Scotch pine (*Pinus sylvestris* L.).

Forest fires are the greatest problem for the nature protection in Deliblatska peščara. According to the evidence of the forest enterprise "Banat" from Pančevo, in the area of the forest management unit "Deliblatski pesak" (Deliblato sand), 259 forest fires were recorded in the period of 1948 to 2009 (averagely 4.18 per year). Fires occurred each year with the exception of 1980, 1992, 2004, 2006, and 2008. The total fire spread area is 11,923.5 ha in all fires in the mentioned period (averagely 192.31 ha per year), while the total fire spread area of forests 6,128.93 ha (averagely 98.85 ha per year). In this period, ground fires occurred most (88.8%), while the rest of the fires reached the canopy of pine plantations. The cause of the fires was the human factor in 64% of the cases, while the origin for 36% of the fires was not determined. At this moment, we do not have data on fires originated from arson, negligence or accident. About 86% of the fires occurred in the interval 9:00 a.m. - 18:00 p.m. The end of winter and beginning of spring, as well as summer months have been critical periods for the fires to occur in Deliblatska peščara. Almost a half of all the fires (48%) from the examined period were recorded during March and April (collectively), while about 26% of the fires occurred in the period June-September. Although most fires occurred in March and April, the fires which occurred during summer spread over larger areas and caused more damage. The largest forest fires were recorded in Deliblatska peščara in 1973, 1990, 1996 and 2007. The fire of 1973 only occurred at the beginning of spring, while others occurred in summer.

A hypothesis that the mentioned four disastrous fires occurred as the consequence of the solar activity was tried to be tested in this paper. Stevančević (2004) first indicated the possibility that the charged particles of the solar wind (SW) cause forest fires, while Todorović et al. (2005), Radovanović et al. (2007), Ducić et al. (2008), Gomes and Radovanović (2008), Radovanović and Gomes (2009), Radovanović et al. (2009), Stevančević and Todorović (2010) and Stevančević (2010) also came to significant results. According to the results of these researches, the characteristics of the forest fires caused by the SW have been the large fire spread areas and the phenomenon of hundreds and even thousands of isolated fires in some area. These fires are followed by strong winds, so that they spread very fast and they are difficult to be extinguished. Fires can be caused by the positive or negative charged particles of the SW, so that proton and electron fires can be distinguished. Generally, the mentioned results suggest the SW charged particles burn through the plant mass in certain conditions and thus cause the initial phase of the flame. The process which directly precedes the depositing of the charged particles towards the ground is in the close connection with the hydrodynamic seizing of air masses by the SW.

The existence of the connection between the atmospheric circulation and solar activity was pointed out by Radovanović et al. (2003). On the other hand, the connection between some indexes and forest fires was also determined in the USA and South-Eastern Asia. Norman and Taylor (2003) found that Pacific Decadal Oscillation (PDO) and El Niño-Southern Oscillation (ENSO) influenced fires in the pine dominated forests in the southern Cascade Mountains in north-eastern California. The fires were the most widespread when the PDO was in warm or regular phase. Schoennagel et al. (2005) ascertained that the combination of either warm or cold phases of ENSO and PDO can be brought into the connection with the increasing number of fires in the Rocky Mountains. Dixon et al. (2008) determined the existence of the significant correlation between the ENSO, PDO values and other indexes and fire variables for the state of Mississippi (USA). It is also known that the disastrous fires in Indonesia in 1997 were in connection with ENSO (Jim, 1999; Stolle and Tomich, 1999; Fuller and Murphy, 2006).

Another hypothesis in this paper has been the existence of the connection between the number of the forest fires in Deliblatska peščara and the index of the atmospheric circulation. The AMO (Atlantic Multidecadal Oscillation) index was chosen for this part of the research, for which it is supposed that could be in the statistically more significant correlation with forest fires in Europe. Having in mind the connection of the atmospheric circulation and solar activity, the eventual confirmation of this hypothesis could be considered as the evidence of the connection between the forest fires in Deliblatska peščara and the solar activity. It is emphasized in the researches that the initial phase of the fire had probably occurred due to burning of biomass by charged particles. Also, it is necessary to emphasize their assertive opinion that the simulation in laboratory conditions is needed for the

  DOI: 10.5775/fg.2067-4635.2011.026.i

confirmation of the mentioned hypothesis. Radovanović et al. (2005), Radovanović (2010).

DATA AND METHODS

The researches of the potential possibility that the SW is the cause of the four largest forest fires in Deliblatska peščara in the period 1948-2009 are based on the following of the solar activity in the period which preceded them. The periods of the entry of the energetic regions and coronary holes into geo-effective position were analysed. The available data of the ACE satellite were also used (structure, speed, temperature and density of the SW particles). Moreover, in the case of the fires from 2007, the satellite images were used which showed the occurrence of the forest fires in the surrounding regions (part of the Mediterranean, the Balkans).

The meteorological data were taken from the web site of the Hydro-Meteorological Office of the Republic of Serbia due to non existence of measuring station in Deliblatska peščara (Observatory Belgrade: 1973, 1996, 2007). The data for 1990 (Vršac) were taken from www.tutiempo.net. The basic data on the fire spread areas are given in the Table 1.

Table 1. Largest forest fires in Deliblatska peščara in the period 1948-2009

	March 27-29, 1973	August 30-September 9, 1990.	August 10-16, 1996.	July 24-31, 2007
Fire spread area (ha)	1,006.69	881.60	3,815.40	546.79
Fire spread area of forests (ha)	748.38	705.16	2,235.01	414.58
Fire spread area of conifers (ha)	478.05	636.11	1,557.63	333.50
Fire spread area of deciduous (ha)	270.33	69.05	677.38	81.08
Other fire spread areas (ha)	258.31	176.44	1,580.39	132.21

Source: Forest service 'Banat', Pancevo
Public enterprise 'Vojvodinasume', Novi Sad

RESULTS AND DISCUSSIONS

Before 'large' fire from 1973, nine fires were recorded in Deliblatska peščara in only six days. There were large areas under Austrian pine and Scotch pine plantations near the locality where the fire was ascertained on the 27th of March. The wind was changing direction occasionally and the fire spread towards the north and south. The fire spread over 3 km long and 2 km wide area at almost 13:00 p.m. In the meantime, large number of people came to the place of fire (employed in the forest enterprise, firemen and inhabitants of surrounding villages). In the afternoon hours, the gusts of wind called košava (it blows across Serbian plains) became stronger, seizing the fire balls and throwing them 30-50 meters ahead and thus spreading the fire more rapidly. The night was used for the fire extinguishing and on the 28th of March 1973 the fire was brought under control at 1:00. During the night smaller fires were being extinguished and unburned stumps and separate trunks throughout the following night. About 4,500 people were engaged and the machinery used in the fire extinguishing (Sekulić and Šljivovački, 1975).

According to data from the observatory Belgrade, the mean daily air temperature was 13.8°C, the maximum 19.5°C and the minimum 9.4°C on the 27th of March. At 7:00 a.m. 10.2°C was recorded and 19.0°C at 14:00 p.m.

The hypothesis that the SW charged particles caused this fire cannot be completely examined due to the lack of the corresponding satellite data. However, there are some elements which indicate that possibility. The assumptions that workers caused the fire were not proved. Therefore, the cause of the fire remained unknown. The total fire spread area was 1,006.69 ha, although 'only' 13.5 hours passed from the time when the fire was noticed until its bringing under control. The occurrence of 9 fires in six days immediately before the 27th of March points out to the SW (large number of fires in short period of time).

"Fire balls" which contributed to the fire spreading were particularly interesting. The similar phenomenon was seen in 1871 in the fire which spread over Peshtigo (USA). The case has been known by a large number of casualties in this fire (http://www.peshtigofire.info/).

Nevertheless, we are not able to make an adequate analogy between the processes on the sun and the origin of large forest fire from 1973 due to the lack of data.

The fire from 1990 was noticed on the 30th of August at 15:45 p.m. on the locality "Kajtasovački vinogradi" in the compartment 474, near the forest border. This part of Deliblatska peščara was under large areas of pine plantations. According to data from the meteorological station Banatski Karlovac, the air temperatures exceeded 33°C, while the relative air humidity was below 30%. About 20 days before the fire occurred, there had not been rainfalls. The fire became weaker during the first night, but almost around 5:00 a.m. it became again strong at several places. In the period of 8:00 to 11:00 a.m., it was extinguished by helicopters. The wind blew 4-5 m/sec, often changing direction. The head of the fire extended in length of 2.5 km. The helicopters came back at almost 18:00 p.m. and planes also joined the fire extinguishing. The next day (the 1st of September), a large number of people were engaged in extinguishing and helicopters and airplanes were used again. Even above that, wildfires blazed up on several locations at 13:30 p.m. The fire was brought under control at late afternoon hours. The following day (the 2nd of September), the fire was brought under control at evening hours. Fires burned up to the 5th of September at some places (according: "Report and analysis on the fire in Deliblatska peščara", FE "Banat" Pančevo, October 1990).

In the period immediately before the fire, an intensive activity was recorded on the sun. The average value of solar flux at 2.8 GHz was 222.6 sfu in August, which was close to the maximum for the 22nd cycle (Stevančević, 2004). Relatively frequent changes of the wind blowing direction were also recorded in this case. Frequent intensification of the fire and breaking out of new ones in irregular intervals also indicate the pulsation of the SW. The concrete determination of the analogue connection between the charged particles ejecting from the sun towards the Earth and the time of the origin of the initial phase of the flame has been considerably impeded by the lack of adequate satellite data, as in the previous case.

In the summer 1990, almost the same time as large fire, catastrophic fires occurred on Athos peninsula in Greece, the worst ever recorded in this area. The fires burned two weeks and spread over about 1,500 ha of chestnut forests and bush vegetation. The fire spreading was also contributed by strong winds (Dimitrakopoulos and Sakelaridis, 1990). Dimitrov and Jurčec (1991) mentioned long dry period in the spring and summer of 1990 and larger forest fires which occurred on the Croatian coast. The fires were occurring in the second half of summer, while several were ascertained at the end of August and the beginning of September (e.g. the 28th of August-Trogir and the 4th of September-Brač).

The fire from 1996 was registered on the 10th of August at 10:40 a.m. in the southern part of Deliblatska peščara on the locality of Vrelo, section 54 and in pine stands. The fire spread rapidly towards north-west. It soon broke out the first line of defense which was formed on the forest road between the forestry services "Vrelo" and "Topila" line (compartments 53 and 54). The fire was decided to be extinguished by helicopters and airplanes due to large areas under pine plantations. However, extinguishing from the air started three days later. The second day of the fire (the 11th of August), the destructive power of fire spread so much that the second line of defense had to be formed. Many people were arranged along the road with fire engines and hard machinery. However, this line of defense was broken out, too. The fire spread towards north-west and north-east rapidly. It was brought under control on the 14th of August by effective extinguishing from helicopters and airplanes. It rained the next day and the day after which brought to complete fire extinguishing (Munćan et al., 2004).

Having in mind that the fire from 1996 has been the largest one ever recorded in Deliblatska peščara, a survey of air temperatures, as well as relative humidity was given in the Table 2 for the period before, throughout and after the fire. Bold values in the table refer to the period of the fire duration.

Table 2. Air temperatures (maximum, minimum and mean) and mean relative air humidity from observatory Belgrade for the period of the 3rd to 21st of August 1996

Date	Air temperature (°C)			Mean relative air humidity (%)
	max	min	mean	
3	33.7	21.0	28.2	59
4	27.4	18.6	19.8	78
5	24.8	15.2	19.8	68
6	26.3	14.8	21.4	56
7	28.3	15.7	23.0	56
8	25.6	17.7	21.7	63
9	26.9	17.4	21.7	55
10	**28.5**	**13.8**	**21.9**	**55**
11	**30.8**	**17.4**	**24.0**	**41**
12	**26.8**	**20.8**	**23.4**	**48**
13	**29.2**	**21.2**	**24.5**	**50**
14	**29.9**	**18.0**	**24.6**	**54**
15	**30.3**	**19.4**	**23.0**	**70**
16	**22.0**	**17.5**	**19.2**	**85**
17	24.2	15.4	19.2	77
18	21.1	15.9	17.9	85
19	23.9	16.9	19.1	80
20	26.8	15.0	20.5	70
21	27.1	14.1	21.0	69

Source:http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php

According to the Observatory Belgrade data for the 10th of August, the air temperature was 17.3 °C at 7:00 a.m., while 27.5 °C at 14:00 p.m. It turned out that at the time when fire was registered (10:40), the air temperature was not extreme in the surroundings. During the fire, air temperature exceeded 30°C only on the 15th of August. However, fire was not spreading that day since it was brought under control previously.

  DOI: 10.5775/fg.2067-4635.2011.026.i

The fire spread wood mass was 247,206 m^3 (230,895 m^3 of conifers and 16,311 m^3 of deciduous). This fire spread over the areas of all structures in Deliblatska peščara. The area of fire, observed by outer borders, was nearly 7,000 ha. However, the fire bypassed some parts within the area, and it broke off at some places.

It was determined by the analysis of the solar parameters that the energetic region 7981 was on the visible side of the sun at the beginning of August (Fig. 1).

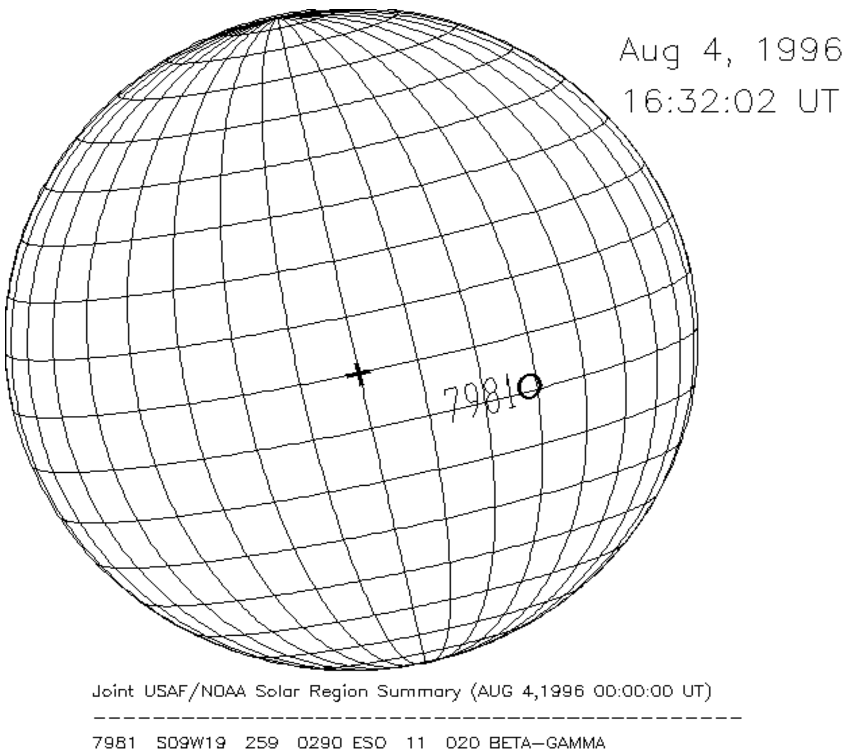

Fig. 1. Position of energetic region 7981 on the sun on August 4th 1996 (the site from which the image was taken is not in the function due to the operation stoppage of the satellite)

The region 7981 entered the geo-effective position on the 4th of August and in the following days it emitted the strong SW towards the Earth. The temperature of electrons was about 600,000 °C.

The magnetic structure of the sources of energy (beta-gamma) and the temperature of particles indicate that there is a possibility that electrons in the structure of the SW can be the cause of the largest forest fire in the recent history of Deliblatska peščara. Moreover, the fire area was elongated, which is typical for the fires caused by electrons. The length of the fire spread area was 19.5 km, while width was different, from 1 km in the north-west to 5 km in the central part. The frequent changes of the wind blowing directions were also noticed throughout the whole fire, as well as breaks out of new fire areas in irregular time intervals.

The fire from 2007 was noticed between 21:30 and 22:00 p.m. on the 24th of July in the area of Forestry Management Unit Bela Crkva (compartment 471, department a, Sokolica region) in the artificially grown stands of Scotch pine (*Pinus sylvestris* L.) of about 40 years of age. The fire first seized the tree-tops and spread over the surrounding sections, which was contributed to a great extent by strong wind of changeable direction. Problems with wind of changeable direction and intensity continued, so that fire got into the fenced area of the hunting ground (compartments 428 and 429) and spread over a lumber store, too. In the meantime, the number of people engaged in extinguishing was enlarged so that it was brought under control at around 18:00 p.m. Nevertheless, the next morning (the 26th of July) fires occurred on several locations. Further spreading was prevented by effective intervention in the lines of defense. Late in the afternoon the wind speed decreased so larger interventions were not necessary during the night. The following day (the 27th of July) fires occurred at several locations but they were brought under control. At around 15:00 p.m. fire extinguishing began by airplane, which dropped 40 tons of water on the fire spread area. During the 28th of July the number of engaged people on extinguishing gradually decreased and duty was

DOI: 10.5775/fg.2067-4635.2011.026.i

introduced which lasted to the 31st of July when it rained (Gomes et al., 2009).

According to data from observatory Belgrade, the maximum air temperature was 43.6 °C on the 24th of July, however the fire broke out between 21:30 and 22:00 p.m. (it was 29.8 °C at 21:00, while relative air humidity was 36%).

It can be seen from the Fig. 2 that the coronary hole CH 279 was in geo-effective position on July 21st 2007.

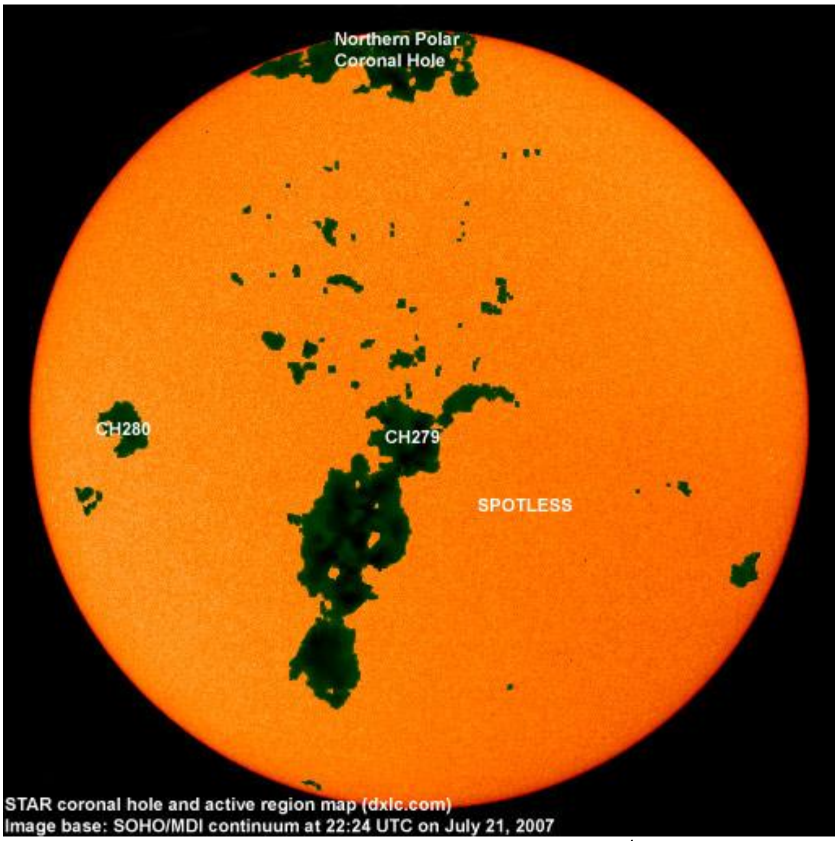

Fig. 2. Position of coronary hole on the sun (July 21st 2007) (http://www.dxlc.com/solar/index.html)

Coronary mass ejections (CMEs) from the coronary holes and /or energetic sources which are in geo-effective position are by rule followed by the striking wave of the SW particles in the interplanetary space (Fig. 3).

Instruments which measure the speed of the SW particles on the satellite detected clearly the influx of energy aimed towards the Earth. In this case, the parameters of temperatures and speeds of particles are not characterized by too high values (in comparison with cases analysed by Gomes and Radovanović, 2008) and almost do not indicate the potential danger from fires in vegetative cover.

However, this cannot be said for density of particles (90 p/cm3 approximately – Fig. 4). Moreover, it can be noticed that there is a delay in the maximum speed of the SW in relation to the maximum density of particles for about one day.

If the previous three figures are compared, the temporal coincidence of the striking wave of the SW particles and geo-magnetic disturbance on Earth can clearly be noticed (Figs. 3, 4, and 5). Simultaneously with fires in the area of the Mediterranean, the fires also occurred in the area of Manitoba (Canada). The connection between these events was explained by Radovanović et al. (2009).

While examining the connection between fires in Deliblatska peščara and AMO, Pearson's correlation coefficient was applied to annual data, as well to moving decadal values.

The statistical analysis by seasons showed the highest antiphase correlation throughout the summer months for moving decadal values ($r = -0.612$), statistically significant at $p = 0.01$ (Fig. 6).

DOI: 10.5775/fg.2067-4635.2011.026.i

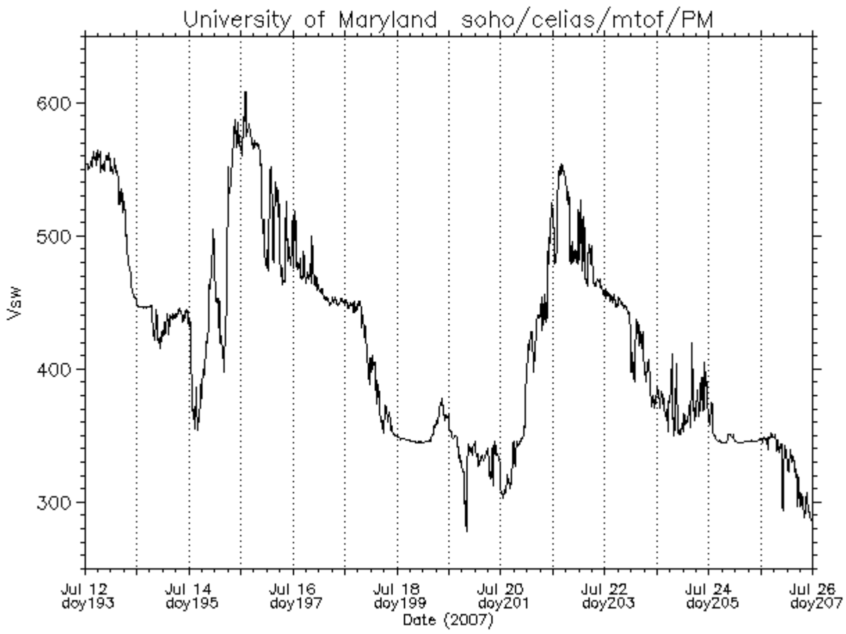

Fig. 3. Speeds of protons reached approximate values of 550 km/s at the beginning of July 21st 2007 (http://umtof.umd.edu/pm/crn/)

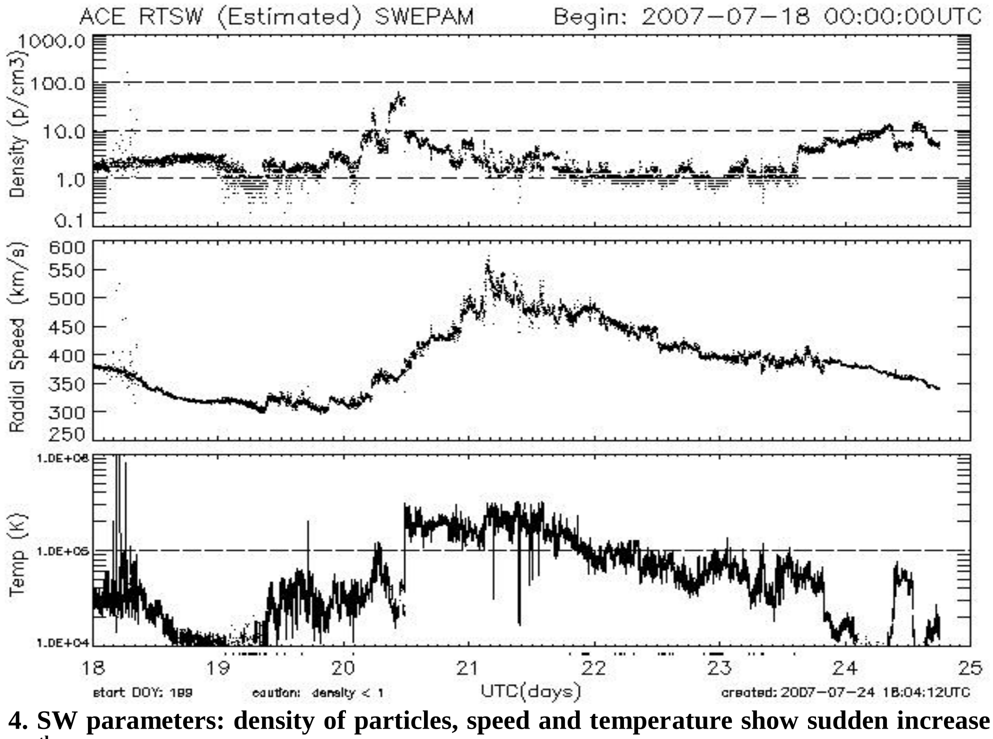

Fig. 4. SW parameters: density of particles, speed and temperature show sudden increase on July 20th 2007 (http://umtof.umd.edu/pm/crn/)

The connection is weaker in other cases: spring – 0.32, autumn –0.417. Possible connection between the mentioned processes was also noticed by other scientists. “Years of extensive fires are related to extreme drought conditions and are significantly related to the La Nina phase of ENSO, the negative (cool) phase of the PDO, and the positive (warm) phase of the AMO. The co-occurrence of the phase combination of La Nina-negative PDO-positive AMO is more important to fire occurrence than the individual influences of the climate patterns” (Sibold and Veblen, 2006). Similar thoughts had Schoennagel et al. (2007): “There is a mounting evidence that the recent shift to the positive phase of the AMO will promote higher fire frequencies in high-elevation western U.S. forests.”

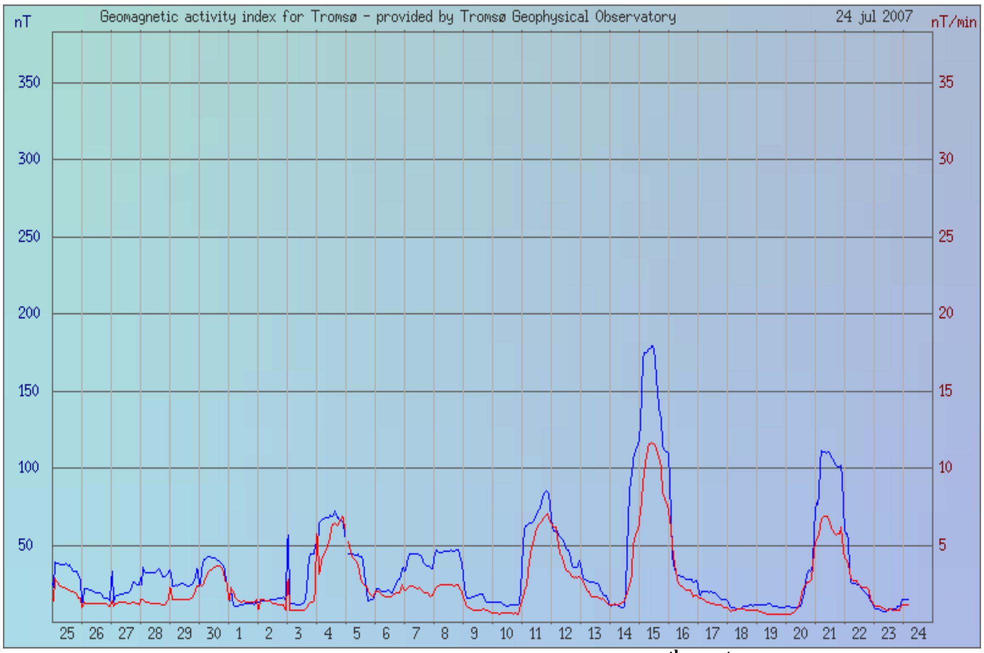

Fig. 5. Geomagnetic disturbance is clearly noticed on the 20th-21st of July 2007, which also indicates the temporal coincidence with the phenomenon of coronary hole in the geo-effective position (http://flux.phys.uit.no/ActIx/)

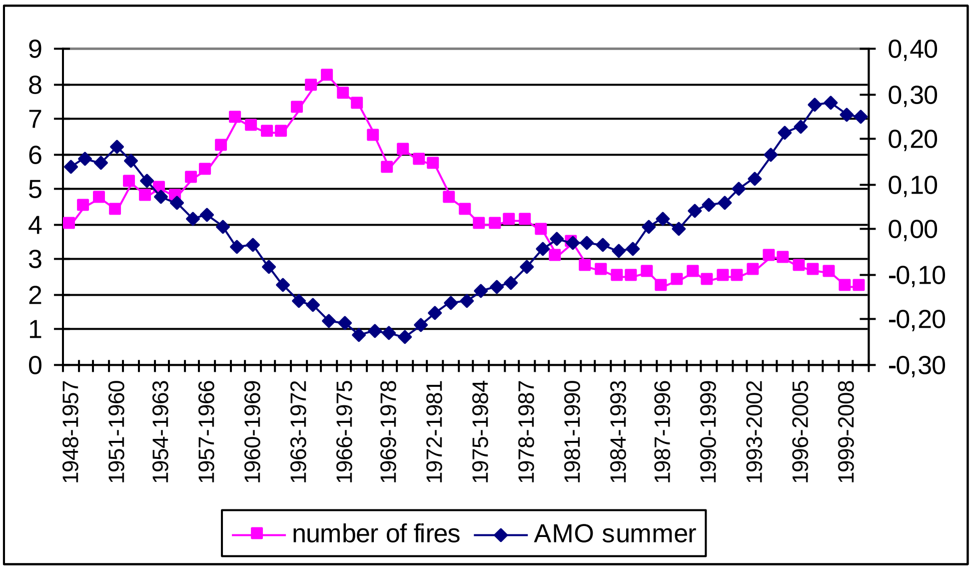

Fig. 6. Correlation of (movable decadal values) AMO (summer) – annual number of fires in Deliblatska peščara (1948-1957 to 2000-2009)

CONCLUSION

There are not enough elements, due to the lack of data, to make a clear enough conclusion that the SW caused the forest fire in Deliblatska peščara in the period of 27th-29th March 1973. However, the size of the fire spread area, strong wind of changeable direction and the phenomenon of 9 fires in six days immediately before this fire are leading to this conclusion.

The forest fire of the 30th of August to the 5th of September 1990 occurred in the period of the intensive solar activity. The average value of solar flux at 2.8 GHz was 222.6 in August, while there were 201 sunspots on the visible side of the sun. That year the largest number of strong proton winds was recorded with the temperature of over 1,000,000 ºC. The shape of the fire spread area (irregular, round) is characteristic for proton fires. Throughout this period, frequent changes of the wind blowing direction were also recorded, as well

  DOI: 10.5775/fg.2067-4635.2011.026.i

as breaking out of the new fire areas. The dynamics of fires, size of the fire spread surface and duration also fit in the assumption on the SW as the potential cause. Even though this fire has been the largest one ever recorded in Deliblatska peščara, in the time of its occurrence the air temperature was not extremely high.

The largest forest fire in recent history of Deliblatska peščara (August, 10th-16th 1996) was in the temporal analogy with the inflow of the SW energy from energy region 7981. The mentioned region entered the geo-effective position on the 4th of August. The form of fire (length-19.5 km, width-1-5 km) was characteristic for fires caused by electrons. The dynamics of fire, the size of fire spread surface and its duration also fit in with the assumption on the SW as potential cause. Even though this fire has been the largest one ever recorded in Deliblatska peščara, the air temperature was not extremely high in the time of the fire occurrence.

In the case of the fire from 2007 (July 24th-31st), the coronary CH279 hole was the source of energy on the sun which entered the geo-effective position on the 21st of July. The speed of protons was around 550 km/s, while the density of particles around 90 p/cm^3. In the time of striking of the SW particles, geo-magnetic disturbance was also recorded. Many fires were recorded in the area of the Mediterranean in the period that followed.

The statistical analysis of the number of fires and AMO also indicated the anti-phase connection between these events. Thus, the indirect indications are that the SW could be the cause of not just fire occurrence for which the causes have not been known, but hydrodynamic air mass seizing, too. On the basis of presented results we are of opinion that the future researches can be aimed at three basic directions.

- The first one is connected with the establishing of the chronological connection between forest fires and processes on the sun on statistically satisfied number of samples.
- The second one relates to experimental laboratory researches that could at least approximately simulate the conditions for which there is a conviction that can be responsible predisposition to the phenomenon of the initial phase of fire.
- The third approach is about astrophysical phenomena and processes which need a detailed parameterization as well as specific study of the particle penetration mechanism from space toward Earth's surface i.e. stand of forests.

ACKNOWLEDGEMENTS

The paper was funded by the Ministry of Science of the Republic of Serbia, grant III 47007.

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  DOI: 10.5775/fg.2067-4635.2011.026.i

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 117-128
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.029.i

Observed changes in precipitation in the Danube river lower basin in the context of climate change

Nina NIKOLOVA[1], Constanţa BORONEANŢ[2]

[1] Assoc. Prof., PhD. St. Kliment Ohridski University of Sofia, e-mail: nin_n@abv.bg
[2] Senior Scientist, PhD, Centre for Climate Change (C3), University Rovira I Virgili, Tortosa, Spain; e-mail: constanta.boroneant@urv.cat

Received on <January 30, 2011>, revised on <February 6, 2011>, accepted on <February 25, 2011>

Abstract

The study presents the observed variability and changes in precipitation regime in the Danube river lower basin, which is situated along both sides of the border between Bulgaria and Romania. The research is based on monthly precipitation totals recorded at 22 meteorological stations from Bulgaria and Romania. The investigated period is 1961-2007 out of which two reference periods are considered, the last 30 years (1978-2007) and the usually used WMO reference for the contemporary climate (1961-1990).

The main objective of the study is to give actual information about precipitation variability in the region in the context of global climate change. The results of the work point out on some characteristics of extreme precipitation events in the region – drought and high precipitation, and on the role of natural mechanisms for precipitation variability.

Based on the statistical methods we have used, the results can be summarized as follows:

- Summer precipitation represents 30-35% of annual precipitation total followed by spring precipitation with about 25-28% of annual values. Autumn precipitation is between 22-24% of annual values in most of the stations. Winter precipitation represents about 20% of annual precipitation
- The wet periods have been observed at the end of the 1960's and at the beginning of the 1970's
- The intensive drought from 1983 to 1993 has been confirmed by calculating the precipitation indices like as Rainfall Anomaly Index and Cumulative Anomaly Index. The driest year during the investigated period was 2000.
- Increasing occurrence of extremely wet months has been observed since 2002

Keywords: *precipitation, extreme events, NAO index, Bulgaria, Romania*

Rezumat. Schimbări observate în regimul precipitaţiilor atmosferice în bazinul inferior al Dunării în contextul schimbărilor climatice globale

Studiul prezintă variabilitatea şi schimbările observate în regimul precipitaţiilor sezoniere în bazinul inferior al Dunării, care este situat de-o parte şi de alta a frontierei dintre Bulgaria şi România. Cercetarea se bazează pe datele lunare de precipitaţii înregistrate la 22 de staţii meteorologice din Bulgaria şi România. Perioada de studiu este 1961-2007 din care s-au considerat două perioade de referinţă, ultimii 30 de ani (1978-2007) şi perioada considerată în mod obişnuit de OMM ca referinţă pentru climatul actual (1961-1990).

Obiectivul principal al studiului este prezentarea unei informaţie actuale despre variabilitatea precipitaţiilor din regiune în contextul schimbărilor climatice globale. Rezultatele studiului evidenţiază câteva caracteristici ale evenimentelor cu precipitaţii extreme în regiune – secetă şi precipitaţii abundente - şi asupra rolului mecanismelor naturale în variabilitatea precipitaţiilor.

Pe baza metodelor statistice pe care le-am utilizat rezultatele pot fi sintetizate astfel:

- Cantităţile de precipitaţiile din timpul verii reprezintă 30-35% din totalul cantităţilor anuale, cele din primăvară 25-28%, cele din timpul toamnei 22-24%, iar cele din iarnă aproximativ 20% din totalul cantităţilor anuale.
- Cele mai ploioase perioade s-au înregistrat la sfârşitul deceniului 1960 şi la începutul deceniului 1970.
- Seceta intensă din perioada 1983-1993 a fost confirmată atât de Indicele RAI (Indicele Anomaliei de Precipitaţii) cât şi de Indicele CA (Anomalia Cumulată) a precipitaţiilor. Anul 2000 a fost cel mai secetos din perioada analizată.
- Începând cu anul 2002 s-a obserevat o creştere a numărului de luni cu precipitaţii mult excedentare.

Cuvinte cheie: *precipitaţii, evenimente extreme, indice NAO, Bulgaria, România*

INTRODUCTION

Warming observed over the past several decades is consistently associated with changes in the hydrological cycle. In this regard, increasing atmospheric water vapor, changes of precipitation characteristics, changes in the magnitude and the intensity of extreme events, widespread melting of snow and ice and, changes in soil moisture and runoff have been intensively reported. The fourth Assessment Report (AR4) of the IPCC pointed out that the 100-year linear trend (1906–2005) of 0.74ºC is larger than the corresponding trend of 0.6ºC

(1901–2000) given in the Third Assessment Report (TAR), (IPCC, 2007). The increase in global surface temperature leads to significant melting of snow and ice and reduces the areas covered with snow and ice cover (Brown and Alt, 2001; Goodison et al., 2007).

Studies on precipitation variability show decreasing trend in the Central and Southern Europe and increasing trend in the Northern Europe. The Balkan Peninsula is characterized by a general decreasing trend of precipitation since the beginning of the 1980s (Alexandrov, 2004).

However, heavy rains have been observed in many parts of Bulgaria and Romania. During the flooding events of the last years in Romania (2005 and 2006) and other regions in the central and south-eastern Europe, losses of life and very high economic damages have been experienced. On the other hand, in the southern Europe including the northern part of Bulgaria and the southern part of Romania, it has been observed that in most of the cases, heavy rains occurred during long lasting dry months. These facts illustrate how climate extremes become more frequent and more intense during the last decades.

The aim of this study was to provide detailed information in our region of interest about:

- seasonal variation of precipitation;
- temporal and spatial changes of extreme precipitation months;
- link between precipitation variability and large scale circulation processes, in particularly in relation with North Atlantic Oscillation (NAO).

DATA AND METHODS

The Danube river lower basin, situated on both sides of the border between Bulgaria and Romania is one of the main agricultural areas for Bulgaria and Romania as well.

The present paper present a part of the results obtained in the framework of Bulgaria–Romania Joint Research Project ”Observed changes in precipitation regime in the Danube river lower basin in the context of climate change“.

We used monthly precipitation data for 22 meteorological stations situated on both sides of Danube river on the territories of Bulgaria and Romania. According to their geographical situation and to the peculiarities of the study area the stations have been grouped into three groups: 1) western part of the study area which includes the stations Tr. Severin, Calafat, Băileşti, Bechet, Caracal, Tr. Măgurele, Vidin, Vratsa, Lom, Oryahovo, Kneja and Pleven; 2) central part including the stations Alexandria, Giurgiu, Obraztsov chiflik, Razgrad, Bucureşti-Băneasa and Călăraşi and 3) eastern part of the region with the stations Sulina, Tulcea, Galaţi and Hârşova (Fig. 1).

The main investigated period is 1961-2007. In order to investigate the changes in the variability of precipitation two 30-year reference periods have been used: 1961-1990 and 1978-2007.

In order to avoid the influence of non meteorological factors on climatologic data, homogeneity testing and then homogenization of the initial time series were made by using the AnClim software (Stepanek, 2006 and http://www.climahom.eu/AnClim.html).

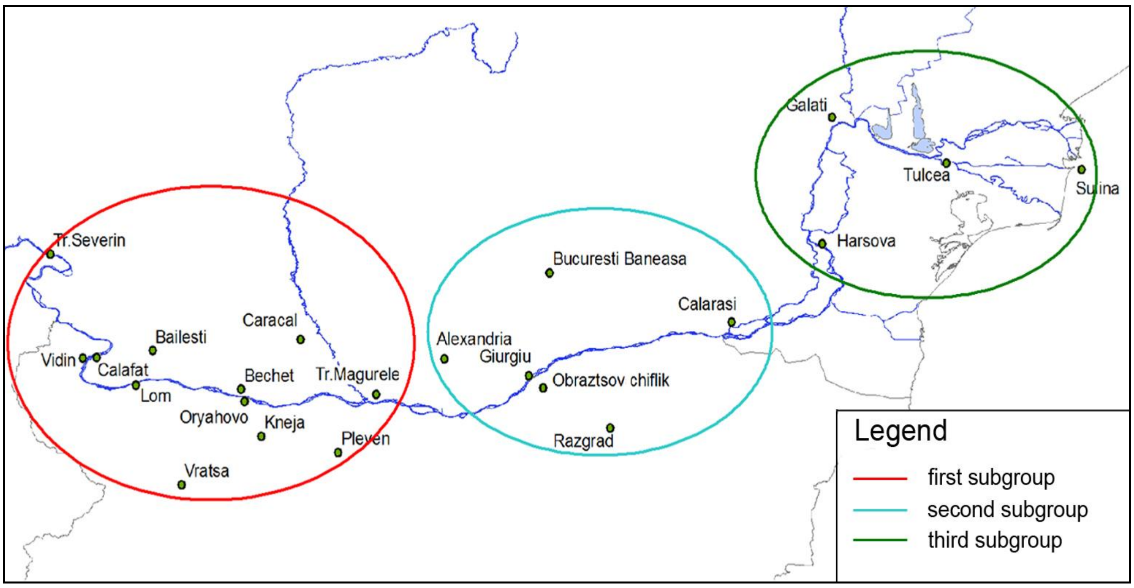

Fig. 1. Meteorological stations used for the research

  DOI: 10.5775/fg.2067-4635.2011.029.i

All time series of monthly precipitation totals, where breakpoints have been detected, were adjusted (Manea et al., 2010). The seasonal precipitation was determined by summing the monthly precipitation totals as follow: winter – December, January, February; spring – March, April, May, summer – June, July, August and autumn – September, October and November.

The link between winter precipitation and atmospheric circulation was examined on the base of gridded sea level pressure (SLP) monthly means extracted for the Atlantic-European domain (30ºW-50ºE; 30º-80ºN) from the NCEP Reanalysis web site at http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html. The time series for winter NAO index has been calculated as average of monthly values ((DJF)) of NAO indices available at Climate Research Unit web site http://www.cru.uea.ac.uk/cru/data/nao/.

Regional differences in the variability of rainfall and duration of dry and wet periods are determined by Rainfall Anomaly Indices (RAI) and Cumulative precipitation Anomalies (CA). These indices are used by many authors (Keyantash and Dracup, 2002; Hänsel and Matschullat, 2006, etc.) for determining the drought and assess its magnitude expressed as positive and negative anomalies.

Rainfall Anomaly Index is used to calculate annual precipitation anomalies (dry events). It is calculated by

$$RAI = -3\frac{P_i - \overline{P}}{\overline{E} - \overline{P}},$$

where P_i is annual precipitation total for each year, $\overline{P}$ is the average annual precipitation for the period 1961-1990, and $\overline{E}$ is the average of the ten lowest precipitation totals (the driest 10 years) for the investigated period. Cumulative Precipitation Anomalies (CA) are used in order to determine the duration of drought event. CA are calculated as follow: 1) the differences between seasonal or annual precipitation for each year ($\boldsymbol{P_i}$) and average values for the period 1961-1990 ($\overline{\boldsymbol{P}}$) are calculated; 2) those anomalies are cumulated.

$$\boldsymbol{CA = \sum_{i=1}^{n}(P_i - \overline{P})},$$

From the graphical representation of this quantity, the negative slopes of the graph indicate the duration of drought event (Hänsel and Matschullat, 2006).

Extreme wet month is defined as a month whose monthly precipitation total is higher than the 90^{th} percentile of the empirical distribution during the reference period 1961-1990. As extreme dry month, we consider the month with precipitation total lower than the 10^{th} percentile of the empirical distribution.

In order to determine the influence of the large scale mechanisms on precipitation variability, a link between the North Atlantic Oscillation (NAO) and winter precipitation in our region is investigated. The NAO refers to a north-south oscillation in the atmospheric mass with centers of action near Iceland and over the subtropical Atlantic from the Azores across the Iberian Peninsula. NAO occurs in all seasons but during winter it has a dominant role for precipitation variability in the Atlantic European region including our domain. During the months of December through March, the NAO accounts for more than one-third of the total variance of SLP over the North Atlantic (Hurrell, 2000). According to Rimbu and Boroneant (2000), 32% of the total variance of the decadal winter precipitation in Europe is explained by a spatial structure of sea level pressure (SLP) associated to the NAO. During the positive phase of the NAO, negative precipitation anomalies occur over the southern part of Europe (Wibig, 1999). In our study, the time series for winter NAO index has been calculated as an average of monthly values ((DJF)) of the NAO index.

The EOF analysis was used to identify the principal modes of winter variability of sea level pressure and precipitation which are coherently varying. The EOFs were calculated as unitary eigenvectors of the covariance matrix. Each EOF can be regarded as a spatial mode of variability.

DISCUSSIONS

The main contribution to annual precipitation totals comes from summer precipitation. Exceptions are made only for a few stations in the western part of the study area where the spring precipitation is higher or equal to summer precipitation. In general, the summer precipitation accounts for about 30-35% of annual precipitation (Fig. 2). The second contribution comes from spring precipitation which accounts for about 25-28% of annual precipitation. At some stations from the eastern part of study area, autumn precipitation ranks on the second place in annual amount after the summer precipitation but in most of the investigated stations, autumn precipitation follows spring precipitation with 22-24% from annual totals. The winter precipitation represents the lowest contribution to the annual total. In the eastern part of the study area, as well as in the western part, at most of the stations the winter precipitation accounts for about 20% of the annual precipitation total.

Variability of seasonal precipitation

According to the *Rainfall Anomaly Index (RAI)* calculated for the three groups of stations, the driest winters have been observed in the eastern part of the Danube river lower basin since 1971 (Fig. 3)

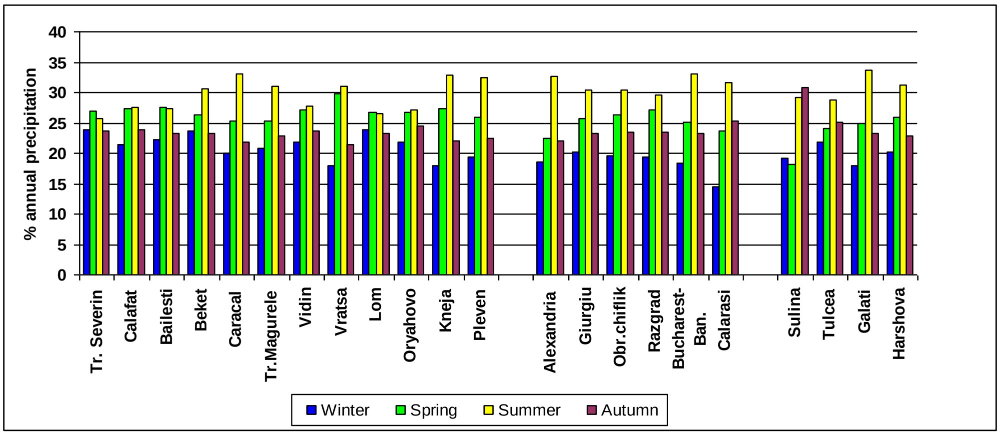

Fig. 2. Distribution of seasonal precipitation as % of annual precipitation total for the period 1961-2007

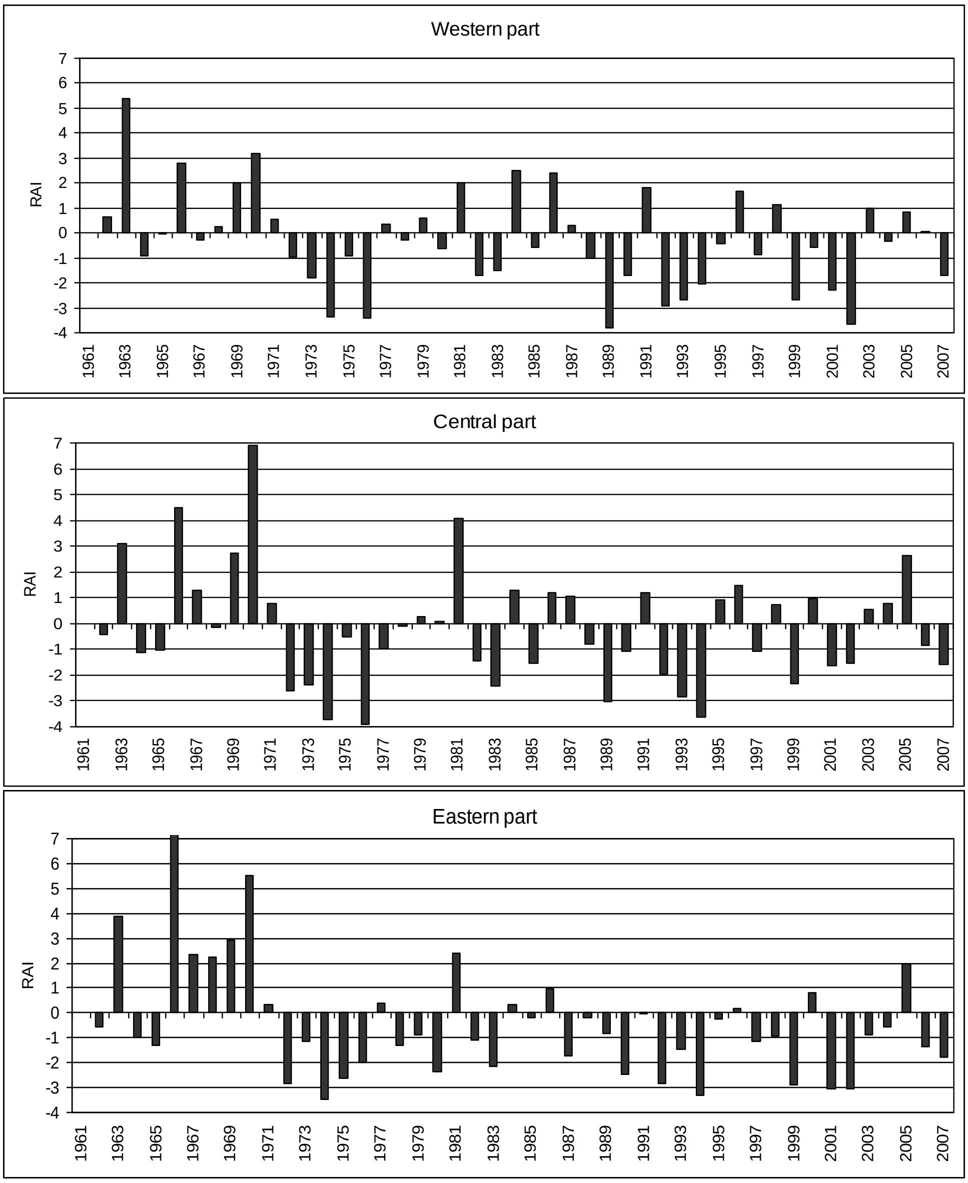

Fig. 3. RAI for winter precipitation

  DOI: 10.5775/fg.2067-4635.2011.029.i

The values of RAI show that the winters have been wet from 1962 to 1970 at all stations but most pronounced at the eastern group of stations. According to RAI the highest winter precipitation for the period 1961–2007 has been observed in 1970 for the central group of stations, in 1966 for the eastern group and 1963 for the western group of stations, respectively. Since 1971 the winter precipitation has shifted to dry characteristic at most of the stations in the region. However, during that period, in the western and central group of stations several wet years have been observed.

According to RAI, the spring precipitation is characterized by an interannual variability that not clearly shows any dominant trend (Fig. 4). The spring drought is well expressed in 1968, 1983, 1986, 2000, 2003 and 2007.

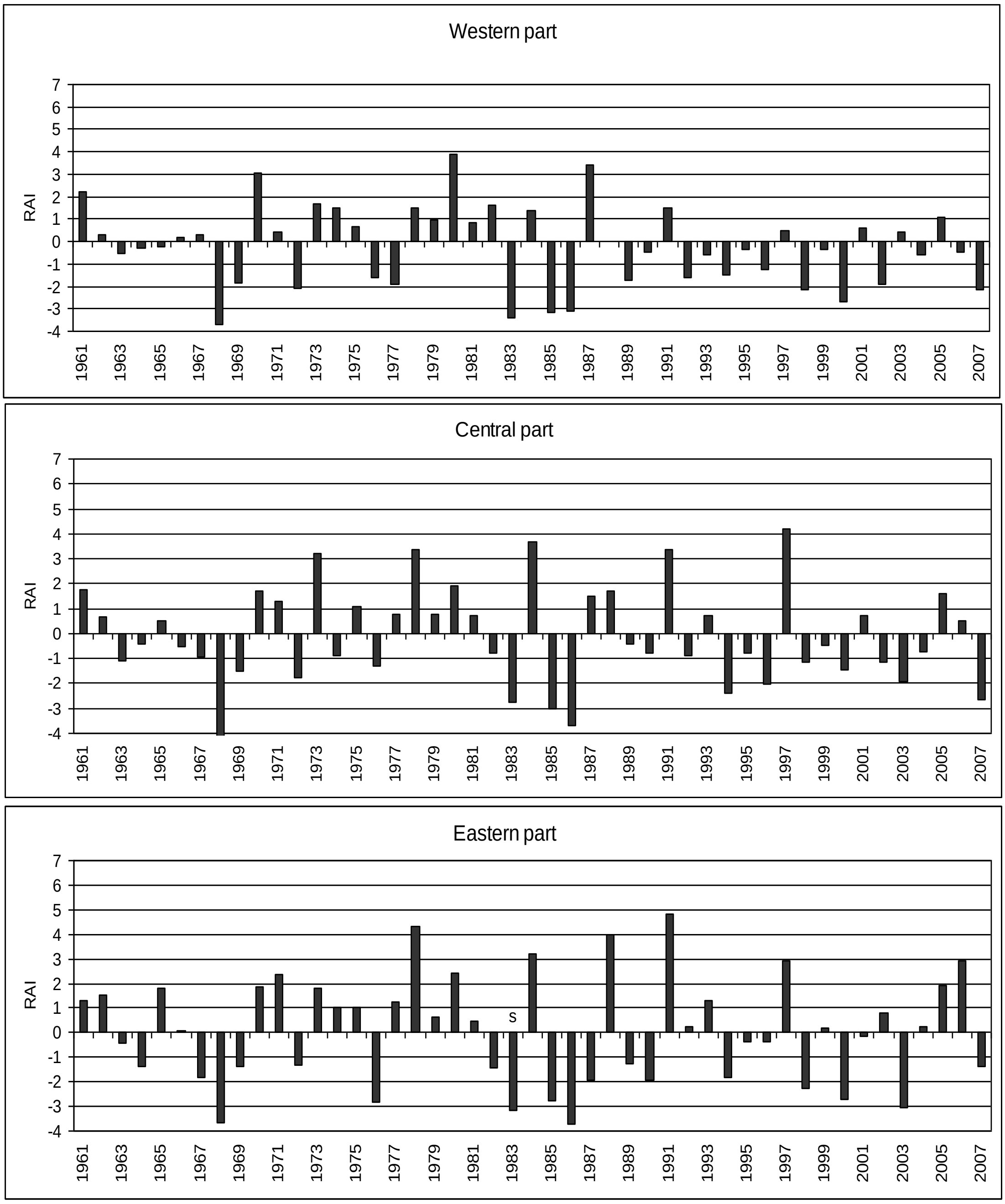

Fig. 4. RAI for spring precipitation

Unlike the spring, during summer, according to RAI, since 1961 till 1965 a dry period has been detected at most of the analyzed stations and then a wetter period followed (1966-1976). Starting with 1977 till 2007 the summer precipitation has shifted to dry. However, during that generally dry period at most of the stations, extremely wet years have been recorded such as 1997 in the eastern group of stations and 2005 in the central and western group of stations (Fig. 5). It is worth to note that these

DOI: 10.5775/fg.2067-4635.2011.029.i

were the years when heavy precipitation gave rise to severe floods in Romania.

During 1961-1980, the autumn precipitation is characterized by successive wet and dry years at most of the stations. The wettest year was 1972 at all the stations. That period was followed by dry years till the mid of 1990's when a shift to wetter period was shown in the RAI at all stations. The wettest years have been recorded at the central group of stations (Fig. 6).

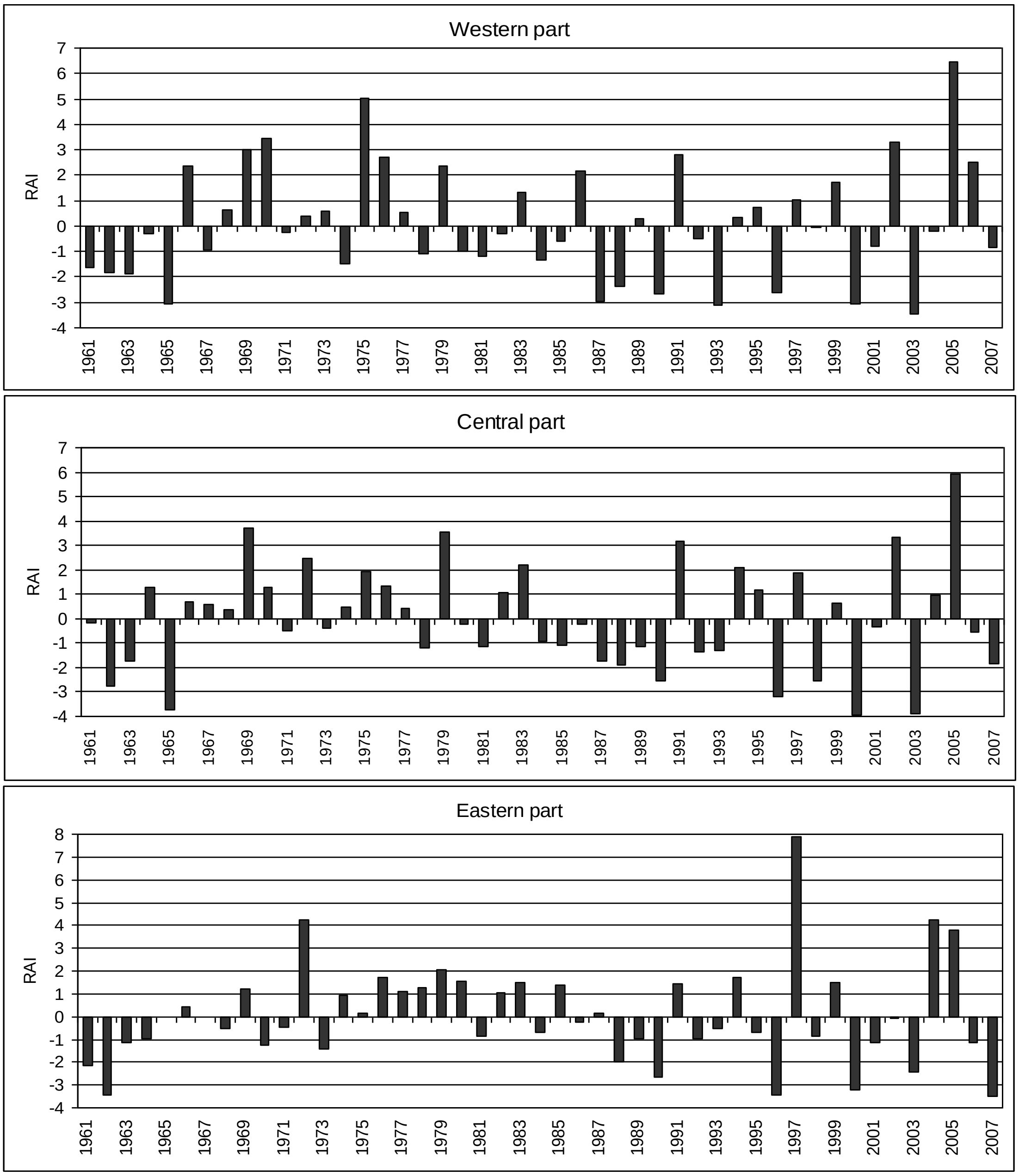

Fig. 5. RAI for summer precipitation

Cumulative anomaly (CA) allows us to determine the periods with positive and negative phases in the time series of seasonal precipitation. The positive phase from 1962 to 1971 is characteristic for winter precipitation. The following negative phase continues until 1976 (1978). During the last 30 years of the investigated period there are one positive phase of winter precipitation (1976/1978–1987/1988) and one negative (1987-2002) as shown in Fig. 7.

There is asynchrony in the occurrence of positive and negative phases in time series of spring precipitation for various stations. The positive phase from 1969 to 1980/1984 is established in most of investigated stations followed by negative phase lasting to 2004.

The beginning of the period is characterized by a negative phase of the summer precipitation, which continued until 1965 (1968). The following is a positive phase lasting from 1965 to 1983 being

  DOI: 10.5775/fg.2067-4635.2011.029.i

observed in the most of stations in the central and eastern part of study area, while for the stations of western part the positive phase is better expressed from 1968 to 1977/1979. The negative phase in summer precipitation is established from 1983 to 2003. For some stations from the first group (western) the negative trend continued from 1979 to 1996. In some of the investigated stations there is a slightly expressed positive phase in the summer precipitation for the period 1993-1999 but it generally remains the negative trend. There is a positive slop in the time series of summer precipitation since 2003 in most of the investigated stations (Fig. 8).

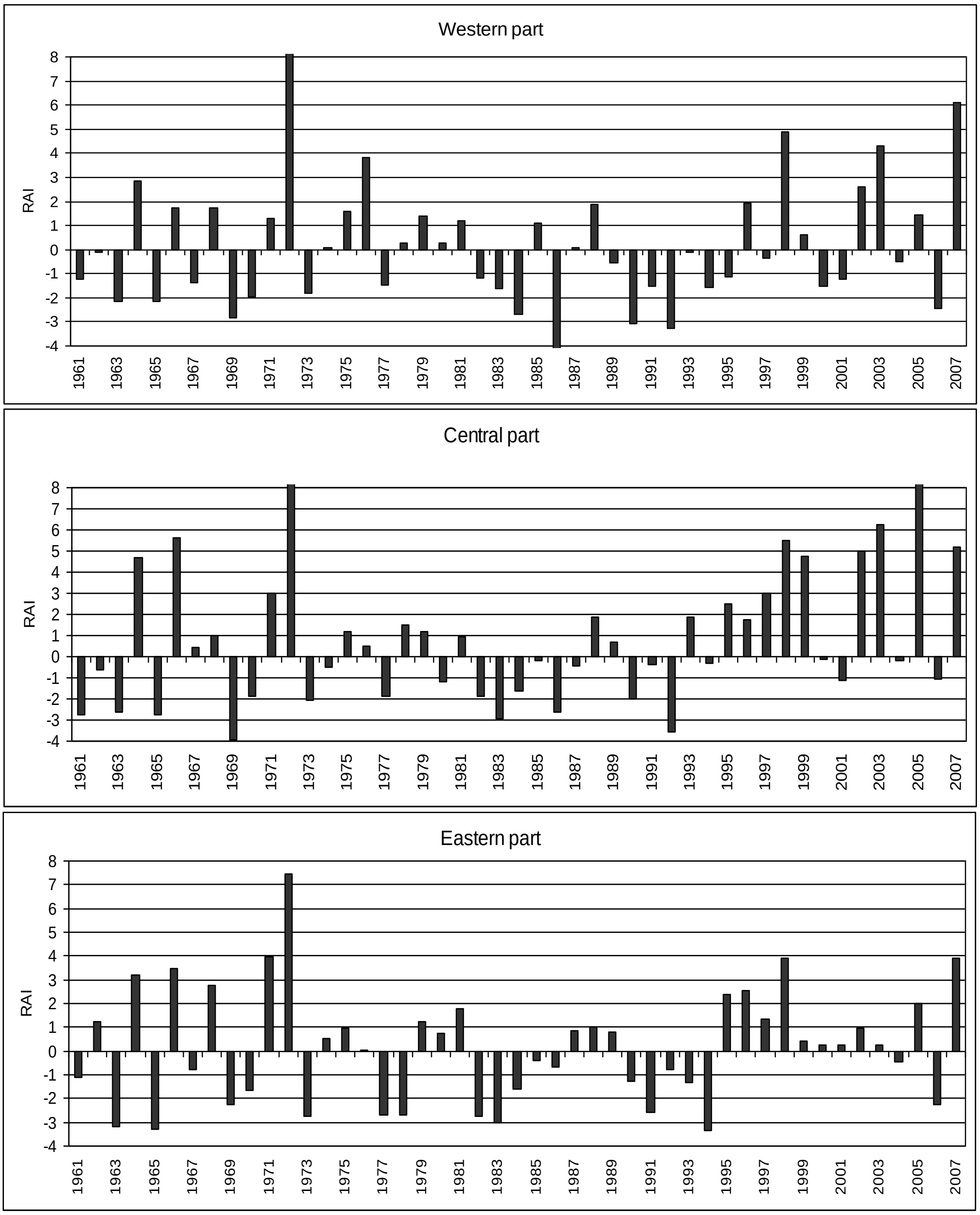

Fig. 6. RAI for autumn precipitation

Unlike summer, in autumn there is not well-defined negative phase at the beginning of the period. The minimum during the autumn precipitation in 1970, expressed in almost all investigated stations makes impression. The subsequent positive phase lasted until 1981/1982 at the stations located in the western part of the Danube plain of the Bulgarian territory, and in some Romanian stations (Turnu Severin, Calafat, Băileşti, Bechet).

DOI: 10.5775/fg.2067-4635.2011.029.i

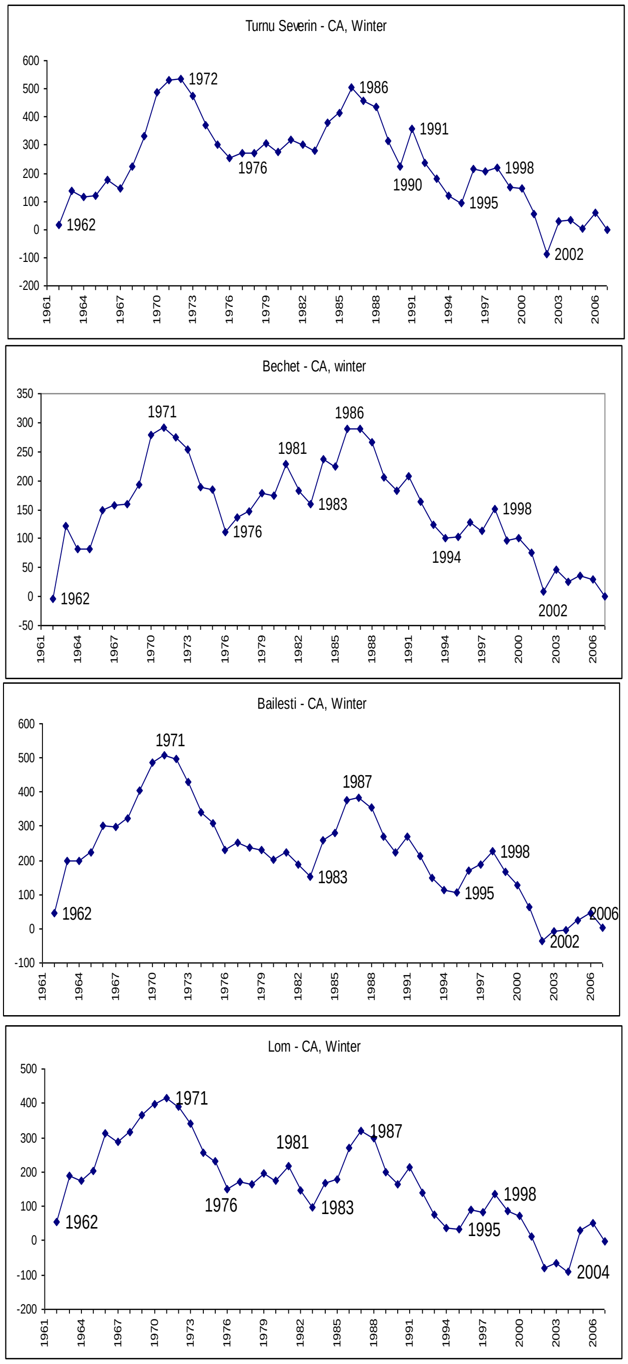

Fig. 7. Cumulative anomalies (CA) of winter precipitation

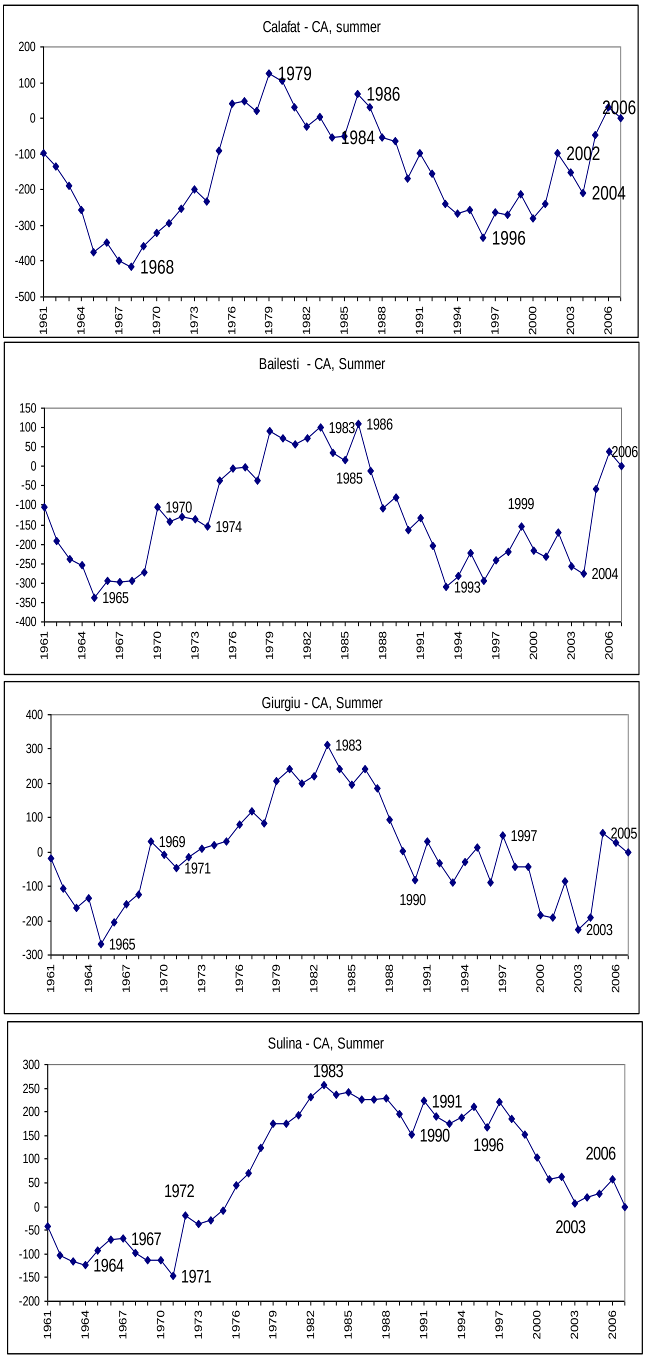

Fig. 8. Cumulative anomalies (CA) of summer precipitation

The eastern part of study area is characterized by negative phase in autumn precipitation with duration from 1972 to 1994. From 1994/1995 until the end of the investigated period in all stations, the positive phase of the autumn precipitation is established.

Link between winter precipitation and atmospheric circulation. The dynamics of the atmosphere is an important internal factor for the genesis of climate and its variability. It is characterized by global atmospheric circulation, which represents all major air currents at a large spatial scale. In order to establish a connection between seasonal precipitation and atmospheric circulation, the indices of the North Atlantic Oscillation (NAOI) are used. In most of the cases, the correlation between seasonal precipitation and NAOI is negative but a statistically significant correlation is established only for winter season. This is explained by the activation of NAO during this period of the year. The most well-defined

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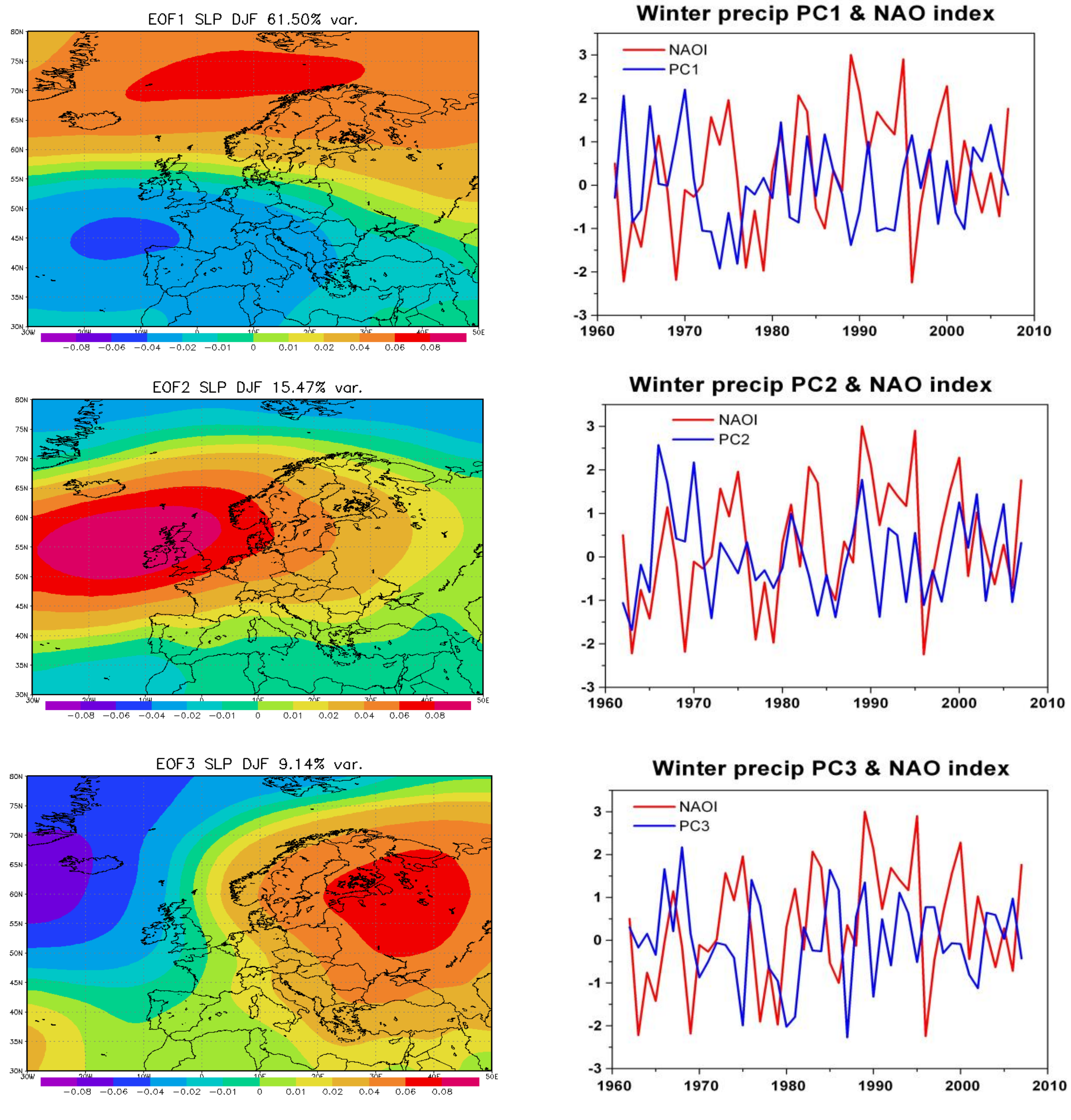
correlation is established at the stations from the western half of the study area.

The EOF analysis was performed to detect the main patterns of variability for the SLP in the Atlantic-European sector. The results show that SLP is one of the main factors influencing precipitation variability in the region. The main characteristics of spatial distribution of the winter SLP can be summarized as follows (Fig. 9a):



a) **b)**

Fig. 9 Relationship between sea level pressure (SLP) variability and winter precipitation: a) spatial configurations of the main leading EOFs and the explained variances and, b) relationship between the series of PC coefficients associated to the main leading EOFs (PC1, PC2 and PC3) of precipitation variability in the Danube river lower basin and the series of NAO index during winter

- EOF1 shows the principal pattern of SLP variability which actually corresponds to the NAO pattern. This mode explains 61.50% of the total variance of winter SLP.
- the EOF2 pattern shows a mono-polar like structure of SLP, centered over the North Atlantic and the Great Britain. This mode of SLP variability accounts for 15.47% of the variance.
- the EOF3 pattern accounts for 9.14% of total SLP variance and characterizes the blocking situations over the Europe.

The analysis of the series of PC1 coefficients associated to EOF1 of winter precipitation and the

DOI: 10.5775/fg.2067-4635.2011.029.i

time series of NAO indices show that the winter precipitation variability is in opposite phase with the NAO. This means that during the positive phase of the NAO the winter precipitation anomalies are negative at the stations in Danube river lower basin and, vice versa (Fig. 9b, upper panel).

Spatial and temporal variability in extreme precipitation months in lower part of the Danube river basin during the period 1961-2007.

Analyzing the occurrence of the three driest and the three wettest months during a year allows us to determine dry and wet periods. According to this criterion, 1983-2003 represents the driest period out of the analyzed period 1961-2007. 2000 appeared as the driest year at 64% of investigated stations and it is the driest year during the period 1961-2007, followed by 1992 and 1990. According to the same criterion, extremely wet months were more often recorded during the period 1966-1980 and the wettest year was 1969 which ranked with three and even more wet months at 55% of the investigated stations, followed by 1972 and 1966. During the last years of the investigated period 1961-2007 3 and more extremely wet months have been observed at 40% of the stations during 2005 (Fig. 10). In most of the years, three and more than three extremely precipitation months have been observed in less than 20% of the investigated stations.

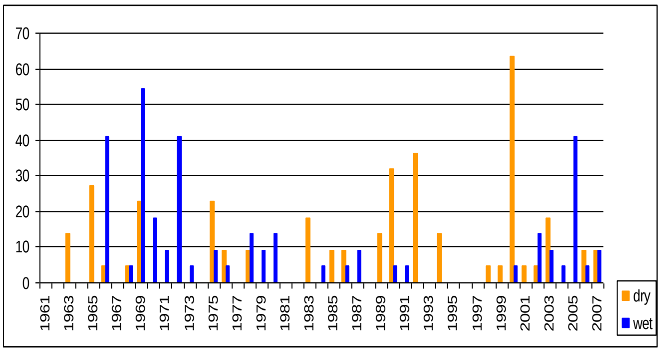


Fig. 10. Percentage of the stations with 3 or more than 3 extremely precipitation months

The general tendency of the climate of the lower Danube river basin during the period 1961-2007 shows lightly predominance of wet months over dry months (Fig. 11a). Nevertheless, for the period 1978-2007 in the most of the investigated stations, the dry months have been observed more often than wet months (Fig. 11b).

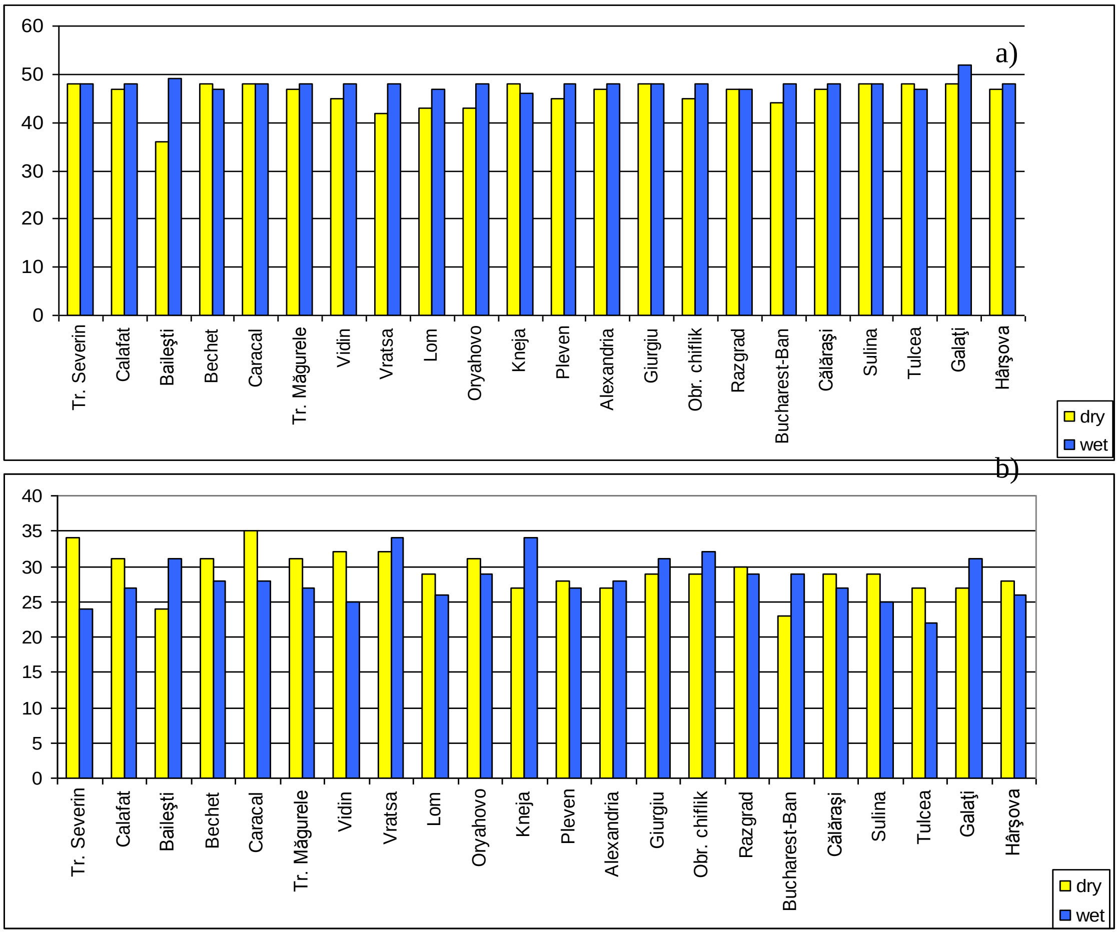


Fig. 11. Number of extreme precipitation months for the periods: a) 1961-2007; b) 1978-2007

  DOI: 10.5775/fg.2067-4635.2011.029.i

The correlation coefficients between the average data for the number of extreme precipitation months and the NAOI show that the relation is better for recent periods (Table 1)

Table 1.
Correlation coefficients between the average number of extreme precipitation months and the NAOI

	1961-2007	1978-2007	1961-1990
Dry months	0.34*	0.53*	0.24
Wet months	-0.19	-0.30*	-0.15

* marked coefficients are statistically significant at $p< 0.05$

CONCLUSION

• According to the RAI in the most of years winters have been dry. The wet years have been observed mainly in the first part of the investigated period. In spring and summer the occurrence of wet years increases but the magnitude of dry events is bigger than that of wet events. The wet autumns are characteristic mainly for the last decades of the investigated period.

• CA clearly show positive phases of seasonal precipitation during the first part of investigated period as the negative are observed mainly since the beginning of 1980's.

• The extremely wet months are more frequent from the beginning of the investigated period to 1972. That wet period is characteristic mainly for winter and summer precipitation. The drought is well expressed during the 1980's.

• During the last years, the occurrence of extreme events has increased. Heavy rainfalls have been observed in many parts of Bulgaria and Romania. On the background of a general tendency of drought, the precipitation totals have been maximal during the summer of 2005. The driest years during the period 1961-2007 are 2000, 1992, 1990 and 1965.

• The main factor for precipitation variability in the Danube river lower basin is the variability of SLP. The relation between NAOI and precipitation is better determined for winter period.

• The results of the research are important for better understanding the relationship between precipitation and related physical processes. The knowledge on spatial and temporal occurrences of extremely dry and wet months will help for further developments of various strategies for mitigation and adaptation to climate change and for effectively tackling environmental problems.

• The results can be further used for impact studies on climate change impacts in agriculture, water resources, energy supply and tourism in both countries in the Danube river lower basin.

ACKNOWLEDGEMENTS

This study was supported by the National Science Fund, Ministry of Education, Youth and Science, Bulgaria Contract No. БРС 7/2007 and the National Authority for Scientific Research, Romania contract No. 100/2008 AAd 1 under the Grant for Bulgaria–Romania Joint Research Project "Observed changes in precipitation regime in the Danube river lower basin in the context of climate change".

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 129-139
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.030.i

Indexes of Spring Arrival between 2000 and 2010 in Oltenia

Octavia BOGDAN[1], Ion MARINICĂ[2], Andreea Floriana MARINICĂ[3]

[1]Geography Institute of the Romanian Academy, octaviabogdan@yahoo.com
[2]RMC Oltenia, ionmarinica@yahoo.com
[3]Jacobs University Bremen, seryblack@yahoo.com

Received on <November 18, 2010>, revised on <January 30, 2011>, accepted on <May 30, 2011>

Abstract

The present paper deals with the conditions related to spring arrival in Oltenia between 2000 and 2010. A first general evaluation may be achieved by comparing the mean general indexes for the entire region of Oltenia for each spring, which are calculated as a mean of the indexes of spring arrival for all the meteorological stations from Oltenia, including the mountainous area.

Out of the 11 analysed years, the lowest value was 171.1°C, registered in the spring of 2003, which followed the coldest winter (2002-2003) of the studied interval (Bogdan, Marinică, Marinică, 2010); the highest value reached 460.7°C and it was registered in the spring of 2002 that followed a warm winter, 2001-2002, the general mean of which is on the 9th place in the increasing hierarchy of the general temperature means for winter during the analysed interval.

The general mean of the index for the 11 analysed years is 366.0°C with a positive percentage deviation of 43.2%, which, according to a Hellmann's type of criterion established by us, emphasizes that springs were early (E) during the entire period.

The negative deviation of the latest spring (2003) was of -29.1.1%, which means a late spring (L). The second value of the index was 262.9°C, which means a normal spring. The positive deviation of this general mean of the spring arrival index for the spring in question (2003) reached 7.1%, which means a normal spring, in fact, the single normal spring of the entire interval. For Oltenia, as well as for the entire country, the decade 2000-2010 was warm. It stands out through – the warmest winters, which also registered the highest frequency, the earliest springs, the hottest summers with the more extended dog days' periods, the exceeding of certain absolute thermal maximum values in the country, some of them considered real "climatic thresholds", all induced by the climate variation limits of the end of the 20th century and the beginning of the 21st century. The predominance of early springs represent a proof of the regional climatic changes during this interval.

.**Keywords:** *spring arrival indexes, spring arrival criterion, spring arrival conditions, early springs, climatic risk of early spring arrival*

Rezumat. Indici de împrimăvărare în perioada 2000-2010 în Oltenia

În prezenta lucrare sunt studiate condiţiile de împrimăvărare în Oltenia în intervalul 2000-2010. O primă evaluare generală o putem face comparând indicii medii generali pentru întreaga regiune Oltenia din fiecare primăvară, care se obţin ca medie a indicilor de împrimăvărare calculaţi la staţiile meteorologice din Oltenia, inclusiv arealul de munte aferent Olteniei.

Din cei 11 ani luaţi în calcul, cea mai mică valoare a fost 181,1°C, înregistrat în primăvara anului 2003, care a urmat după cea mai rece iarnă (2002-2003) a acestui interval analizat (Bogdan, Marinică, Marinică, 2010) şi cea mai mare valoare a fost 499,4°C înregistrată în primăvara anului 2002 (care a urmat după iarna caldă 2001-2002, a cărei medie generală ocupă locul 9 în ierarhia crescătoare a mediilor generale de temperatură pentru anotimpul de iarnă în intervalul analizat).

Media generală a indicelui de împrimăvărare pentru cei 11 ani este 366,2°C cu o abatere procentuală pozitivă de 43,2%, care după un criteriu de tip Hellmann (întocmit de noi) arată că în întreg intervalul analizat primăverile au fost timpurii (Ti).

Abaterea negativă a celei mai târzii primăveri (2003) a fost de -29,1%, ceea ce înseamnă o primăvară târzie (T). A doua valoare a indicelui de împrimăvărare a fost de 262,9°C, adică o singură primăvară normală. Abaterea procentuală pozitivă a acestei medii generale a indicilor de împrimăvărare a acestei primăveri (2003) a fost de 7,1%, ceea ce desemnează o primăvară normală (N), singura primăvară normală din tot acest interval. Pentru Oltenia ca şi pentru întreaga ţară, intervalul 2000-2010 a fost cald în întreg ansamblul său, remarcându-se prin: cele mai calde ierni care au avut şi cea mai mare frecvenţă, cele mai timpurii primăveri, cele mai călduroase veri cu cele mai întinse perioade caniculare, depăşirea unor maxime termice absolute pe ţară şi la staţiile meteorologice, unele din acestea considerate ca adevărate „praguri climatice" impuse de limitele de variaţie ale climatului de la sfârşitul secolului al XX-lea şi începutul secolului al XXI-lea. Predominarea primăverilor timpurii reflectă o dovadă a schimbărilor climatice regionale remarcate mai ales în acest interval.

Cuvinte cheie: *indici de împrimăvărare, criteriu pentru împrimăvărare, condiţii de împrimăvărare, primăveri timpurii, riscul climatic al primăverilor timpurii.*

INTRODUCTION

Warming conditions are essential for vegetation development during the year. Generally, plants, animals, people, as well as the entire ecosystem are thermophilous. In case certain well-defined thermal standards are not reached, vegetation development is hardly possible or even entirely compromised. Food resources of a region depend on the good development of the vegetation and, in certain cases, the economic consequences are quite severe. Once climatic warming became a pregnant phenomenon, especially after 1990, early spring arrivals were more frequent due to the more intense and often penetrations of warm Mediterranean or tropical air in Romania (Bogdan and Marinică, 2009). Among the most affected regions were, of course, those located in the south and west of the country, where the frequency of western circulation, which bring warm and moist oceanic air, increased on the background of global warming.

DATA AND METHODS

In order to quantify the thermal conditions during spring, it was defined ***the spring arrival index as a sum of the mean daily positive values measured between the 1st of February and the 10th of April***.

In order to prove this situation, we have calculated the index of spring arrival (I) for each year and for the entire Oltenia, as well as its percentage deviation (Δ %) compared to the normal (N)[1], which allowed us the achievement of a Hellmann classification of different types of springs (Table no. 1).

We further render (Table no. 1) a type of Hellmann criterion made up by us for spring arrival index.

For Oltenia[2], as well as for the entire country, the interval 2000-2010 was entirely warm, and we mention some of the warmest winters, which also registered the highest frequency, the warmest summers with the most extensive and intense hot periods, when certain absolute thermal maximum values were exceeded at some meteorological stations. Certain values were considered real “climatic thresholds” induced by the variation limits of climate during the 20th century.

Table 1
Criterion of Hellmann type for the spring warming index

Deviation % compared to the normal I	Spring type	Abbreviation
≤-70	Excessively late	**EL**
-69,9…-50	Very late	**VL**
-49,9…-30	Late	**L**
-29,9…-10	Little late	**LL**
-9,9…+10	Normal	**N**
10,1…30,0	Little early	**LE**
30,1…50,0	Early	**E**
50,1…69,9	Very early	**VE**
≥70	Excessively early	**EE**

Some climatologists believe these values are hard if not impossible to be soon exceeded. Thus, we mention the absolute thermal maximum value for July, which was exceeded twice in only 7 years, while the previous record had been dating for 86 year (Marinică, 2006; Bogdan and Marinică, 2007). We shall further analyse the early spring warming between 2000 and 2010 within Oltenia.

We may render a *first general evaluation* by comparing the general mean indexes for the entire Oltenia for each spring, which can be obtained as an average of the spring warming indexes calculated for each year at all the meteorological stations from the region, including the mountainous area (Table no. 2, Fig. no. 1).

We notice that out of the 11 studied years, the lowest value was 181.1°C, registered in the spring of 2003 (Table no. 2), which followed a cold winter (2002-2003) (Bogdan et al., 2010), while the highest value reached 499.4°C in the spring of 2002 and it was registered after a warm winter 2001-2002 (the general average is the 9th in the increasing hierarchy of the general winter temperature means of the analysed interval[3]).

The general mean of the spring arrival index for the 11 years is 366.2°C, with a positive percentage deviation of 43.2%, which, according to the criterion proposed by us, indicate that all the springs were early (E) (Table no. 2). The negative deviation of the latest spring (2003) was -29.0%, which means a late spring (L) according to the aforementioned criterion. The second value of the

[1] It was considered normal (N) the value obtained through the mediation of spring warming indexes for the interval 1901-1990 (we had archive data for this interval). The annual value of the spring warming index for each station comes from the sum of the positive daily mean temperatures for February, March and the first decade of April, and the general annual value represents the mean of the annual values registered at all the stations in the region.

[2] region located in southwestern Romania

[3] The hierarchy of the winters from the interval 1999-2000 – 2009-2010, according to the increasing values of the mean temperature for the entire region is: 2002-2003, 2009-2010 2005-2006, 2008-2009, 2003-2004, 2007-2008, 1999-2000, 2004-2005, 2001-2002, 2000-2001, 2006-2007 (Bogdan, Marinică, Marinică, 2010).

  DOI: 10.5775/fg.2067-4635.2011.030.i

spring warming index was 262.9°C for the spring of 2005, registered after the winter 2004-2005, the general mean of which is the 8th in the increasing hierarchy of winter temperature means. 2005 is also one of the rainiest years in the history of meteorological observations from Romania.

Table 2
Hierarchy of spring arrival indexes (°C), general average values for the entire Oltenia region[4].

Hierarchy	Year	Index	N	Δ°C	Δ%	T
1	2003	181.1	255.8	-74.3	-29.0	L
2	2005	262.9	255.8	7.1	2.7	N
3	2006	300.0	255.8	44.2	17.3	LE
4	2004	331.3	255.8	75.5	29.5	LE
5	2010	339.3	255.8	83.5	32.6	E
6	2009	360.0	255.8	104.2	40.7	E
7	2000	408.1	255.8	152.3	59.5	VE
8	2001	421.8	255.8	166.0	64.9	VE
9	2008	453.5	255.8	197.7	77.3	EE
10	2007	471.4	255.8	215.6	84.3	EE
11	2002	499.4	255.8	243.6	95.2	EE
Average		366.3	255.8	110.5	43.2	E

Source: Processed data

The percentage deviation of this general mean of the spring warming index (2005) was 2.7%, which according to our criterion, indicates a normal spring (N), *the only normal spring during the analysed interval*.

DISCUSSIONS

1. The spring of 2000

2000 marked, in Oltenia as well as in the entire country, *the appearance of intense heat waves and extended canicular periods.*

The hot summer came after an early spring – the arrival index is the 7th in the increasing hierarchy for the analysed period in Oltenia (Table no. 2). The winter 1999-2000 was also warm and, according to the general mean, it is the 7th in the increasing hierarchy.

[4] Index = index of spring arrival, namely the sum of the positive daily mean temperatures from the interval February 1 – April 10 (∑T°C) (http://www.meteoromania.ro/); N= multiannual mean of the spring warming index for the interval 1901-1990; Δ°C= deviation of the spring warming index (positive or negative) expressed in °C compared to the normal (N), namely (I-N); Δ%= The same deviation in % from the normal (N); Type see Table no. 1. From Table no. 2, it results: 1 late spring; 1 normal; 2 little early; 2 early; 2 very early and three exceptionally early. On the whole, in Oltenia, springs were early (E). T= Type of spring.

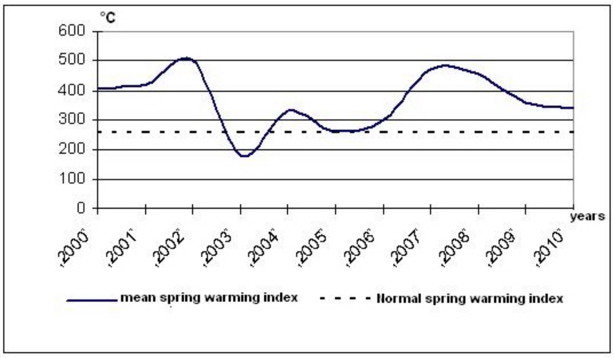

Fig. 1 Variation of the mean spring arrival index in Oltenia between 2000 and 2010

The general mean of spring arrival index for the entire Oltenia was 408.1°C and its deviation compared to the general multiannual mean was positive, respectively 59.5%, which make us classify this spring as very early (VE) (Table no. 2). The warming indexes calculated for the meteorological stations from Oltenia varied between *264.0°C at Voineasa* and *574.3°C at Calafat*; their percentage deviations compared to the multiannual mean values oscillating between 102.8% at Polovragi and 230.4% at Calafat. Within most of the region, this spring was excessively early (EE). In the mountainous area, spring warming was also excessively early with deviations between 119.0% at Ob. Lotrului and 253.9% at Parâng.

Following the percentage share of the temperature sum of each month that express the percent of the arrival index achieved in the respective month at each station, one may notice that the highest rate of the early arrival corresponds to March. For each month the rapport was: in February, it oscillated between 14.0% at Voineasa and 26.9% at Calafat; in March, it varied between 42.0% at Polovragi and 48.5% at Bâcleș, and the mean daily positive temperatures registered in the first decade of April contributed to the achievement of values of 26.5% at Calafat and 39.2% at Polovragi.

According to Hellmann criterion, *February* was warm (W) with deviations of the monthly means between 1.8°C at Voineasa and 4.3°C at Calafat. March was warmish (Ws) with deviations of the monthly mean values between 0.3°C at Voineasa and 2.2°C at Calafat compared to the normal, while April was warm (W), registering deviations of 1.4°C at Ob. Lotrului and 3.4°C at Calafat.

2. The spring of 2001

The spring of 2001 was very early (VE) and the general mean of the spring arrival index reached 421.8°C, occupying the 8th place in the increasing hierarchy for the analysed period.

DOI: 10.5775/fg.2067-4635.2011.030.i

Warming thermal conditions in 2001

The positive deviation of the general mean compared to the general multiannual mean (N) was 166.0°C, namely 64.9%, which allows us to consider it as very early (VE). The values of the warming indexes at the meteorological stations from Oltenia oscillated between 308.6°C at Voineasa and 515.2°C at Calafat.

The positive deviations of spring arrival indexes compared to the multiannual means varied between 42.3% at Bechet and 99.7% at Voineasa.

Spring arrival was excessively early (EE) at 8 of 17 meteorological stations (including Ob. Lotrului) (47.1%), very early (VE) at 5 stations, and early (E) at 4 stations, namely 23.5%.

Within the mountainous area, the positive deviation of the spring arrival indexes was 81.5°C at Ob. Lotrului and 88.1°C at Parâng, what in percentage terms means deviations of 407.5% and, respectively, 383.0%.

The sum of the positive daily mean temperatures in February oscillated between 81.2°C at Rm. Vâlcea and 114.8°C at Dr. Tr. Severin and the percentage of these sums of the spring arrival index varied between 13.0% at Apa Neagră and 22.5% at Dr. Tr. Severin, the mean of this month reaching 14.3% for the entire Oltenia. According to Hellmann criterion, February 2001 was warm (W) within the entire region except for the mountain area where it was warmish (Ws). The sums of the positive daily mean temperatures in February are comparable to the ones registered in the first decade of April.

The sum of the positive daily mean temperatures in March oscillated between 207.6°C at Voineasa and 315.3°C at Calafat. The percentage share of these sums to the spring warming index was comprised between 56.0% at Dr. Tr. Severin and 68.1% at Parâng, the mean for the entire Oltenia being 61.3%. March 2001, according to Hellmann criterion, was warm (W) in the entire region.

The sum of the positive daily mean temperatures in the first ten days of April was 94.7°C at Polovragi and 119.0°C at Apa Neagră. The percentage of these sums to the warming index varied between 21.5% at Dr. Tr. Severin and 32.7% at Voineasa, while in the mountainous area it was 31.9% at Ob. Lotrului and 40.9% at Parâng

According to Hellmann criterion, April was thermally normal within the entire Oltenia.

We may conclude that the sums of the positive daily mean temperatures were preponderant for the spring warming index.

3. The spring of 2002

The general mean of the spring arrival index was 499.4°C, the highest value registered in the analysed interval. The deviation compared to the general multiannual mean (N) was of 243.6°C, namely 95.2%, which means it was an exceptionally early spring (EE), the highest deviation of the analysed interval.

The sum of the positive daily mean temperatures in February 2002 oscillated between 30.4°C at Voineasa and 211.8°C at Calafat, the highest of the analysed interval. The percentage share of these sums to the spring arrival indexes calculated for each meteorological station varied between 30.1% at Tg. Jiu and 38.3% at Polovragi.

According to Hellmann criterion *February 2002* was very warm (VW) in the entire region and the positive deviations of the monthly mean values compared to the multiannual values varied between 5.3°C at Tg. Logreşti and Apa Neagră and 7.6°C at Drăgăşani (Bogdan, Marinică, Marinică, 2010).

The sum of the positive daily mean temperatures in March 2002 were between 207.6°C at Polovragi and 319.4°C at Calafat, the highest of all March months of the interval 2000-2010. The percentage share of these sums to the spring arrival indexes were comprised between 51.0% at Polovragi and 55.6% at Tg. Jiu; in the mountains, it varied between 53.5% at Voineasa and 62.4% at Ob. Lotrului.

According to Hellmann criterion, *March 2002* was warm (W) and the positive deviations of the monthly means to the multiannual monthly means were of 2.7°C at Voineasa and 4.8°C at Drăgăşani.

The sum of the positive daily mean temperatures in the first decade of April 2002 varied between 57.4°C at Voineasa and 84.5°C at Craiova; the percentage of these sums to the spring arrival index oscillated between 10.8% at Polovragi and 14.8% at Craiova.

According to Hellmann criterion, *April 2002* was thermally normal (N) within the entire region. The deviations of the monthly means compared to the multiannual values were negative, most of them registering -0.9°C and -0.3°C.

4. The spring of 2003

It was a late spring (L) and the *mean of spring arrival indexes* registered the lowest value of the analysed interval, 181.1°C, with a negative deviation of -74.3°C, namely -29.0% (Table no. 2).

The spring of 2003 came after the coldest winter of the interval (Bogdan, Marinică, Marinică, 2010), the general mean value of which for the entire Oltenia was -1.3°C.

  DOI: 10.5775/fg.2067-4635.2011.030.i

It is worth mentioning that after this late spring, at the European level, it followed a canicular summer called by the climatologists from Western and Central Europe "killer summer" due to the extreme intensity of the heat waves that generated an impressive number of casualties in July and August. It marked a rapid passage from a cool or even cold weather to an excessively hot one.

Spring arrival conditions

Spring arrival indexes oscillated between 133.5°C at Voineasa and 244.4°C at Dr. Tr. Severin, while the deviations compared to the multiannual mean values were all negative (except for one settlement). They were between -113.0°C at Dr. Tr. Severin and 5.4°C at Apa Neagră.

February 2003 was cold (C) within the entire region (Bogdan, Marinică, Marinică, 2010) and the negative deviations of the monthly temperatures oscillated between -4.5°C at Apa Neagră and -3.5°C at Dr. Tr. Severin, Băileşti, and Rm. Vâlcea.

Consequently, just a few mean daily values were positive and their sum for the entire month was between 0.0°C at Bâcleş, Voineasa, Ob. Lotrului, and Parâng and 4.2°C at Apa Neagră. The percentage share of the positive mean monthly temperatures was insignificant – 0.0% at Bâcleş, Voineasa, Ob. Lotrului, and Parâng and 2.0% at Tg. Logreşti.

March 2003 was also cold within most of the Oltenia, except for some reduced areas located in the south-west and the Subcarpathian Depression Tg. Jiu-Câmpu Mare, where it was normal (N). The negative deviations of the mean monthly temperatures oscillated between -1.9°C at Craiova and -0.5°C at Tg. Logreşti and Tg. Jiu. The sum of the positive daily mean temperatures were the lowest of the analysed interval and varied between 79.6°C at Polovragi and 167.2°C at Dr. Tr. Severin. Their percentage share to the spring arrival index were between 62.0% at Craiova and Caracal and 69.1% at Bâcleş. Within the mountainous area, these percentages varied between 66.6% at Voineasa and 92.5% at Ob. Lotrului. We conclude that the monthly sums of the positive daily mean temperatures essentially contributed to the achievement of the spring arrival indexes.

April 2003 was cold within most of Oltenia, except for some reduced areas located in the south and the Subcarpathian Depression, where it was normal.

The sums of the positive daily mean temperatures during the first decade of the month varied between 44.6°C at Voineasa and 79.1°C at Calafat, while their percentage share to the spring arrival indexes were between 29.7% at Apa Neagră and 37.7% at Craiova and Caracal. Cold weather registered in winter prolonged during spring leading to the late development of the vegetation, including crops, as well as to the extension of dwelling heating.

5. The spring of 2004

The mean arrival index was 331.7°C, the 4th as value in an increasing hierarchy; the positive deviation compared to the normal (N) was 75.5°C, namely 29.5%, which means a little early spring (LE).

The spring arrival indexes calculated for the meteorological stations were between 264.1°C at Polovragi in the Subcarpathian Depression and 428.9°C at Băileşti, in the Oltenia Plain. *The deviations compared to the multiannual means* (N) were all positive and varied between 31.8°C at Dr. Tr. Severin and 135.1°C at Apa Neagră, while the percentage deviations oscillated between 8.9% at Dr. Tr. Severin and 77.0% at Voineasa.

In the mountains, spring arrival was excessively early (EE), registering high deviations from the normal, 119.0°C at Voineasa and 72.4°C at Ob. Lotrului.

Spring arrival conditions

February 2004 was warmish (Ws) within most of the region, with positive deviations oscillating between 1.0°C at Tg. Logreşti, Tg Jiu, and Rm. Vâlcea and 2.8°C at Calafat, except for the Oltenia Plain and Drăgăşani area, where it was warm (W) (Bogdan, Marinică, Marinică, 2010).

The monthly sums of the positive daily mean temperatures were between 19.2°C at Voineasa and 54.1°C at Calafat, while their percentage share to the spring arrival index oscillated between 6.9% at Bâcleş and 13.6% at Calafat, in the south-west of the region.

March 2004 was warmish (WS) within the entire region registering positive deviations of 0.7°C at Bâcleş (the only area where this month was normal form the thermal point of view) and 1.9°C at Calafat.

The monthly sums of the positive daily mean temperatures oscillated between 156.2°C at Polovragi and 271.5°C at Băileşti; the percentage shares of these sums to the spring arrival indexes were between 58.9% at Calafat and 63.3% at Băileşti. *In the mountainous area*, these shares were significantly greater and varied between 59.6% at Voineasa and 67.2% at Parâng. We notice again that March thermal regime decisively contributed to the achievement of arrival indexes.

DOI: 10.5775/fg.2067-4635.2011.030.i

April 2004 was thermally normal (N) in most of the region and warmish (WS) within the Subcarpathian Depression and in the mountains. The positive deviations were between -0.1°C at Rm. Vâlcea (the only exception!) and 1.3°C at Voineasa and Ob. Lotrului, and 1.4°C in the Parâng.

The sums of the positive daily mean temperatures during the first decade of the month varied between 86.5°C at Polovragi and 116.0°C at Caracal; the percentage shares of these months to the arrival indexes oscillated between 27.5% at Calafat and 33.3% at Voineasa.

6. The spring of 2005

The mean general index for Oltenia reached 262.9°C, namely the second value in the increasing hierarchy for the analysed period. Its positive deviation compared to the multiannual average of only +7.1°C, namely +2.8%, allows its classification as a normal spring (N), the only normal spring (Table no. 1). *Within the Oltenia Plai**n***, spring arrival varied from normal (N) to little late (LL), registering preponderantly negative percentage deviations from +17.1% at Dr. Tr. Severin to 8.0% at Caracal. *In the eastern part of the region* and in the hilly area, spring arrival was normal (N) to LE (LE). The percentage deviations oscillated between -4.0% at Tg. Jiu and 23.6% at Tg. Logreşti, mainly due tot the frequent thermal inversion phenomena from Oltenia, which are favoured by relief, types of circulations and pressure regime. *In the high mountainous area,* spring arrival was excessively early registering percentage deviations between 127.8% at Parâng and 244.0% at Ob. Lotrului.

It is worth mentioning that 2005 was the rainiest year in the history of meteorological observations and the excessively rainy period covered the interval April-September, the top corresponding to the summer months.

Spring arrival conditions in 2005

In February, the monthly sums of the positive daily mean temperatures varied between 13.1°C at Voineasa and 48.0°C at Rm. Vâlcea, while their percentage shares to the arrival indexes were between 5.6% at Băileşti and 16.8% at Rm. Vâlcea. According to Hellmann criterion, if taking into account the mean monthly temperature, February 2005 was cold (C) in the entire Oltenia. According to the monthly means registered at the meteorological stations, it was cool (Cl) only in the Subcarpathian area, while in the rest of the region it was cold. The deviations compared to the multiannual monthly means were comprised between -3.8°C at Băileşti and -1.0°C at Polovragi and Parâng, with only one exception, 0.6°C at Bâcleş.

*In March***,** the sums of the positive daily mean temperatures varied between 87.9°C at Voineasa and 182.5°C at Calafat; their percentage shares to the spring arrival index were between 47.4% at Voineasa and 62.7% at Calafat. *In the mountains,* these oscillated between 47.9% at Parâng and 61.5% at Ob. Lotrului.

In April, the monthly sums of the positive daily mean temperatures during the first decade of the month oscillated between 77.6°C at Polovragi and 102.5°C at Bâcleş; their percentage shares to the arrival indexes were between 30.5% at Calafat and 45.6% at Voineasa. In the ***mountain area,*** they were between 38.4% at Ob. Lotrului and 52.1% at Parâng.

7. The spring of 2006

The general mean of spring arrival indexes for the entire region was of 300.0°C, the third value in the increasing hierarchy for the analysed period; the percentage deviation was 17.3% which allows us to classify it as a little early spring (LE).

It was a rainy spring within whole Europe, with a rapid arrival following a winter with rich precipitation amounts, which brought to the registration of the highest discharge of the Danube (15,900 m^3/s at Baziaş on the 17^{th} of April, 2006) and to severe floods along its lower course.

Spring arrival indexes oscillated between 212.2°C at Voineasa and 357.2°C at Dr. Tr. Severin. *In the west of the Oltenia Plain*, spring arrival was normal, while in the *east and north,* it was little early (LE) to early (E), registering positive percentage deviations of 12.7% at Caracal and 37.7% at Voineasa. *In the mountains,* spring arrival was exceptionally early as it installed by the end of February.

Spring arrival conditions in 2006

According to Hellmann criterion, *February 2006* was thermally normal (N) within most of the region, except for certain areas located in the hilly region and the Subcarpathian Depression (Tg. Logreşti, Apa Neagră, Tg. Jiu) where it was cool (Cl); the deviations of the monthly means compared to the multiannual means were negative and oscillated between -1.6°C at Apa Neagră and Ob. Lotrului and -0.1°C at Polovragi and Parâng. *In the mountainous area,* it was normal at Parâng and cool at Ob. Lotrului.

The monthly sums of the positive daily mean temperatures in February were comprised between 27.4°C at Voineasa and 48.1°C at Drăgăşani, while

  DOI: 10.5775/fg.2067-4635.2011.030.i

their percentage shares to the spring arrival indexes oscillated between 10.2% at Tg. Jiu and 13.9% at Bâcleş, with a general mean value of 12.2% for the entire Oltenia.

According to Hellmann criterion, *March 2006* was normal in the entire region, registering deviations of the monthly mean temperatures comprised between -0.9°C at Voineasa and +0,8°C at Tg. Logreşti. *The monthly sums of the positive daily mean temperatures* oscillated between 93.1°C at Voineasa and 197.5°C at Dr. Tr. Severin. The percentage shares of these sums to the spring arrival indexes were between 43.9% at Voineasa and 55.3% at Dr. Tr. Severin.

April 2006, according to Hellmann criterion, was warmish (Ws) within most of the region, except for certain areas from the Oltenia Plain (Craiova, Cracal), the Subcarpathian Depression (Polovragi), and the mountains (Ob. Lotrului), where it was thermally normal (N). the deviations of the monthly mean values were comprised between 0.2°C at Polovragi and 1.4°C at Tg. Jiu. *The monthly sums of the positive daily mean temperatures* during the first decade varied between 91.7°C at Voineasa and 119.6°C at Băileşti, while their percentage shares to the spring arrival indexes were between 32.2% at Dr. Tr. Severin and 43.2% at Voineasa.

8. The spring of 2007

The general mean of spring arrival indexes was of 471.4°C, the 10th value in the increasing hierarchy for the analysed period, while the positive deviation compared to the multiannual mean reached 215.6°C, or 84.3%, which means an exceptionally early spring (EE).

Spring arrival indexes varied between 343.2°C at Voineasa and 580.7°C at Dr. Tr. Severin, while the deviations were all positive, comprised between 188.7°C at Voineasa and 267.2°C at Drăgăşani. Their percentage shares oscillated between 62.5% at Dr. Tr. Severin and 122.0% at Voineasa. According to the established criterion, the spring of 2007 was excessively early (EE) wihtin most of the Oltenia, except for the south-western part of the Oltenia Plain where it was very early (VE).

After a very dry January within most of the region, there followed *February and March that were exceptionally rainy*, then, *April very dry* (VD) in the entire region. During the last part of May, rains started again, then June and July were also very dry and exceptionally dry. The summer of 2007 was canicular, registering two heat exceptional waves in June and July (Bogdan, Marinică, 2007, 2008).

Spring arrival conditions in 2007

After Hellmann criterion, *February 2007* was warm (W) within the entire region, registering positive deviations of the monthly mean temperatures compared to the multiannual values that oscillated between 3.6°C at Tg. Logreşti and 4.9°C at Băileşti and Caracal. *The monthly sums of the positive daily mean temperatures* were between 85.1°C at Voineasa and 166.1°C at Băileşti, which represents the second place after February 2002. The percentage shares of these sums to the spring arrival indexes varied between 24.8% at Voineasa and 29.2% at Băileşti.

March 2007, according to Hellmann criterion, was warm (W) in the entire region, registering positive deviations of 2.2°C at Bâcleş and 3.3°C at Tg. Jiu. *The monthly sums of the positive daily mean temperatures* were comprised between 183.0°C at Voineasa and 298.2°C at Dr. Tr. Severin, while their percentage shares to the spring arrival indexes were between 48.9% at Calafat and 53.3% at Voineasa.

April 2007, according to Hellmann criterion, was warmish (WS) within most of the region, except for the extreme south-west and the east of the Oltenia Plain where it was warm (W) and normal at Tg. Logreşti, Polovragi, Voineasa, and Ob. Lotrului. The deviations of the monthly mean values compared to the multiannual values were between 0.5°C at Polovragi and Ob. Lotrului and 2.6°C at Calafat. *The monthly sums of the positive daily mean temperatures during the first decade* were comprised between 75.2°C at Voineasa and 126.5°C at Calafat, while their percentage shares to the achievement of the spring arrival indexes were between 20.9% at Tg. Logreşti and 23.5% at Polovragi.

9. The spring of 2008

The general mean of spring arrival indexes was of 453.5°C, the ninth value in the increasing hierarchy for the analysed period, while the positive deviation compared to the multiannual mean value was of 197.7°C, namely a percentage of 77.3%, which make us consider it an excessively early spring (EE).

Spring arrival indexes oscillated between 359.9°C at Voineasa and 558.7°C at Calafat; the deviations compared to the multiannual values were between 173.3°C at Rm. Vâlcea and 270.1°C at Apa Neagră, while the percentage ones, between 51.3% at Dr. Tr. Severin and 133.0% at Voineasa.

DOI: 10.5775/fg.2067-4635.2011.030.i

According to the criterion achieved by us, *spring arrival was very early* (VE) within the Oltenia Plain and certain areas of the Subcarpathian Depression (Tg. Jiu) and the Olt Couloir (Rm. Vâlcea) and *excessively early* (EE) within most of the region.

Spring arrival conditions in 2008

February 2008 was warm (W) in the entire region according to Hellmann criterion, while the deviations of the monthly mean temperatures were comprised between 2.4°C at Tg. Logreşti and 3.7°C at Calafat. *The monthly sums of the positive daily mean temperatures* were comprised between 80.1°C at Voineasa and 141.1°C at Dr. Tr. Severin, while their percentage shares to the spring arrival indexes varied between 19.0% at Caracal and 26.1% at Dr. Tr. Severin. *In the mountains,* these contributions were between 32.7% at Parâng and 39.3% at Ob. Lotrului.

March 2008 was warm (W) within the entire region according to Hellmann criterion and the deviation of the monthly mean temperatures varied between 2.1°C at Voineasa and 3.8°C at Bechet and Caracal. The monthly sums of the positive daily mean temperatures were comprised between 185.1°C at Voineasa and 298.8°C at Bechet. The percentage shares of these sums to the spring arrival indexes varied between 51.3% at Polovragi and 56.9% at Caracal.

April 2008 was warmish (WS) within most of the region, except for certain small hilly areas and parts of the Subcarpathian Depression where it was normal (N) (Tg. Logreşti, Tg. Jiu, and Apa Neagră).

The deviation of the monthly means compared to the multiannual values were comprised between -0.1°C at Polovragi and 1.7°C at Calafat. *The monthly sums of the positive daily mean temperatures during the first decade* were between 93.4°C at Polovragi and 124.7°C at Calafat, while their percentage shares to the spring arrival indexes were between 22.0% at Dr. Tr. Severin and 26.3% at Voineasa.

10. The spring of 2009

The general mean of spring arrival indexes reached 360.0°C, registering a positive deviation of 104.2°C, namely 40.7%, which signifies an early spring arrival (E).

The spring arrival indexes calculated for all the meteorological stations oscillated between 299.2°C at Polovragi and 419.8°C at Dr. Tr. Severin. The positive deviations compared to the multiannual mean values were between 62.4°C at Dr. Tr. Severin and 175.7°C at Apa Neagră, while the percentages oscillated between 17.5% at Dr. Tr. Severin and 99.5% at Voineasa. Consequently, the spring arrival was little early (LE) in the south-west and extreme south-east of the Oltenia Plain, early (E) in Băileşti Plain, Mehediţi Hills, and the north of Dolj County, as well as partially within the Subcarpathian Depression and the Olt Couloir at Rm. Vâlcea, very early (VE) within the hilly area of Gorj and Vâlcea conties, and excessively early (EE) within the Subcarpathian Depression, at the foot of the mountains and in the mountainous area.

Spring arrival conditions in 2009

February 2009 was thermally normal (N) within most of the region, according to Hellmann criterion, except for the extreme south-west of the Oltenia Plain where it was cold (C), at Calafat, and cool (Cl) at Bechet, as well as in certain parts of the Subcarpathian Depression (at Apa Neagră and Polovragi) and the mountainous area. The deviations of the monthly mean temperatures were comprised between -4.5°C at Calafat and Ob. Lotrului and 0.7°C at Voineasa (Bogdan, Marinică, Marinică, 2010). *The monthly sums of the positive daily mean temperatures* were comprised between 40.6°C at Voineasa and 75.5°C at Dr. Tr. Severin, while their percentage shares to the spring arrival indexes varied between 13.1% at Bâcleş and 18.0% at Dr. Tr. Severin.

March 2009 was warmish (Ws) within most of the region and thermally normal (N) within the Băileşti Plain, certain areas of the Subcarpathian Depression, Mehedinţi Hills, and in the submountainous and mountainous area (Voineasa). The deviations of the monthly mean vales compared to the multiannual temperatures were between 0.3°C at Voineasa and 1.3°C at Drăgăşani and Tg. Jiu. *The monthly sums of the positive daily mean temperatures* oscillated between 128.9°C at Voineasa and Polovragi and 222.6°C at Bechet, while the percentage shares of these sums to the spring arrival indexes varied between 41.8% at Voineasa and 53.4 at Bechet.

April 2009 was warmish (Ws) within most of the region and warm (W) in the areas of Drăgăşani, Tg. Jiu, and Voineasa, thermally normal (N) in the south-west and extreme south-east of the Oltenia Plain, Polovragi area in the Subcarpathian Depression. *In the mountains,* it was warmish at Ob. Lotrului and warm at Parâng. The monthly sums of the positive daily mean temperatures during the first decade varied between 126.7°C at Bechet and Polovragi and 149.7°C at Apa Neagră, registering percentage shared to the achievement

  DOI: 10.5775/fg.2067-4635.2011.030.i

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of the spring arrival indexes between 30.3% at Bechet and 45.0% at Voineasa.

11. The spring of 2010

The general mean of spring arrival indexes was of 339.3°C, the fifth value in the increasing hierarchy for the analysed period, while the percentage deviation compared to the multiannual mean value was of 30.0%, which make us consider it an little early spring (LE), at only 0.1% from the class E.

Spring arrival indexes varied between 259.3°C at Polovragi and 403.8°C at Dr. Tr. Severin. The positive deviations compared to the multiannual mean values oscillated between 36.9°C at Calafat and 132.9°C at Tg. Logreşti, while the percentage deviations between 10.7% at Calafat and 56.0% at Tg. Logreşti. Spring arrival was little early (LE) within most of the Oltenia Plain and the Subcarpathian Depression, early (E) in the east of Oltenia, Mehedinţi and Vâlcea Hills, very early (VE) partially within the Subcarpathian Depression, and excessively early in the mountains (EE).

Spring arrival conditions in 2010

February 2010 was cool (Cl) within most of the region, except for the south-west of the Oltenia Plain where it was cold (C), while at Tg. Jiu, Drăgăşani, Rm. Vâlcea, and Parâng, it was thermally normal (N). The deviations of the monthly means were negative and varied between -3.2°C at Bechet and -0.2°C at Parâng. *The monthly sums of the positive daily mean temperatures* were comprised between 40.7°C at Băileşti and 76.6°C at Rm. Vâlcea, while their percentage shares at the achievement of spring arrival indexes varied between 11.4% at Băileşti and 20.6% at Rm. Vâlcea.

March 2010 was cold (C) within most of the region, except for the extreme south-west of the Oltenia Plain (Calafat) where it was cool, as well as at Drăgăşani.

The deviations of the mean monthly temperatures were negative and varied between -1.3°C at Parâng and -2.8°C at Apa Neagră and Rm. Vâlcea.

In the interval March 6-12, the weather was cold characterized by snowfalls and blizzards which led to the formation of a thick snow cover and there were emitted yellow code warnings. *The monthly sums of the positive daily mean temperatures* were comprised between 187.4°C at Rm. Vâlcea and 220.5 at Dr. Tr. Severin, while their percentage shares between 50.5% at Rm. Vâlcea and 56.8% at Băileşti.

April 2010 was cold (C) within most of the region, except for a mall area in the south-west of the Oltenia Plain (Calafat, Dr. Tr. Severin), Drăgăşani and Rm. Vâlcea, where it was cool (Cl), while in the mountains, it was thermally normal. The deviations of the mean monthly values were negative and varied -3,6°C at Polovragi and -0,5°C at Parâng.

The monthly sums of the positive daily mean temperatures during the first decade oscillated between 80.3°C at Polovragi and 117.9°C at Dr. Tr. Severin, while the percentage shares to the achievement of the spring arrival indexes varied between 28.9% at Rm. Vâlcea and 32.0% at Caracal and Bâcleş.

In Fig. 2, we render the spatial distribution of the spring arrival indexes registered in the 11 analysed years.

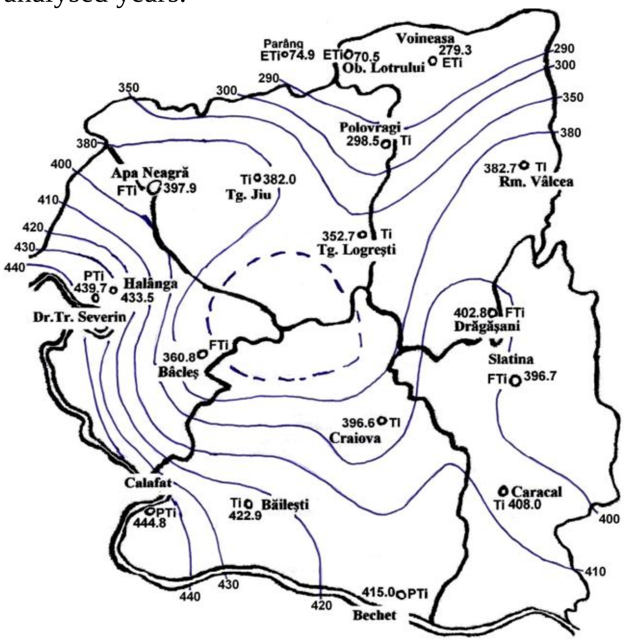

Fig. 2 Mean indexes of spring arrival for the interval 2000-2010

CONCLUSION

During the analysed period, there were registered 9 early spring of a total of 11, which emphasizes that the rate of early springs reached 81.8%, a normal one (9.1%), and a late one (9.1%).

Among these, two springs were little early (LE) namely 18.2%, two were early (E), namely 18.2%, two very early – 18.2%, and three excessively early – 27.3%. According to the general mean of the spring arrival indexes for the 11 studied years and its deviation from the multiannual mean, the entire period is classified in the category of early springs (E) (Table 3). The predominance of early springs might be a proof of the regional climatic changes we noticed especially in the last decade of the 20th

DOI: 10.5775/fg.2067-4635.2011.030.i

century and the first decade of the 21st century. We consider eloquent the values rendered in Fig. 3.

In the mountainous area, most of the spring arrival was excessively early, thus confirming climatic arrival in this region, which is more intense than in the low plain or hilly-plateau areas.

The territorial distribution of these indexes emphasizes the presence of an area in the south-west and south of Oltenia that registered the earliest springs (Fig. 2). This is a consequence of the intensification of the atmospheric circulation from the southern part of the continent, the Mediterranean Sea and Northern Africa; warm tropical Mediterranean or continental (Asian or North-African) air advections reach the south-west of Romania during the entire year, but especially in winter and spring.

They penetrate in Oltenia through the Danube Defile and the Timok Valley and are blocked by the orographical barrier of the Carpathians in the region, which triggers massive winter and spring arrival.

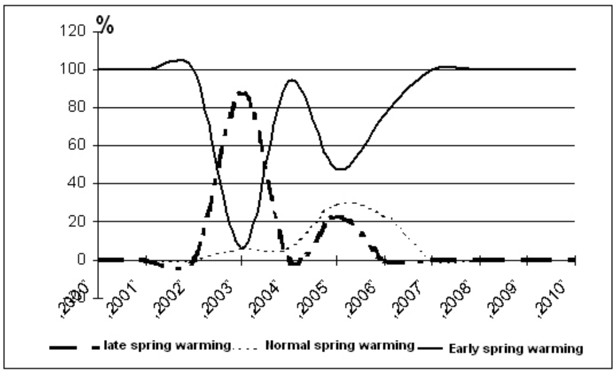

Fig. 3 Types of spring arrival according to the percentage values type/meteorological station of the indexes of spring arrival in Oltenia between 2000 and 2010

Spring arrival indexes decrease from south-west and south, northwards and north-eastwards, according to the direction of the landforms and altitude increase.

We remark the area located in the south of Gorj County, north of Dolj County, and west of Mehedinţi County (where the three counties neighbours each other) where there are achieved more reduced warming indexes, even if there are also registered excessively early springs in certain years, according to the deviations from the multiannual means.

The earliest spring was registered in 2002, followed according to the decreasing value of the general mean of the spring arrival indexes for the entire Oltenia, by the springs of 2007 and 2008.

The highest share to the achievement of the spring arrival indexes is represented by the sums of the positive daily mean temperatures registered in March, which makes it right to consider March as the first spring month.

For the achievement of the excessively early spring arrival, the sums of the positive daily mean temperatures registered in February had an important contribution.

Usually, *the first decade of April* is cold and there occur late hoarfrost by the end of the month. *Early, very early, and excessively early springs* were marked by the occurrence of cold or cool April months with sometimes quite intense hoarfrosts, which affected the already developed vegetation and produced important damages.

Early springs generally occurred after warm winters and thus, they came as a prolongation of the warm weather registered in winter.

Late or normal spring arrival occurred after cold winters.

During the cold or cool April months, vegetation, even if it is well developed, stagnates and it occurs its gradual deterioration, especially in the case of vegetables, orchards, and vineyards. Even if the hoarfrosts are not severe, low temperatures registered during the cold nights or even during the cold or cool days, hinder the fecundation processes at fruit-trees leading to extremely reduced fruit productions. This is why, we may consider *early spring arrival a climatic risk*.

During excessively early spring arrival, there were registered dry April and May months, which badly damaged agricultural crops and vegetal cover.

Spring arrival conditions are essential for the good development of crops during the entire agricultural year.

If spring arrival is early, all crops start the vegetation period in March or even February, and these discrepancy usually maintains during the entire agricultural year; in certain situations, cold weather registered in April reduces these differences, but it negatively affects vegetation.

If spring arrival is late, all crops start the vegetation period late and, in some cases, only in May the differences reduce, but, there are years when the differences are quite clear during the entire agricultural year, and the weather early cooling registered in autumn affect the crops that do not reach their maturity phase.

Our conclusions regarding the types of spring warming are well correlated with the monthly types of weather for the spring resulted after applying Hellmann criterion, which indicates the accuracy of our criterion for rendering the types of spring arrival.

  DOI: 10.5775/fg.2067-4635.2011.030.i

Table 3 Spatial-temporal distribution of the types of spring arrival

Meteorological Station	Hm	Year and types of spring arrival											No cases			% types		
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	cL	cN	cE	cL%	cN%	cE%
Dr. Tr. Severin	77	E	E	VE	L	N	LL	N	VE	VE	LE	LE	2	2	7	18.2	18.2	63.6
Calafat	66	VE	E	EE	LL	LE	LL	N	VE	VE	LE	LE	2	1	8	18.2	9.1	72.7
Bechet	65	VE	E	EE	L	LE	LL	N	VE	VE	E	LE	2	1	8	18.2	9.1	72.7
Băileşti	56	VE	E	EE	L	E	LL	N	EE	VE	E	LE	2	1	8	18.2	9.1	72.7
Caracal	112	VE	VE	EE	L	E	N	LE	EE	VE	LE	LE	1	1	9	9.1	9.1	81.8
Craiova	190	VE	VE	EE	L	LE	N	LE	EE	EE	E	LE	1	1	9	9.1	9.1	81.8
Slatina	165	EE	EE	EE	LL	E	LE	LE	EE	EE	E	E	1	0	10	9.1	0.0	90.9
Bâcleş	309	EE	EE	EE	L	LE	LE	LE	EE	EE	E	E	1	0	10	9.1	0.0	90.9
Tg. Logreşti	262	E	VE	EE	LL	E	LE	LE	EE	EE	VE	VE	1	0	10	9.1	0.0	90.9
Drăgăşani	280	EE	EE	EE	LL	E	LE	LE	EE	EE	VE	E	1	0	10	9.1	0.0	90.9
Apa Neagră	250	EE	EE	EE	N	VE	LE	E	EE	EE	EE	VE	0	1	10	0.0	9.1	90.9
Tg. Jiu	210	E	VE	EE	LL	LE	N	LE	EE	VE	E	LE	1	1	9	9.1	9.1	81.8
Polovragi	546	E	EE	EE	L	LE	N	LE	EE	EE	E	LE	1	1	9	9.1	9.1	81.8
Rm. Vâlcea	243	E	VE	EE	L	LE	N	LE	EE	VE	E	LE	1	1	9	9.1	9.1	81.8
Voineasa	587	EE	EE	EE	LL	EE	LE	E	EE	EE	EE	-	1	0	9	10.0	0.0	90.0
Ob. Lotrului	1404	EE	EE	EE	EL	EE	EE	EE	EE	EE	EE	-	1	0	9	10.0	0.0	90.0
Parâng	1585	EE	EE	EE	LE	EE	EE	EE	EE	EE	EE	EE	0	0	11	0.0	0.0	100.0
Oltenia (average)		VE	VE	EE	L	LE	N	LE	EE	EE	E	E	1	1	9	9.1	9.1	81.8
CL(No cases**)**		0	0	0	15	0	4	0	0	0	0	0	19	11	155	10.3	5.9	83.8
CN(No cases**)**		0	0	0	1	1	6	4	0	0	0	0						
CE(No cases**)**		**17**	**17**	**17**	**1**	**17**	**8**	**14**	**17**	**17**	**17**	**17**						
C**L**%		0.0	0.0	0.0	88.2	0.0	23.5	0.0	0.0	0.0	0.0	0.0	10.3					
C**N**%		0.0	0.0	0.0	5.9	5.9	29.4	23.5	0.0	0.0	0.0	0.0	5.9					
C**E**%		100.0	100.0	100.0	5.9	94.1	47.1	76.5	100.0	100.0	100.0	100.0	83.8					

*Source: Processed data (*Types of spring warming: *cL=class of late spring warming*= EL+VL+L+LL; *cN=class of normal spring warming*, namely the number of cases with normal spring warming N; *cE=class of early spring warming*=LE+E+VE+EE*)*

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 140-148
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.032.i

The Climatic Water Deficit in South Oltenia Using the Thornthwaite Method

Carmen-Sofia DRAGOTĂ[1], Monica DUMITRAŞCU[1], Ines GRIGORESCU[1], Gheorghe KUCSICSA[1]
[1]Institute of Geography, Romanian Academy, Physical Geography Department, 12 Dimitrie Racoviţă street, 023993 Sector 2, Bucharest, Romania, e-mail: igar@geoinst.ro

Received on < February 7, 2011>, revised on <March 16, 2011>, accepted on <April 25, 2011>

Abstract

Understanding the dryness and drought phenomena is fundamental in explaining the landscape features and the rational use of water resources in a region. The authors aim to assess the climatic water deficit (WD) in one of the most sensitive regions in Romania in terms of aridity: Southern Oltenia. Defining and characterizing the intense aridity was done based on the Thornthwaite method under a multi-annual regime (1961-2007) and during the growing season (April-October) in order to reveal the climate suitability for human activity and the optimum conditions for the main crops. In southern Oltenia the Thornthwaite aridity index values (Iar-TH) (%) defines an arid area, increasing from north to south and south-west from 40-45% to 50%. The highest values displaying a pronounced aridity (Iar-TH ≥ 50%) cover a significant part of the Blahniţa Plain, Desnăţui Plain, Southern Romanaţi Plain (Dăbuleni Field), the Jiu Valley and the entire Danube Plain (about 65% of the entire surface).

Keywords: *climatic water deficit (WD), Thornthwaite Aridity Index (I_{ar}-TH), PET, South Oltenia, aridity and drought*

Rezumat. Deficitul de apă climatic în sudul Olteniei folosind Metoda Thornthwaite

Cunoaşterea fenomenelor de ariditate şi secetă sunt esenţiale atât în explicarea caracteristicilor peisajului cât şi în utilizarea raţională a resurselor de apă dintr-o regiune. Autorii îşi propun evaluarea deficitului de apă climatic (DEF) în unul dintre cele mai sensibile regiuni ale ţării în ceea ce priveşte ariditatea: sudul Olteniei. Definirea şi caracterizarea aridităţii ca intensitate s-a realizat pe baza valorilor obţinute prin metoda Thornthwaite atât în regim anual multianual (1961-2007), cât şi în perioada de vegetaţie (aprilie-octombrie) pentru a evidenţia favorabilitatea climatului pentru dezvoltarea în condiţii optime a culturilor agricole. În sudul Olteniei valorile indicelui de ariditate Thornthwaite (I_{ar}-TH) (%) definesc un domeniu arid, crescând dinspre nord spre sud şi sud-vest, de la 40-45% la 50%. Cele mai mari valori, exprimând o ariditate pronunţată (I_{ar}-TH ≥ 50%) acoperă o parte însemnată a Câmpiilor Blahniţei şi Desnăţuiului, sudul Câmpiei Romanaţiului (Câmpul Dăbuleni), luncile Jiului şi Oltului şi toată Lunca Dunării (cca. 65%).

Cuvinte cheie: *deficitul de apă climatic (DEF), Indicele de Ariditate Thornthwaite (I_{ar}-TH), ETP, sudul Olteniei, aridizare şi secetă*

INTRODUCTION

Water resources and quality are declining, thus representing a severely limiting factor, particularly jointly with the increasing aridity due to global warming predicted by climatic models and scenarios. These scenarios estimate that the drought will persist and increase in intensity in critical agricultural regions of Europe (especially in the southern and south-eastern regions) as well as in Asia, Africa and North America, regions that will suffer pronounced dryness, heat, water shortage and an increasingly reduced agricultural production (Păltineanu et al., 2007a, Păltineanu et al., 2009).

Current climate changes accepted by the international scientific community are supported by the analysis of already conducted long term observational data, which started in the late twentieth century. They are individualized through *significant thermal contrasts* and *increased precipitations* as well as by the *emergence in the probability of the occurrence of extreme events* such as: expanded intervals with temperatures characteristic for the warm and cold seasons, prolonged droughts, extreme heat and aridity phenomena, heavy rainfall, increased frequency of thunderstorms, etc. All of this induces discontinuities in the variability of climatic parameters in areas more or less extended, creating a large negative impact on the environment.

The latest IPCC Report on the change of key climatic parameters, based on observational data on a global scale and on various scenarios of possible future changes, reveals an accelerated transition to a warmer climate characterized by situations with extreme temperatures and frequent heat waves, excessive droughts, in some regions and heavy rainfall, in others etc. (IPCC, 2007).

Studies conducted in Romania, highlighting the drivers of global climate change, shows as major outcomes: increased air temperature, decreased precipitation, reduced access to drinking water, and ultimately the extended aridity during the crop growing season in the southern regions of Romania, having a great impact on agricultural production. Most arid regions of Romania (considered on a global scale under the Köppen climate classification) are generally in the south, southeast and east of the country (Marica and Busuioc, 2004; Păltineanu et al., 2007a, 2007b, 2009; Busuioc et al. 2010, Sandu et al., 2010).

Along with the general climate changes, climatic water deficit develop drought, aridity or even desertification phenomena which, according to the hierarchy of natural hazards conducted by Bryant, 1991, is ranked first, based on the territory it currently occupies, the evolution trend as well as human victims and material damages it causes. In our country, some regions were individualized, in terms of landscape features, as undergoing desertification: Dobrogea, Southern Oltenia, and Southern Moldova.

According to the climatic regionalization, Southern Oltenia falls in the climatic sector with Mediterranean influences developing thermal characteristics (> 10^{o}C) and precipitation (500-600 mm/year) specific for the plain areas in the south of the country.

DATA AND METHODS

The paper aims to determine the **climatic water deficit (WD)** in southern Oltenia using the ***Thornthwaite Method*** in order to reflect the climate suitability for human activity and for the optimal development of spontaneous vegetation and reference crops (wheat and maize).

When preparing the paper, climate data from the meteorological stations in the analysed area (Craiova, Caracal, Calafat, Băileşti) has been used, as well as from meteorological stations of Turnu Măgurele and Drobeta Turnu Severin, the adjacent area, seen as support stations. The observation period was 1961 - 2007. In order to define and characterize the aridity and the climatic water deficit in the analysed area the Thornthwaite Aridity Index values for the growing season (April-October) were depicted as it is considered the most affected by these restrictive climate characteristics. For identifying them the following have been analysed: air and soil temperature, relative humidity, saturation deficit, rainfall (annual amounts of precipitation, half-year period, seasonal, monthly, the maximum amount fallen in 24 hours, liquid and solid precipitation frequency), direction and wind speed (Fig. 1).

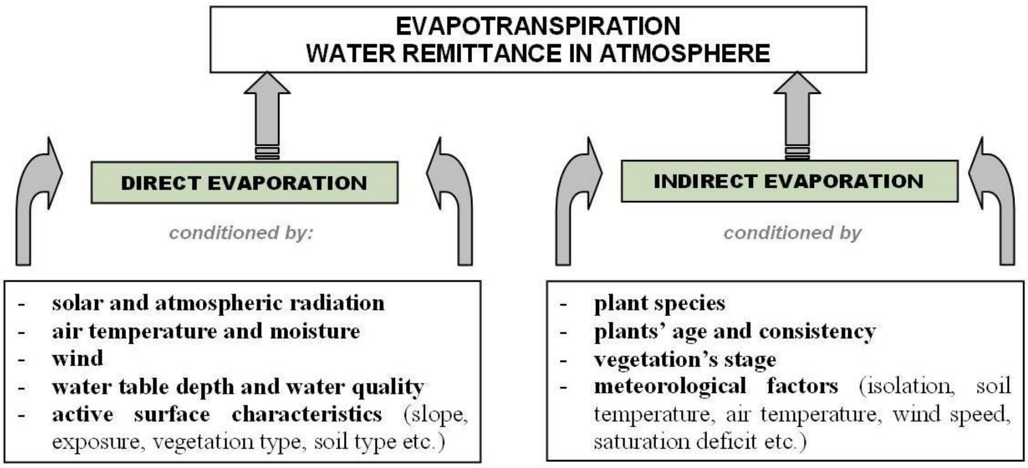

Fig. 1. The scheme of water remittance in atmosphere through evapotranspiration

When talking about climatic water deficit triggering aridity and drought, several factors are used, often based on air temperature, precipitation, potential evapotranspiration (PET), dominant wind direction and speed, solar radiation, vegetation type, soil water reserves, groundwater depth, etc. (Şerban, 2010). It is also the case of aridity indexes, which are taking into consideration one or more of these climatic parameters. In this relationship, a critical element is **precipitation** on which the parameter values and spatial distribution of drought and dryness largely depend. In the southern Oltenia, the annual mean precipitation values varies between 500-600 mm (Fig. 2), with a close variability ecart, having the mean annual amplitude of only 62.5 mm (the highest quantities being registered at Craiova meteorological station, and the lowest at Calafat).

DOI: 10.5775/fg.2067-4635.2011.032.i

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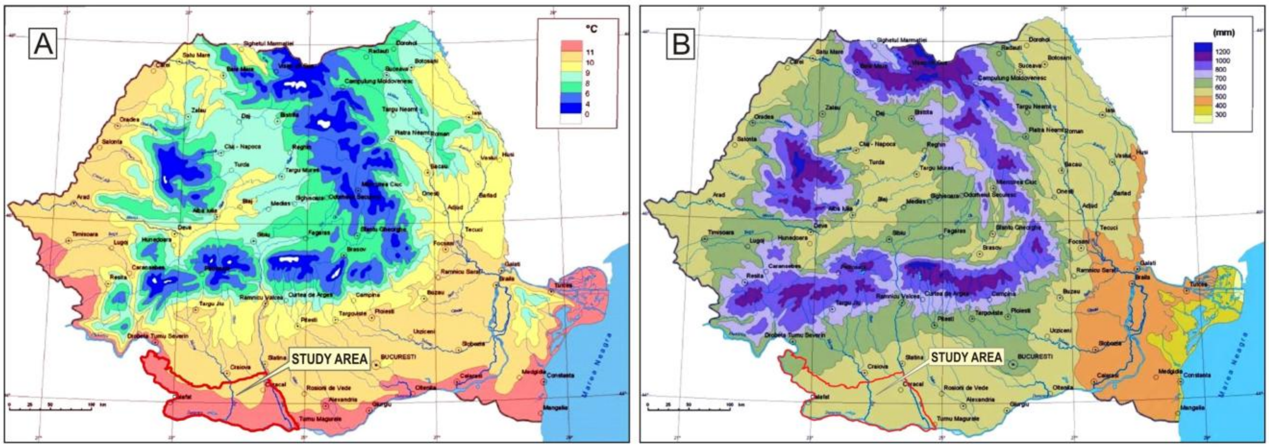

Fig. 2. Mean annual temperatures (A) and annual precipitation amounts (B) in Romania (1961-2000) (Sandu et al., 2009)

In the study-area, at all time scales (1961-2007), precipitation quantities generally increase westwards, so that at Drobeta Turnu Severin (located in the surrounding area) 667.2 mm are registered. During the growing season the mean monthly precipitation amounts are roughly similar in all the weather stations taken into consideration (Table 1), while May and June are the months when the maximum precipitation values are registered and October when the minimum rainfall is recorded (Dragotă, 2006).

The second meteorological element of interest in analyzing the soil water deficit and hence of the dryness degree specific for the Oltenia Plain, is the **air temperature** which oscillates around the 11°C on an annual regime. During the growing season it reaches around 17.5°C, scoring the maximum values in July when (22-23 °C) (Table 2). High temperatures and especially prolonged and intense heat waves may change dramatically the water balance by increasing the evapotranspiration thus favouring the intensity of drought. In addition, heat waves, which are increasing in the past 30 years, produce thermal stress to plants both in duration and intensity, inducing negative effects on crop development and production (Sandu et al., 2010).

Evapotranspiration is considered another key element in analysing climatic water deficit. It appears as a complex phenomenon, which represents the amount of water evaporated from the soil and that eliminated through transpiration by plants, registering different levels from one region to another, depending on different factors (Fig. 3).

This climatic parameter defines precisely the assembly of water losses through the two mentioned processes (evaporation and transpiration) initially determined empirically, based on climate data.

Table 1. Mean monthly and annual precipitation amounts in the South Oltenia (1961 - 2007)

Meteorological stations	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Reference meteorological stations													
Craiova	36.0	34.2	38.6	50.8	65.1	72.8	61.8	51.2	43.8	39.0	51.5	46.8	591.5
Caracal	34.4	33.0	38.3	46.6	58.9	68.1	62.8	52.2	38.9	36.3	45.0	41.7	555.1
Calafat	33.5	34.0	37.4	48.9	58.3	56.3	49.7	39.3	39.9	39.1	47.4	45.1	529.0
Băileşti	37.9	37.0	39.7	50.3	60.4	58.1	53.0	43.1	40.2	39.4	50.7	48.3	558.1
Support meteorological stations													
Turnu Măgurele	36.2	32.9	35.7	40.1	57.2	58.6	57.1	48.8	42.3	34.3	43.9	40.8	527.80
Drobeta Turnu Severin	46.9	44.6	46.6	61.5	71.7	67.6	60.5	44.2	47.8	50.8	59.3	65.6	667.2

Source: National Meteorological Administration database

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Table 2. Mean monthly and annual temperature in the south Oltenia (1961 - 2007)

Meteorological stations	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Reference meteorological stations													
Craiova	-1.8	0.4	5.1	11.3	16.8	20.3	22.4	21.8	17.2	11.3	5.1	-0.1	10.8
Caracal	-1.8	0.4	5.4	11.6	17.3	21.0	23.0	22.2	17.7	11.5	5.2	0.0	11.1
Calafat	-0.7	1.3	6.1	12.2	17.7	21.3	23.3	22.6	18.0	11.9	5.7	0.8	11.7
Băileşti	-1.4	0.7	5.7	12.0	17.7	21.1	22.9	22.2	17.5	11.3	5.1	0.2	11.3
Support meteorological stations													
Turnu Măgurele	-1.7	0.6	5.8	12.2	17.8	21.4	23.3	22.5	17.8	11.6	5.3	0.2	11.4
Drobeta Turnu Severin	-0.2	1.7	6.2	12.1	17.4	21.0	23.1	22.6	18.0	12.1	6.1	1.2	11.8

Source: National Meteorological Administration database

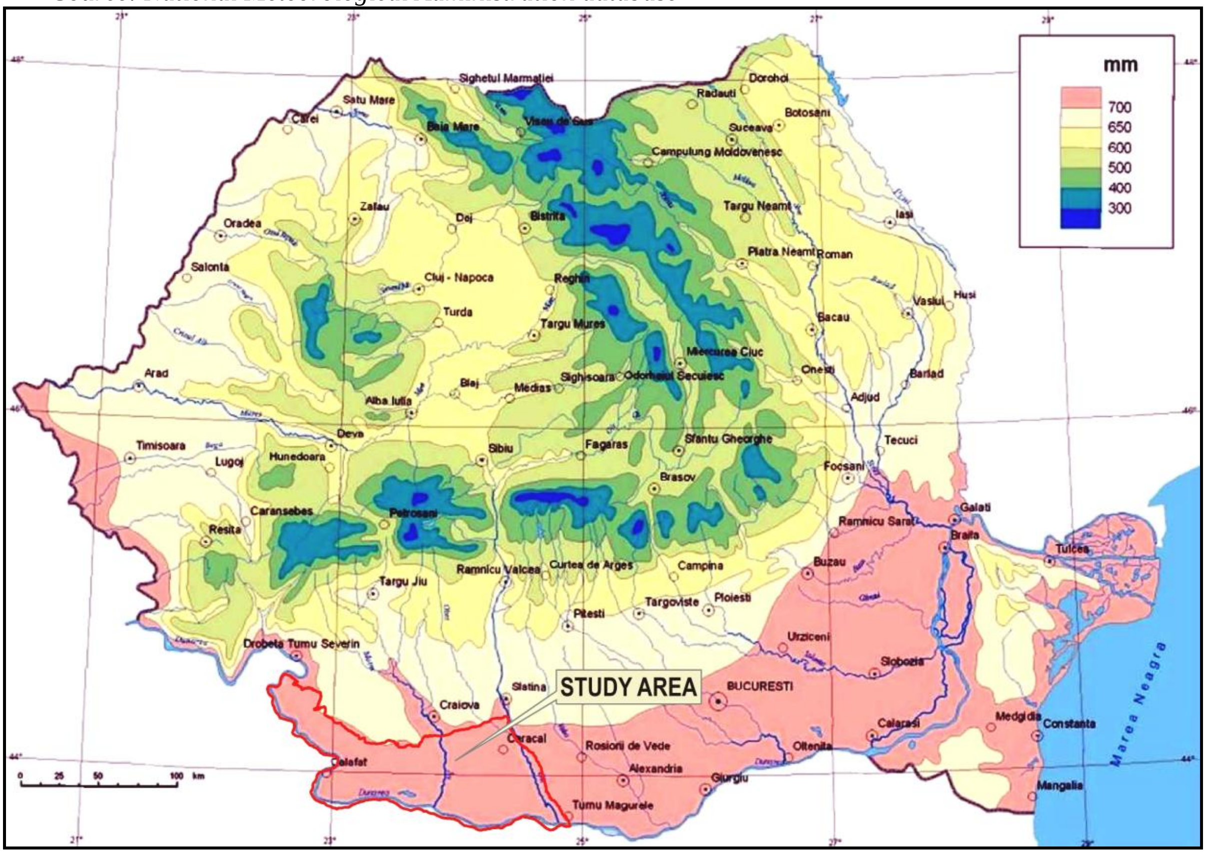

Fig. 3. Mean annual evapotranspiration (Thornthwaite) values in Romania (Sandu et al., 2009)

Subsequently, while the diversification of the application domains, different ways of calculating the potential evapotranspiration, have resulted.

Thus, at international level, many methods and formulas for calculating the potential evapotranspiration have been developed, based on one or more climatic factors aimed at being applicable in several areas: air temperature (Thornthwaite, Blaney-Criddle, Klatt, Holdrige), air saturation deficit (Aplatiev, Ivanov, Papadakis), several climatic factors (Turc) energy balance (Pennman, Bouchet), etc. (Păltineanu et al., 2007a; Sandu et al., 2009). The most broadly used method of calculating potential evapotranspiration in Romania is considered to be that of Thornthwaite (Păltineanu et al., 2009).

This parameter measures total water losses through evaporation and transpiration of a reference plant layer (generally grass), having a uniform height of several inches and supplied with plenty of water during the high growing season. It is calculated using the formula:

$$PET = 16 \cdot \left(\frac{10t}{I}\right)^a F(\lambda)$$

where:

t = mean temperature (ºC) for the considered period (month, decade);

I = annual thermal index

$$I = \sum_{n=1}^{12} i_n \;,\; i_n = \left(\frac{t}{5}\right)^{1.514} \quad = \textit{monthly thermal index}$$

$$a = 6.75 \cdot 10^{-7} \cdot I^3 - 7.71 \cdot 10^{-5} \cdot I^2 + 1.79 \cdot 10^{-2} \cdot I + 0.49$$

DOI: 10.5775/fg.2067-4635.2011.032.i

F(λ) = correction term according to latitude and month.

In the present paper, the authors also considered the Thornthwaite aridity index (1948) with the aim of highlighting the climatic water deficit in the South Oltenia, defining and characterizing the aridity extent. The index could be used both on an annual basis as well as for the growing season (April-October), using the formula:

$$\text{Iar-TH } (\%) = 100 \times \Sigma\,(P - PET)/\Sigma\, PET$$

Initially, on a global scale, the Thornthwaite humidity index was defined by the humidity classes (*description*) segmented by units (*criterion*) (Table 3).

Table 3. Thornthwaite aridity index classes and units on a global scale

Type	Description	Criterion
A	Perhumid	$I_{Th} > 100$
B_4	Very humid	$80 < I_{Th} \leq 100$
B_3	Highly humid	$60 < I_{Th} \leq 80$
B_2	Moderate humid	$40 < I_{Th} \leq 60$
B_1	Low humid	$20 < I_{Th} \leq 40$
C_2	Moist subhumid	$0 < I_{Th} \leq 20$
C_1	Dry subhumid	$-20 < I_{Th} \leq 0$
D	Semiarid	$-40 < I_{Th} \leq -20$
E	Arid	$-60 < I_{Th} \leq -40$

Source: Păltineanu et al., 2007a.

Compared to temperate latitudes and climatic conditions specific for Romania in terms of vegetation period (April-October) Iar-TH registers reformulated and adapted aridity classes (Monteith, 1965, Allen 1986, Allen et al., 1989, 1997, 1998, Jensen at al., 1990, Hargreaves, 1989, 1994, Hargreaves et al., 1985; Hattfield and Allen, 1996; Păltineanu et al., 2007b), as follows (Păltineanu et al., 2007a) (Table 4):

Table 4. Thornthwaite aridity index classes and units on a regional scale

Description	Criterion
Semitemperate	0-10
Semiarid	20-40
Arid	> 40

RESULTS AND DISCUSSIONS

In the south of Oltenia, the mean value of the Thornthwaite Aridity Index calculated for all meteorological stations taken into account expresses sharp changes regarding the generating climatic conditions for the period 1961-2007. On an annual regime, the Thornthwaite Aridity Index, ranked in the aridity classes, shows that 28.3% of the analyzed years fell in the *C1 Dry subhumid* class, with 1985, 1989, 1999, 2001, especially the consecutive years 1992-1994, standing out. Only two years 1983 and 2000 (4.3%) show annual values that fit in the *D semi-arid* class. Given that these values represent the average of the whole southern area of Oltenia, the result of the application of the Thornthwaite Aridity Index is significant (Fig. 4, A).

Regarding the vegetation period (April-October) the *D semi-arid* class feature is more pronounced (58.7%), highlighting drier summers in southern Romania. In this context, the moisture deficit highlighted by the Thornthwaite index is more relevant, as this feature is more dominant after 1983. Zero cases of aridity or hyper-aridity were registered, since the Thornthwaite index values for southern Oltenia are averaged (Fig. 4, B).

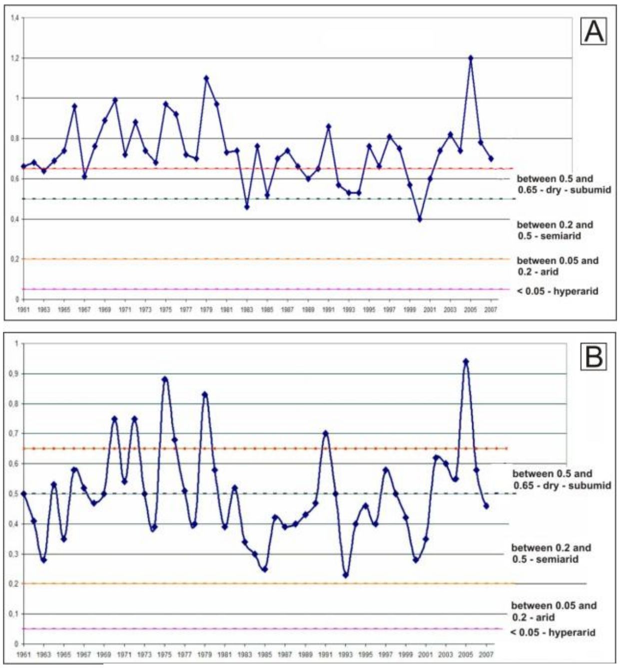

Fig. 4. Thornthwaite Aridity Index values on an annual basis (A) and for the vegetation period (April-October) (B) in South Oltenia

In southern Oltenia the Iar-Th delimits **arid** areas covered by an increase in the degree of aridity from north to south and south-west. In terms of subscribing to vegetation zones characteristic to the Romanian territory, the index values reveal an area with a humidity deficit at the contact between the steppe and forest steppe zone (Dumitraşcu, 2006).

The highest practical applicability of calculating the climatic water deficit and hence of the Thornthwaite aridity index in this predominantly agricultural region is linked to water consumption by crop plants. Thus, the distribution maps for both their growing season (April-October) and the main crops (wheat and maize) were developed.

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In the study-area, the ***maximum intensity of the Iar-TH*** ranges between 50-55 units covering most of Blahniţa, Desnăţui and Romanaţi Plains (Dăbuleni Field) extending to the floodplains and terraces of the Danube, Olt and Jiu Rivers (approx. 550,000 ha, making up 67.57% of the Oltenia Plain). Over 27% of the analysed area displays an Iar-TH of 45-50 units describing an intermediary step of vulnerability to dryness, covering about 230,000 ha in the northern Romanian Plain (Caracal Plain and the Leu-Rotunda Field), North of Segarcea, Blahniţa and Băileşti Plains. The lowest values of Iar-TH (40-45 units) are found at the contact area between the Getic and Mehedinţi Plateaus, only 5.27% of the studied area (Fig. 5).

Irrigation water requirements for the main crops is determined by direct experimental methods (some of which applied in the Oltenia Plain: Maglavit, Caracal, Gogoşu, etc.) and indirect experimental methods in relation to water requirements of plants that are in different phenological phases. Amid the broadly used indirect methods is the Thornthwaite method which defines the correction factors for different crops in soil and climate conditions spatially differentiated. Depending on each plant's phenophase specific for the vegetation period, these factors are essential in the irrigation process for estimating the actual water consumption. Thus, the **maximum real evapotranspiration** (ETC-est) value of major crops in South Oltenia (wheat and maize) is the main and most practical way of valorisation the Thornthwaite aridity index.

For ***wheat*** crops, during the growing season (May-June), ETC-est registers low variations for Romania, from 320-360 mm (Dobrogea, The Romanian Plain, the Moldova Plateau and Banat and Crişana Plains) decreasing to 300 mm in the Transylvania Plateau.

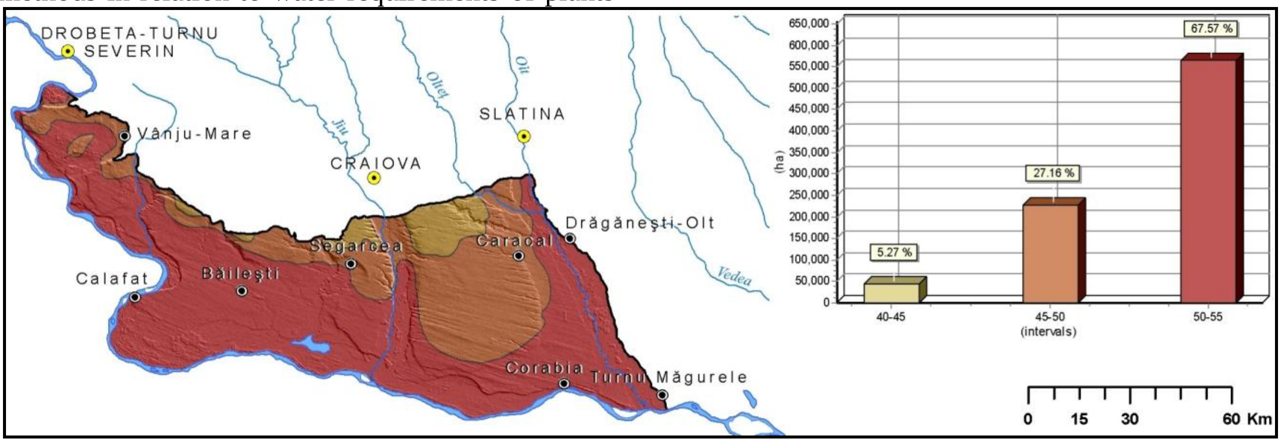

Fig. 5. Spatial distribution of the Thornthwaite (Iar – TH, % mm/mm) aridity index during the vegetation period (April – October) for the main crops in South Oltenia (processed after Păltineanu et al., 2007a)

In Oltenia Plain maximum water consumption values for the entire growing season reaches the highest values in the Danube Plain and in the southern Romanaţi (Dăbuleni Field) and Desnăţui Plains (Segarcea and Băileştiului Plains), reaching 360-370 mm. The values of this parameters decrease from the south, south-west to north, north-east, where in the northern area of Caracal and Desnăţui Plains they reach the lowest level (340-350 mm) (Fig. 6, A). On a national level, for ***corn***, ETC-est values fall in a relatively homogenous field in June, July and August with a maximum of 480-500 mm in Dobrogea and in the south-western extremity of the country, reaching high values (470-490 mm) in the southern Romanian Plain and Bărăgan Plain and increasingly low values (450-480 mm) in the rest of the Romanian Plain, south-east of Moldova and the Crişana and Banat Plains. Minimum values (400-450 mm) are found in Getic Piedmont, the Subcarpathians, the northwest of Moldavian Plateau and Transylvania Plateau.

In the Oltenia Plain, the highest values of ETC-east (500-520 mm) ware registered in the south-western part of the area largely overlapping the southern Desnăţui Plain and the Danube Floodplain. These values decrease to the north and north-east, where they reach 460-480 mm (northern part of Caracal and Desnăţui Plains) (Fig. 6, B).

For characterizing drought-related phenomena, estimating the **climatic water deficit (WD)** in southern Oltenia is compulsory for framing the study-area into a region with different degrees of aridity. The index is based on the relationship between precipitation (P) and potential evapotranspiration (Thornthwaite PET) under a formula agreed by the United Nations Environment Programme (UNEP). Unlike some drought indicators such as SPI (standardized precipitation

DOI: 10.5775/fg.2067-4635.2011.032.i

index), climatic water deficit has the advantage of a more accurate quantification of the water supply needed for a reference crop (Păltineanu et al., 2009).

The largest area of southern Oltenia is characterized by a climatic water deficit between -150 and -200 mm (approx. 60%) particularly noted for the most part of the Romanaţi and Desnăţui Plains. In their southern sectors, especially in the Danube Floodplain, the values of the deficit increase, reaching -200 up to -250 mm (about 20% of the entire analysed territory) and the intake of water required by crops is provided from the underground. In the northern part of the study-area the climatic water deficit is lower (from -100 to -150 mm) covering more than 20% of the territory (Fig. 7).

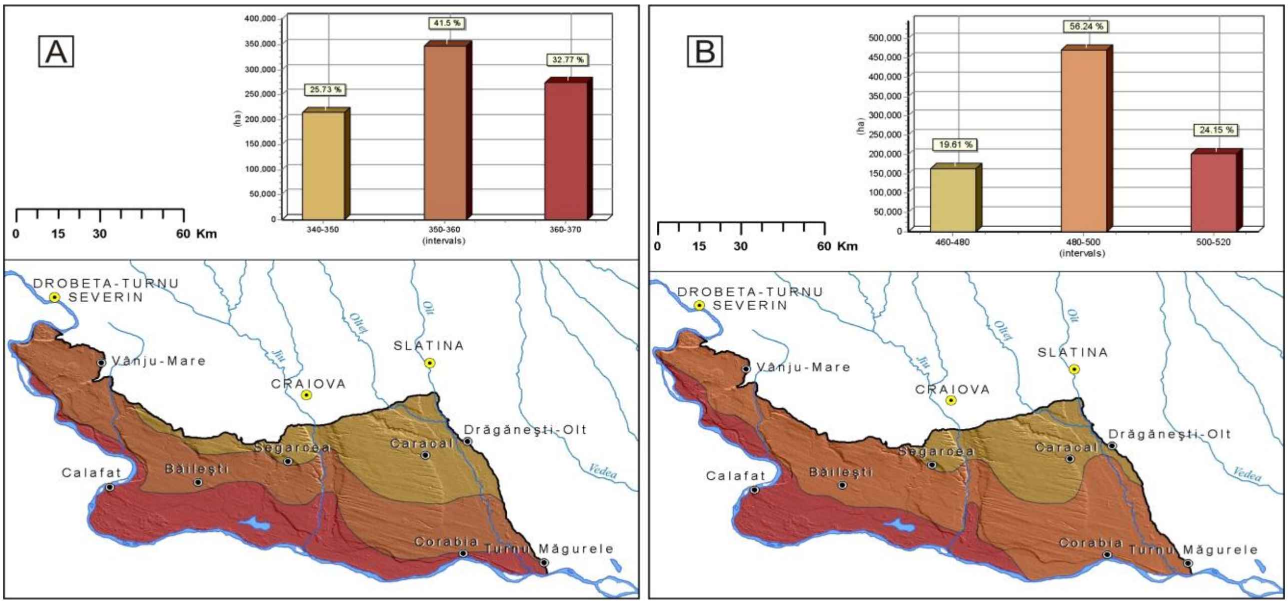

Fig. 6. ETc-est (mm) distribution for wheat (A) and maize (B) during the growing season in South Oltenia (processed after Păltineanu et al., 2007a)

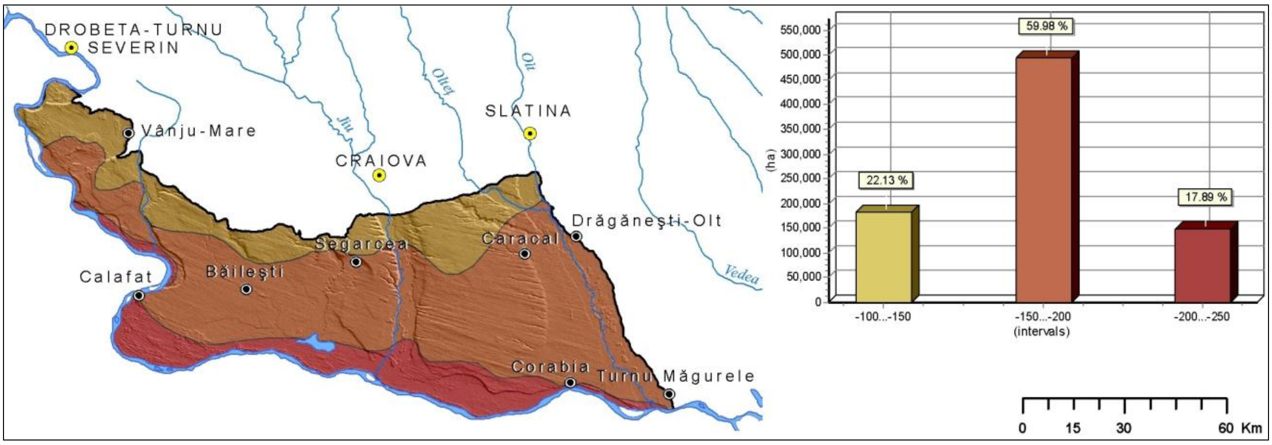

Fig. 7. Spatial distribution of mean annual climatic water deficit versus ET_0 – TH in South Oltenia (processed after Păltineanu et al., 2007a)

The analysis carried out on the climatic water deficit correlated with precipitation amounts for the main crops (wheat and maize) during the high growing season reveals several spatial and quantitative differences. Thus, one can notice that water deficit for wheat registers moderate values in June, since is also the month with maximum rainfall in southern Romania. For maize, however, the values of this agroclimatic parameter are higher, as they are calculated for the month of July, the month with maximum biological activity of this plant, overlapped on its thermal characteristics (maximum values during the year) (Table 5).

In terms of territorial distribution of climatic water deficit, the area best represented in southern Oltenia is the Danube Floodplain, while the northern and central parts of Desnăţuiului and Romanaţi Plains have mean or low values for both crops.

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Table 5. Water requirements and consumption parameters for the main crops during the high growing season in South Oltenia

Main crops	PP (mm)	WD (mm)	Spatial distribution
Wheat (June)	55-70	-50…-60	*Northern Blahniţa, Desnăţui and Romanaţi Plains*
		-60…-70	*Danube Floodplain (Calafat-Corabia Sector)*
Corn (July)	50-65	-70…-80	*Northern and Center Desnăţui and Romanaţi Plains*
		-80…-90	*Danube Floodplain (Drobeta Turnu Severin- Rast Sector)*

Source: National Meteorological Administration

CONCLUSION

The processing of *Thornthwaite aridity index* (annual and for the growing season) and *potential evapotranspiration (Thornthwaite method)* and its components were used in underling the climatic water deficit parameters in southern Oltenia. Based on these values one could frame the study-area into the category of regions most affected by restrictive climatic phenomena, especially aridity and drought, ranking it as second in this regard across the country (Table 6). Therefore, as main outcome, both the extent of natural vegetation and agricultural crops for the area under analysis depends primarily on the climatic water deficit, but also on the main environmental features of a certain region (Fig. 8).

Assessing drought-related indexes and indicators is fundamental in evaluating water deficit and water resources on local and regional scale in order to predict practical measures to control aridity and drought phenomena.

Table 6. Framing the study-area into the agricultural regions of Romania according to the climatic water deficit values (mm) in the growing season

Group	Regions
1	*Eastern Dobrogea*
2	*Western Dobrogea, Bărăgan and the South-Western part of Oltenia Plain*
3	*The South and East of the Romanian Plain and the South-East of Moldova*
4	*The Banato-Crişană Plain*
5	*The hilly extra-Carpathian regions*
6	*Transylvanian Plateau*

Processed after Păltineanu et al., 2007a.

Fig. 8. Aridity and drought related phenomena on sandy-soils in the Leu-Rotunda Field

The importance of estimating climatic water deficit would help forecasting its key components, improving agricultural decision making at the farm or policy level and ultimately assuming specific measures for adapting to climate variability and change (including extreme events).

ACKNOWLEDGEMENTS

The study was developed in the framework of the South-East Europe Transnational Cooperation Programme - *Climate Change and Impacts on Water Supply (CC-WaterS)* project coordinated by Viena City Hall, Austria (2009-2012) http://www.ccwaters.eu/. The project is considering as one of its main case-studies the South Oltenia region, overlapping almost entirely the Oltenia Plain.

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  DOI: 10.5775/fg.2067-4635.2011.032.i

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 149-156
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.033.i

Temperature – Humidity Index (THI) within the Oltenia Plain between 2000 and 2009

Alina VLĂDUŢ [1]

[1] Department of Geography, str. Al. I. Cuza, nr. 13, Craiova, Romania, vladut_alina2005@yahoo.com

Received on <December 15, 2010>, revised on <January 23, 2011>, accepted on <February 20, 2011>

Abstract

Temperature-humidity index, also known as thermal comfort index, represents an extremely used index in mass-media nowadays; it renders an apparent temperature, namely the temperature felt by human body that cools slower at higher values of the relative humidity due to the reduction of the evaporation rate. THI is calculated on the base of several formulas, which corroborate air temperature and relative humidity, the critical threshold being 80. By analysing the statistical date supplied by the Regional Meteorological Center Craiova, it comes out that the years with the highest number of days with THI values above 80 are 2000, 2001, and 2007 for the entire studied territory, when, during summer, the region was affected by numerous heat waves, which led to the frequent exceeding of the 40°C value. The most affected area is located in the central-southern and eastern parts of the Oltenia Plain – 51 days with THI > 80 at Caracal in 2000, 47 days with THI > 80 at Bechet in 2001, and 41 days with THI > 80 at Băileşti in 2007. Regarding the monthly distribution, the most problematic months are, of course, July and August, when it is favoured the penetration of certain extremely hot air masses from northern Africa, as well as thermal convection. During the analysed decade, the highest monthly number of days with values above the threshold was registered at Caracal in August 2000 – 23, at Bechet in August 2001 – 25, and at Băileşti in July 2007 – 20. On the whole, in the 10 analysed years, we remark Băileşti – 76 days in July and 90 in August, Bechet – 84 days in July and 83 in August, and Calafat – 77, respectively 70 days. Increased values of THI mainly affect children and elderly people or those suffering of different diseases. At values lower than 70 of the THI, most of the people feel comfortable, at values comprised between 75 and 80, about half of the population feels thermal discomfort, while at values above 80, even if the discomfort sensation is not obvious, it is recommended to take adequate protection measures.

Keywords: *temperature-humidity index (THI), comfort, discomfort, critical threshold, the Oltenia Plain*

Rezumat. Indicele de temperatură – umezeală (ITU) în Câmpia Olteniei în perioada 2000-2009

Indicele de temperatură – umezeală, cunoscut şi sub denumirea de indice de confort termic, reprezintă un indice foarte des vehiculat în mass-media în ultima perioadă; acesta redă o temperatură aparentă şi anume, cea resimţită de corpul uman, care se răceşte mai lent la valori mari ale umezelii relative, ca urmare a reducerii ratei de evaporare. ITU se calculează pe baza mai multor relaţii care coroborează temperatura aerului cu umezeala relativă, pragul critic fiind 80. Din analiza datelor statistice furnizate de Centrul Meteorologic Regional Craiova, reiese faptul că anii cu cel mai mare număr de zile în care s-a depăşit pragul de 80 unităţi sunt 2000, 2001 şi 2007 pentru întreg perimetrul analizat, când în perioada de vară regiunea a fost afectată de mai multe valuri de căldură, care au dus la depăşirea frecventă a valorii de 40°C. Arealul cel mai expus este cel situat în partea central-sudică şi estică a Câmpiei Olteniei – 51 zile cu ITU > 80 la Caracal în 2000, 47 zile cu ITU > 80 la Bechet în 2001 şi 41 zile cu ITU > 80 la Băileşti în 2007. Ca distribuţie lunară, lunile cele mai problematice sunt bineînţeles iulie şi august, când este favorizată atât pătrunderea unor mase de aer foarte cald dinspre nordul Africii, cât şi convecţia termică. Raportat la decada analizată, la nivel lunar, cel mai mare număr de zile în care s-a depăşit pragul critic s-a înregistrat la Caracal în august 2000 – 23, la Bechet în august 2001 – 25 şi la Băileşti în iulie 2007 – 20. Per total, în cei 10 ani analizaţi se remarcă Băileşti – 76 zile în iulie şi 90 în august, Bechet – 84 zile în iulie, respectiv 83 în august şi Calafat – 77 şi 70 zile. Valorile mari ale ITU afectează cu precădere copiii şi persoanele vârstnice sau cu diferite afecţiuni. La valori mai mici de 70 ale ITU, cele mai multe persoane se simt confortabil, la valori cuprinse între 75 şi 80, circa jumătate din populaţie resimte senzaţie de disconfort termic, iar la valori mai mari de 80, chiar dacă senzaţia de disconfort nu apare, se recomandă măsuri de protecţie adecvate.

Cuvinte cheie: *indice de temperatură-umezeală (ITU), confort, disconfort, prag critic, Câmpia Olteniei*

INTRODUCTION

Among different weather events, human body reacts to temperature changes in the attempt of adapting to the environment. High temperatures, as well as low temperatures have distinct effects on human health. During the warm season, but especially in the interval June-August, increased temperatures induced by the penetration of stagnant, warm air masses represent a significant public health problem in Romania, and especially in the south of the country. This problem will be exacerbated in the near future by the synergistic effects of a warming climate, urbanization, and an ageing population (Luber and McGeehin, 2008). According to different climatic models, it is estimated that summer mortality will increase, even if people acclimatize to high warmth (Kalkstein and Greene, 1997, p. 84). Consequently, in 2000, the National Administration of Meteorology (NAM) started to calculate the temperature-humidity index (THI) and to emit warnings for the population (yellow, orange and red alarm codes).

Common thermal indexes are based on different meteorological factors, such as air temperature, air humidity, air velocity, sunshine (Segal and Pilke, 1981). The THI is a bioclimatic index used to illustrate the temperature felt by the human body, which is calculated by dividing the value of the THI by 2. It renders an apparent temperature, namely the temperature felt by the human body that cools slower at higher values of the relative humidity due to the reduction of the evaporation rate. Consequently, the sensation human body perceives depends not only on temperature, but also on humidity (Table no. 1). For example, we feel quite comfortable if there are 35°C but the relative humidity is only 20%, as the temperature we experience is 27.1°C. In case temperature remains constant but relative humidity increases (at 35°C and 100% relative humidity we feel a temperature of 40.4°C), there develops a discomfort sensation – fatigue, dizziness, heat cramps etc. (Table no. 2). Generally, most people feel comfortable if the index is below 70, but the discomfort sensation increases as the THI values increase (Encyclopædia Britannica, 2010). This issue is also increasingly present and debated in the Romanian literature in the field as well (Teodoreanu and Bunescu, 2007, 2008; Leontie et. al. 2008; Marinica and Marinica 2008; Marinica and Chimisliu, 2009, etc.).

Although all heat-related deaths and illness are preventable, many people are affected by extreme heat every year. However, in spite of the alarm signals triggered by the researchers and media, we consider that there still is an obvious lack of public recognition of the hazard induced by the exposure to extreme heat. For example, the County Health Directorates do not keep a statistics of the number of heat-related casualties, in spite of the fact that, at the international level, the effects of extreme temperature on mortality are considered a key issue.

DATA AND METHODS

The THI data correspond to the period 2000-2009 and they were supplied by Craiova Regional Meteorological Center. There were analysed the THI values supplied by seven meteorological stations: Drobeta Turnu-Severin, Calafat, Bechet, Băileşti, Craiova, Caracal, and Slatina.

There are two calculation methods of the aforementioned index, “a-dimensionally” or “in units” and in Celsius degrees. The threshold values are 80 units or 40°C, but, as the social impact is more obvious if the index is rendered in higher values, it is preferred to be expressed in units.

In Romania, the Temperature – Humidity Index (THI) is generally calculated according to the formula:

THI = (T x 1.8 + 32) – (0.55 – 0.0055 U) [(T x 1.8 + 32) – 58)], where

T = air temperature (°C), U = relative humidity (%).

If THI is: ≤ 65 it means comfort state; 66-79 it means alert state; ≥ 80 it means discomfort state (Dragotă, 2003, p. 47).

Another used formula is the one proposed by Thom (1959): THI = 0.4 (td + tw) + 4.78, where td = dry-bulb temperature, tw = wet-bulb temperature (°C, values indicated by the psychrometer), which represents the effective temperature index (Teodoreanu, 2003, p. 28).

There were also used other climatologic data – mean monthly temperatures, absolute maximum temperatures, temperature deviations etc. in order to render the real dimension of extreme heat.

RESULTS AND DISCUSSIONS

The Oltenia Plain, which represents the south-western extremity of the Romanian Plain, is frequently subject to the penetration of hot, dry or humid air masses originating in the north of Africa or the Mediterranean Sea basin. Consequently, there occur numerous phenomena that may be considered climatic risk phenomena or climatic hazards – heat waves, dryness or drought, rain showers etc. In the last 10 years, there was kept a strict evidence of the number of days with values of the THI > 80.

The annual situation

The mean annual number of days with the THI values above 80 oscillates between 22.1 (Băileşti) and 9.9 (Craiova). The highest values are registered in the southern and western parts of the plain, while the lowest correspond to the northern extremity. Thus, the most exposed area is the Danube Floodplain – Calafat (18.3) and Bechet (20.8). Eastwards, the values are lower, less than 16 days, as the area in question is more exposed to the penetration of continental dry and hot air masses, which triggers lower values of the temperature-humidity index than in the south and west.

  DOI: 10.5775/fg.2067-4635.2011.033.i

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By analysing the data, it comes out that the years with the highest number of days with the THI values above 80 are 2000, 2001, and 2007 for the entire studied area, when, during summer, the region was affected by numerous heat waves, which led to the frequent exceeding of the 40°C value. The most affected areas are located in the central-southern and eastern parts of the Oltenia Plain – 51 days with THI > 80 at Caracal in 2000, 47 days with THI > 80 at Bechet in 2001 and 43 days in 2000, and 41 days with THI > 80 at Băileşti in 2007 (Fig. 1).

Table no. 1 The relation between environmental temperature (°C) and relative humidity (%) and the temperature felt by the human body

Temperature	Relative humidity (%)										
°C	100	90	80	70	60	50	40	30	20	10	5
15	17.5	17.0	16.5	16.0	15.5	15	14.5	14	13.5	12.9	12.7
18	20.2	19.6	19.0	18.4	17.8	17.2	16.6	16.0	15.4	14.8	14.5
20	22.2	21.5	20.8	20.1	19.4	18.7	18.0	17.4	16.7	16.0	15.6
22	24.2	23.4	22.6	21.9	21.1	20.3	19.5	18.7	18.0	17.2	16.8
25	27.5	26.5	25.6	24.7	23.7	22.8	21.9	20.9	20.0	19.1	18.6
28	31.0	29.9	28.7	27.6	26.5	25.4	24.3	23.2	22.0	20.9	20.4
30	33.5	32.2	31.0	29.7	28.5	27.2	26.0	24.7	23.5	22.2	21.6
32	36.1	34.7	33.3	31.9	30.5	29.1	27.7	26.3	24.9	23.5	22.8
35	40.4	38.7	37.1	35.4	33.7	32.1	30.4	28.8	27.1	25.4	24.8
38	45.1	43.1	41.1	39.2	37.2	35.3	33.3	31.4	29.4	27.4	26.5
40	48.4	46.2	44.4	41.9	39.7	37.5	35.3	33.2	31.0	28.8	27.7

Low risk Medium risk Increased risk Very high risk

Table no. 2 Effects of prolonged exposure to high temperature and humidity values

THI	Effects
27–32°C (54–64)	Caution – it is possible to feel a sensation of fatigue in case of prolonged exposure and activity. If a person continues the activity under such circumstances, there can appear heat cramps.
32–41°C (64–82)	Extreme caution – heat cramps and heat exhaustion are possible. If a person continues the activity under such circumstances, there can appear heat stoke.
41–50°C (84–100)	Danger – heat stoke is highly probable if continuing the activity.
> 50°C (>100)	Extreme danger – heat stoke is imminent.

Source: Dolj Public Health Directorate

The monthly situation

Extremely high temperatures and humidity values are characteristic to the warm season of the year. Thus, the threshold value of the THI is generally exceeded in five months, the interval May-September, but the frequency is by far greater in July and August, the warmest months of the year. Thus, the mean values for the interval 2000-2010, oscillate between 0.1 and 9 days per month. The highest monthly means generally correspond to July and August, while territorially, the most exposed regions are located in the south – Calafat, Bechet and the central part of the plain – Băileşti. Northwards and eastwards, the values decrease, and the greatest means do not exceed 6 days.

By summing up the entire number of days with values above the THI threshold, it results that there were registered 221 days at Băileşti, 208 days at Bechet, and 183 at Calafat. For the western, northern and eastern extremities of the plain, the number of days is below 150.

DOI: 10.5775/fg.2067-4635.2011.033.i

With regard to annual variability, the greatest number of days with THI above 80 was registered in 2000, 2001, and 2007, at least in the south and centre of the plain – Calafat: 26 days (12 days in July and 14 in August 2000, 11 days in July and 16 days in August 2001), Bechet (16 days in July and 18 days in August 2000, 18 days in July and 25 days in August 2001), Băileşti (11 days in July and 15 days in August 2001, 20 in July and 11 days in August 2007), Caracal (16 days in July and 23 in August 2000). On the whole, at Băileşti there were registered 76 days in July (34.4%) and 90 days in August (40.7%), while at the opposite pole, we mention Drobeta Turnu-Severin with 50 days in July (44.2%) and 35 in August (31%) and Craiova with 38 days in July (38.4%) and 47 days in August (47.5%) (Fig. 2). The higher percentages registered at the stations with a lower total number of days is induced by the fact that here May and September hold extremely reduced shares.

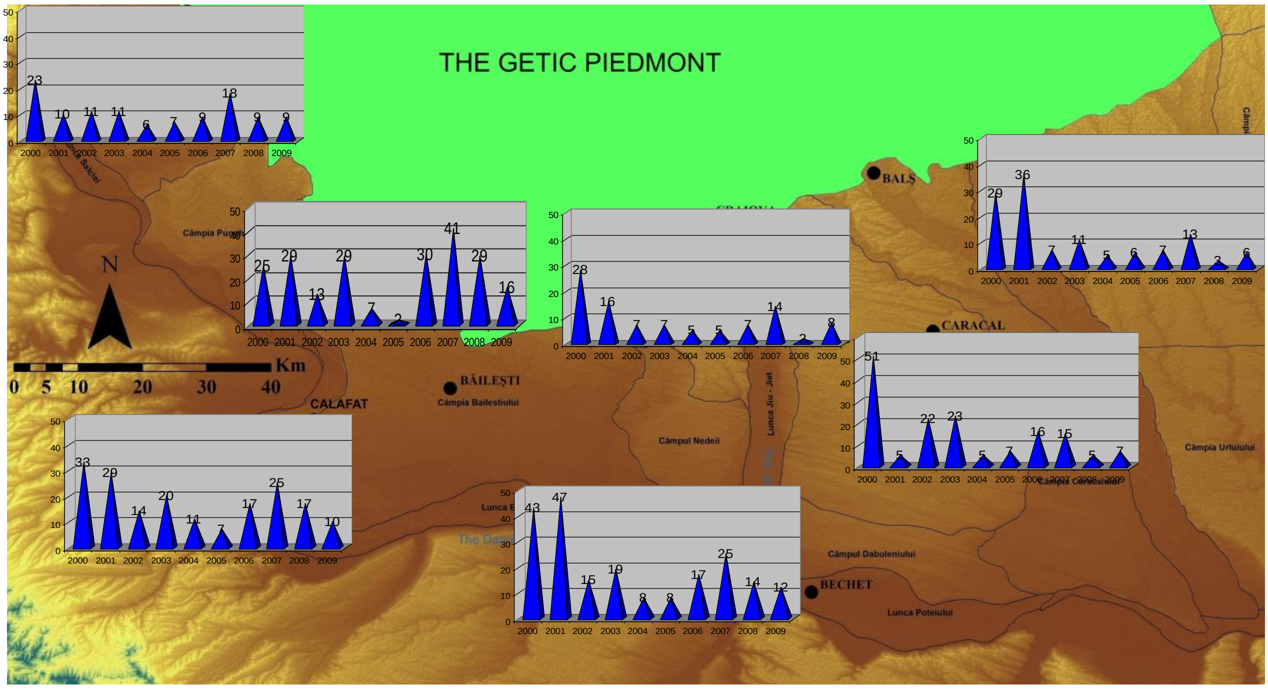

Fig. 1 The total number of days with the THI > 80 between 2000 and 2009

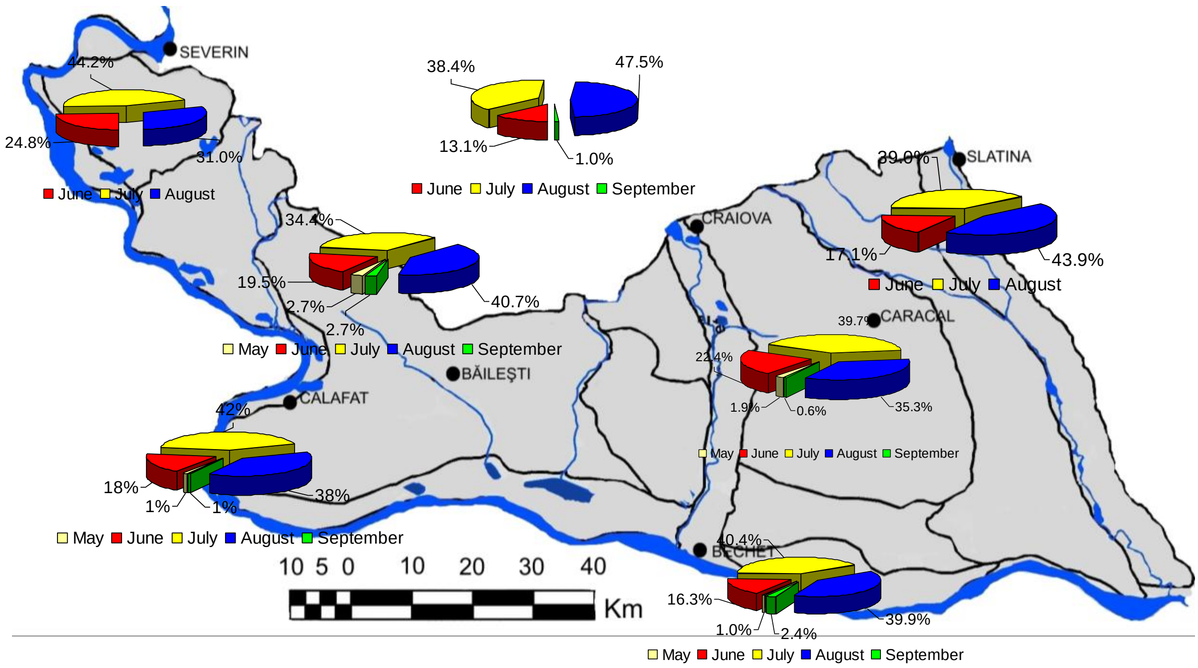

Fig. 2 Monthly shares of the total number of days with the THI > 80

Case studies *June-August 2000*

  DOI: 10.5775/fg.2067-4635.2011.033.i

The entire mentioned interval registered extremely high maximum temperature values. Consequently, the number of days with temperatures above the 30°C oscillated between 16 and 18 within the entire plain in June, between 16 and 19 days in July, and between 21 and 26 days in August. As for the 40°C thereshold, July is the most problematic month, as there were registered 5 days at Bechet, 4 days at Caracal, 3 days at Calafat, and 2 days at the rest of the stations (Table no. 3). In August, there was registered one day with more than 40°C at all the meterolorological stations, except for Slatina.

Table no. 3 The number of days with temperatures above certain thresholds, June-August 2000

Meteorological station	No of days with Tmax.≥… June		No of days with Tmax.≥… July			No of days with Tmax.≥…August		
	≥30°C	≥35°C	≥30°C	≥35°C	≥40°C	≥30°C	≥35°C	≥40°C
Slatina	17	9	18	9	2	21	8	0
Caracal	18	8	19	10	4	23	14	1
Craiova	16	6	15	7	2	23	14	1
Băileşti	16	7	19	11	2	26	14	1
Calafat	16	7	18	12	3	25	13	1
Bechet	18	8	16	12	5	25	12	1
Dr. Tr. Severin	16	6	18	10	2	26	14	1

Source: Oltenia RMC

There were three canicular periods in June 2000 (Bogdan and Marinica, 2007), but the hottest days registered by the end of the month, between 23 and 25. The highest temperature of the month reached 38.7°C at Băileşti on the 23rd, but all the maximum values exceeded 36°C; positive deviations oscillated between 0.9°C (Caracal) and 2.2°C (Craiova) (Table no. 4). The maximum value of the THI was registered at Caracal, on the 23rd, 86.1, while the lowest at Drobeta Turnu-Severin, 82.3, on the 24th.

July 2000 was by far the warmest month of the year both in terms of mean and maximum values. The heat waves penetrated in the area at the beginning and by the end of the month (2-10 and 22-27). As one may notice from Table no. 5, maximum temperature exceeded 40°C within the entire region, the highest values being registered in the Danube Floodplain, generally > 43°C, on the 4th of July.

Temperature deviations are generally lower than those registered in June, as the multiannual mean monthly values are quite increased – they varied between 0.8 (Slatina and Drobeta Turnu-Severin – located in the eastern, respectively western extremities of the plain) and 2.1°C (Caracal). At this last station, there was also registered the greatest number of days with THI>80, namely 16. We mention Bechet as well with 16 days. At these stations, there were recorded the highest values of the THI: Bechet – 89.7 and Caracal – 89.4 on the 5th of the month. In fact, all the maximum values of the THI were quite similar, as the lowest one was 84.2 registered at Drobeta Turnu-Severin.

Overall, the number of days with the THI values greater than the alarm threshold was higher in *August* as compared to July. Here we mention Caracal with 23 days of 31 possible and Bechet with 18 days. The maximum values of the THI were also registered at Caracal, 89.2, and Bechet 87.8. Temperature deviations oscillated between 1.8°C (Slatina) and 2.6°C (Caracal) and except for Slatina, at all the other meteorological stations, deviations were higher than 2°C. Maximum values were registered all on the 23rd of August, the hottest day of the month, and they were generally 2°C higher in the western half of the plain (40.7°C at Calafat) (Table no. 6).

July 2007

Heat was a problem during the summer of 2007, higher temperatures than the multiannual average being registered also in May, June and August. This situation was largely induced by the action of the North African depression, which was located in the southern and central-eastern parts of the continent, including our country. On the background of the penetration of the tropical continental air, there occurred extreme temperatures.

Thus, maximum values exceeded 40°C within the entire plain region, the highest temperature being registered at Calafat, 44.3°C, which represents the new absolute maximum value for July in our country. There were also more than 44°C at Bechet and Băileşti (Table no. 7), all the three values representing new temperature records for these meteorological stations. We also mention a new record number of consecutive dog days – 10, at all the stations from the region and one case of 10 consecutive tropical nights (Tmin>20°C) at Craiova.

Table no. 4 Thermal features of June 2000

DOI: 10.5775/fg.2067-4635.2011.033.i

Meteorological station	June 2000				
	No. of days with THI > 80	**Max. value of THI / date**	**Max. temperature (°C) / date**	**Mean monthly temperature (°C)**	**Temperature deviation (°C)**
Slatina	6	85.5/24	36.8/23	22.6	+ 1.2
Caracal	12	86.1/23	37.5/24	23.1	+ 0.9
Craiova	5	82.8/24	36.4/23	22.8	+ 2.2
Băileşti	6	82.0/24	38.6/23	22.8	+ 1.5
Calafat	7	82.8/25	38.0/23	23.3	+ 1.8
Bechet	9	83.8/23	38.0/23	22.5	+ 1.1
Dr. Tr. Severin	9	82.3/24	38.0/23	23.2	+ 2.0

Source: Oltenia RMC

Table no. 5 Thermal features of July 2000

Meteorological station	July 2000				
	No. of days with THI > 80	**Max. value of THI / date**	**Max. temperature (°C) / date**	**Mean monthly temperature (°C)**	**Temperature deviation (°C)**
Slatina	8	86.8/4	41.0/4	23.8	+ 0.8
Caracal	16	89.4/5	42.3/4	25.0	+ 2.1
Craiova	8	84.5/5	40.5/4	23.9	+ 1.3
Băileşti	6	84.5/4	43.1/4	24.3	+ 1.0
Calafat	12	87.4/4	43.2/4	25.1	+ 1.6
Bechet	16	89.7/5	43.0/4	24.6	+ 1.3
Dr. Tr. Severin	6	84.2/4	42.6/4	24.2	+ 0.8

Source: Oltenia RMC

Table no. 6 Thermal features of August 2000

Meteorological station	August 2000				
	No. of days with THI > 80	**Max. value of THI / date**	**Max. temperature (°C) / date**	**Mean monthly temperature (°C)**	**Temperature deviation (°C)**
Slatina	15	84.3/23	38.2/23	22.3	+ 1.8
Caracal	23	89.2/23	39.5/23	22.4	+ 2.6
Craiova	15	83.8/23	38.0/23	22.2	+ 2.5
Băileşti	13	83.8/23	40.2/23	22.5	+ 2.3
Calafat	14	85.5/23	40.7/23	23.1	+ 2.3
Bechet	18	87.8/23	40.0/23	22.5	+ 2.0
Dr. Tr. Severin	8	85.6/23	40.2/23	23.0	+ 2.5

Source: Oltenia RMC

At the same time, there was registered the highest minimum temperature - 25°C at Calafat, on the 23rd of July and 24.6°C at Caracal on the 24th of July (Burada and Sandu, 2009). Temperature deviations oscillated between 3.0°C at Slatina and 4.3°C at Caracal, about 2°C higher than in the hot interval registered in 2000. Regarding the number of days with the THI > 80, we mention the western half of the plain with more than 10 days (he maximum number is 20 at Băileşti), while in the east, there were only 8 – 10 days. The maximum values of the THI were almost 90, in some areas being reported even greater values.

Heat impact on human health state

The most debated heatwaves, due to the increased number of casualties, registered in the last 50 years were those registered in New York in 1975 and in Western Europe in 2003.

With regard to the impact on the people's health state, mortality and morbidity are quite difficult to be exactly estimated, as there may be a serious delay between the weather event and death time. However, according to Haines et al. (2006), it is absolutely necessary to perform empirical observations of the relationship between short-term variations in weather and mortality over a long period of time in order to determine whether changes in health might be expected as a result of future changes in climate. Studies performed in various regions of the Globe have shown different values at which increases in heat related mortality begin depending on the acclimatization of the population on to local climate conditions (Keatinge et. al., 2000; Kalkstein and Greene, 1997; Curriero et. al., 2002).

Table no. 7 Thermal features of July 2007

  DOI: 10.5775/fg.2067-4635.2011.033.i

Meteorological station	July 2007				
	No. of days with THI > 80	Max. value of THI / date	Max. temperature (°C) / date	Mean monthly temperature (°C)	Temperature deviation (°C)
Slatina	8	82.0/24	41.4/24	26.4	+ 3.0
Caracal	9	82.0/24	41.9/24	27.2	+ 4.3
Craiova	9	83.0/24	42.6/24	26.5	+ 3.9
Băileşti	20	87.0/24	44.0/24	26.9	+ 3.7
Calafat	15	85.0/24	44.3/24	27.4	+ 3.9
Bechet	13	84.0/24	44.2/24	26.5	+ 3.2
Dr. Tr. Severin	11	83.0/24	42.2/24	26.4	+ 3.1

Source: Oltenia RMC

The increases in death rates that have been observed worldwide occur principally in the elderly and infants and they are mainly induced by cardiovascular and respiratory complications. This is why it has not been possible to develop a consistent standardized definition of a heatwave between populations that incorporates the intensity and duration of high temperatures and the population response (Hajat et. al., 2002, p. 367).

Certain studies published in Europe infer that mortality rises linearly as temperature increases and that even moderate heat can trigger excess deaths (Kunst et. al., 1993), but this greatly depends on other environmental conditions as well.

According to the data supplied by certain, unofficial rapports of Dolj, Olt and Mehedinti Public Health Directorates, there were registered an obvious increase of in the number hospitalized people. There was not kept a strict evidence of the morbidity and mortality state induced by the heat waves, but, overall, there were generally reported more than 100 calls per day and more than 10 hospitalization situations. Most people that needed medical assistance accused heat cramps and heat exhaustion – painful spasms usually in muscles of legs and abdomen, heavy sweating, weakness, fainting and vomiting etc., and in some cases even heat strokes that led to several fatalities.

CONCLUSION

Heat waves seem to become a constant climatic risk phenomenon in the south of the country during the warm season. Oltenia Plain represents one of the most vulnerable regions of Romania due to its positioning in the path of extremely hot air masses penetrating from Northern Africa. Consequently, in the last ten years, the region has registered new and alarming thermal records.

By analysing the temperature data, as well as the THI values, we may state that the most exposed part of the plain to such phenomena is the southern one, located along the Danube (Calafat, Bechet, Băileşti). Thus, maximum temperatures for the studied interval were equal or exceeded 44°C (July 2007), temperature deviations were higher than 3°C (also July 2007), while the number of days with the THI>80 was usually greater than ten days per month. When summing up the total number of days registered in ten years, we come to the conclusion that there were 221 days at Băileşti, 208 days at Bechet, and 183 days at Calafat, which means about 6% of the total number of days. Overall, as monthly distribution of the days with the THI>80, we remark the same meteorological stations: Băileşti – 76 days in July and 90 in August, Bechet – 84 days in July and 83 in August, and Calafat – 77, respectively 70 days.

The most problematic years were by far 2000 (the interval June-August) and 2007 (especially July), with the highest values at the level of the entire region. There should be also mentioned July and August 2001 (25 days with the THI>80 at Bechet in August, the greatest number of days registered in a month for the analysed period).

When it comes to the influence of such high values of the THI on human health, children and elderly people or those suffering of different diseases are mainly affected. At values above 80, even if the discomfort sensation is not obvious, it is recommended to take adequate protection measures:

- Avoid excess activity during periods of hot temperatures and high humidity.
- Drink plenty of fluids and replace lost electrolytes (potassium, sodium, chloride, etc.) with foods or supplements.
- Avoid the direct sun exposure – skin cannot loose heat effectively when burned.
- Wear loose-fitting clothing.
- Eat "light" foods such as fruit and vegetables and avoid heavy foods such as proteins, which increase body heat.
- Give the body time to adjust to warmer temperatures during the first hot days.

DOI: 10.5775/fg.2067-4635.2011.033.i

- If necessary, seek areas with cooler temperatures: air-conditioned buildings, forests, lakes or seashores.

Fortunately, the Romanian authorities imposed employers a set of measures (stipulated at the European level) to better cope with extreme heat periods – free water distribution for the employees (2 to 4 l per day), showers, reduction of physical activities, alternance of dynamic and static effort periods etc. Unfortunately, many people, who do not work for public or private companies or even the employers, do not respect these measures. Consequently, each summer, there are registered many casualties and fatalities that might be easily reduced.

ACKNOWLEDGEMENTS

This work was supported by the strategic grant POSDRU/89/1.5/S/61968, Project ID61968 (2009), co-financed by the European Social Fund within the Sectorial Operational Program Human Resources Development 2007 – 2013.

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  DOI: 10.5775/fg.2067-4635.2011.033.i

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 157 – 166
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.034.i

Structural and Non-Structural Measures for Flood Risk Mitigation in the Bâsca River Catchment (Romania)

Gabriel MINEA[1], Liliana ZAHARIA[2]

[1] University of Bucharest, Faculty of Geography, Doctoral school: “Simion Mehedinţi - Nature and Sustainable Development”, gabriel.minea@gmail.com
[2] University of Bucharest, Faculty of Geography, zaharialil@yahoo.com

Received on <December 6, 2010>, revised on <February 21, 2011>, accepted on <March 29, 2011>

Abstract

The most common natural hazards affecting the Bâsca River Catchment (extended over a surface of 785. 1 sq. km in the Curvature Carpathians) are floods and flooding. The purpose of this paper is to investigate and analyze structural and non-structural measures for flood risk mitigating in this catchment.

The study focuses on the main factors which generate and favour floods, as well as on flood characteristics (frequency, the largest floods and its consequences).

The main methods are the statistical analyze hydrologic and climatic data, field observations, expeditionary mapping and spatial analyses using Geographic Information Systems (GIS).

In order to analyse flood potential, there were processes processed maximum instantaneous monthly and annual discharges of the Bâsca River at the Bâsca Roziliei hydrometric station (1953 - 2007), Varlaam I (1956-2005), Comandău h.s. (1968-2005) and of the Bâsca Mică River at the Brebu h.s. (1959-1974) and Varlaam II h.s. (1973-2005).

Considerations on structural and non-structural measures for protection against floods are presented in the last part of the paper. An inventory of structural works in the middle and lower part of the catchment (hydrotechnical and erosion control works) and their condition was made.

Keywords: *floods, structural and non-structural measures, the Bâsca River Catchment*

Rezumat. Măsuri structurale şi nestructurale de diminuare a riscului inundaţiilor în bazinul hidrografic al râului Bâsca (România)

Cele mai frecvente hazarduri naturale care afectează bazinul hidrografic al râului Bâsca (extins pe suprafaţă de 785,1 km^2 în Carpaţii de Curbură) sunt viiturile şi inundaţiile. Prezenta lucrare are drept scop investigarea şi analiza măsurilor structurale şi nestructurale cu rol de diminuare a riscului indus de inundaţii în bazinul menţionat.

Studiul se concentrează pe principalii factori care generează şi favorizează viiturile şi caracteristicile acestora (frecvenţa, cele mai mari viituri şi consecinţe).

Principala metodă este reprezentată de analiza statistică a datelor hidrologice şi climatice, observaţia de teren, cartarea expediţionară şi analiza spaţială utilizând Sisteme Informatice Geografice (SIG).

În analiza potenţialului de producere a viiturilor au fost prelucrate debitele maxime instantanee, lunare şi anuale ale râului Bâsca de la staţiile hidrometrice Bâsca Roziliei (1953 - 2007), Varlaam I (1956-2005), Comandău (1968-2005) şi de pe râul Bâsca Mică de la Brebu (1959-1974) şi Varlaam II (1973-2005).

În ultima parte a lucrării sunt prezentate consideraţii asupra masurilor structurale şi nestructurale de protecţie împotriva inundaţiilor. Este realizat un inventar al lucrărilor structurale din sectorul mijlociu şi inferior al bazinului (lucrări hidrotehnice şi antierozionale) şi este analizată starea acestora.

Cuvinte cheie: *viituri, măsuri structurale şi nestructurale, bazinul hidrografic al râului Bâsca*

INTRODUCTION

Floods are natural hazards with complex consequences, both direct and indirect: geomorphological, economic, social and ecological. They hold about one third (34%) of the total number of natural disasters produced worldwide in the 1900-2007 period (Magdelaine, 2010).

Knowing that in the future flood risk is estimated to raise, due, on the one hand, to increasing frequency and amplitude of flooding, in the context of climate changes, and on the other hand to an increased vulnerability determined by the expansion of socio-economic activities in floodplains (Şerban and Gălie, 2006), measures and actions to limit and reduce floods negative impacts on society and the environment need to be effective. At the Union European level, the management of the floods risk is expected to be completed within a common framework for action set by the 2007/60/EC

Directive "On the assessment and management of flood risks" which requires Member States an integrated flooding risk management with emphasis on *actions of prevention, protection and preparedness*. These involve complex and diverse measures, both structural and non-structural, their judicious combination and adequate to local conditions being necessary.

The purpose of the paper is to highlight the flood potential and also to investigate and analyze the structural and non-structural measures for reducing the flood risk in the Bâsca River Catchment.

The results of the present study complete and update specific information in the uncertain parameters of maximum discharge and floods from the Bâsca River Catchment, published in papers and hydrologic synthesis carried throughout Romania (*Râurile României. Monografie hidrologică*, 1971; Ujvári, 1972) and at regional scale (*Monografia hidrologică a bazinului hidrografic al râului Siret*, 1967; Diaconu, 2005; Zaharia, 2004, 2005; Chendeş, 2007 etc.).

Information concerning terminology and case studies regarding hydric risks were found in papers by: Şelărescu and Podani (1993), Kundzewicz (2002), Sorocovschi (2003, 2004), Armaş (2008), etc.

An inventory of the damages caused by these phenomena has been published by Zăvoianu and Podani (1977) at regional scale and FRMI (1994) and Aquaproiect (2006) for the Bâsca River Catchment.

A model of economic management of negative effects caused by floods in a catchment is developed by the Tennessee Valley Authority even since in 1933 (www.tva.com).

STUDY AREA

Positioned in the external region of the Curvature Carpathians (subunit of the Eastern Carpathians), the Bâsca River Catchment (Fig. 1) has a surface of 785,1 sq km. It lies at a medium altitude of 1081 m between Lăcăuţi Peak (1777 m a.s.l.) and the confluence with the Buzău River (385 m a.s.l.). The Bâsca River (length = 81 km), is one the main tributaries of the Buzău River.

From a demographic point of view, the Bâsca River Catchment is situated in an area with low density (8.35 inhabitants/km^2). In this catchment, there are two communes: Comandău (1,042 inhabitants) and Gura Teghii (3,884 inhabitants) and two villages appertaining to the town of Nehoiu: Bâsca Roziliei (1,428 inhabitants) and Vineţişu (206 inhabitants[1]). The majority of the inhabitants is concentrated in the lower part of the Bâsca River Catchment, especially along the valleys. In the upper part of the catchment, the population is concentrated in Comandău Depression (Comandău Commune).

The humanization of the valleys and the presence of urban and road infrastructure increase flooding vulnerability of these areas.

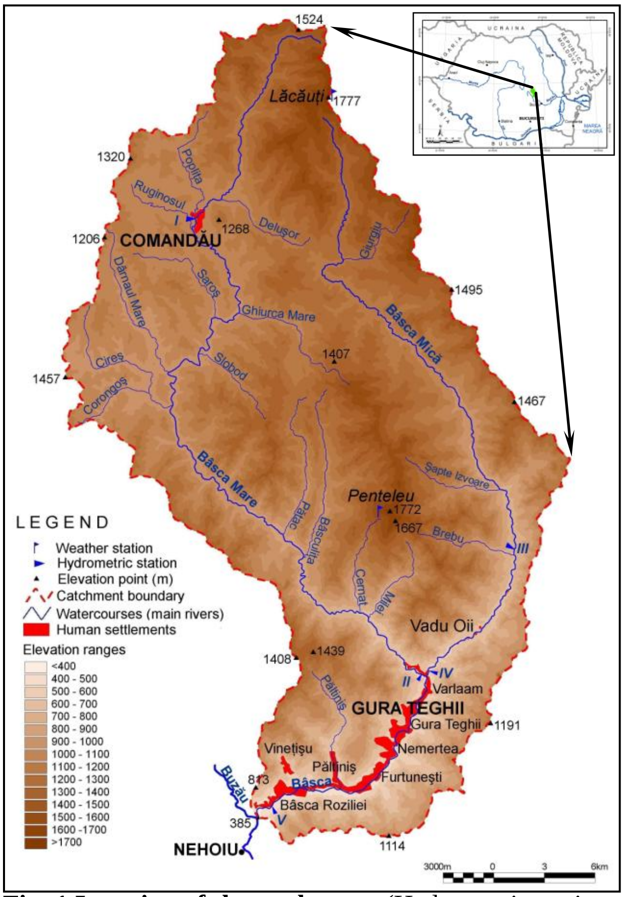

Fig. 1 Location of the study area (Hydrometric stations: I. Comandău; II. Varlaam I; III. Brebu; IV. Varlaam II and V. Bâsca Roziliei**)**

Data source: information processed from topographic maps, scale 1:25,000

DATA AND METHODS

The present analysis in based on the following types of data:

- cartographic data (topographic maps scale 1:25,000 by Military Topographic Department -MTD-, 1982);
- climatic data: precipitations (maximum amounts fallen in 24, 48 and 72 hours and monthly averages) at the Lăcăuţi (1961-2000) and Penteleu (1988-2007) weather stations (w.s.), situated at 1776 m a.s.l. and

[1]The inhabitants number are according to The National Institute of Statistic, Romanian census data, 2002.

  DOI: 10.5775/fg.2067-4635.2011.034.i

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respectively 1632 m a.s.l; these data were provided by the Regional Meteorological Center Muntenia, Buzău and *Clima României*, 2008;
- hydrological data: maximum instantaneous monthly and annual discharges of the Bâsca River at the Bâsca Roziliei hydrometric station (h.s.) (1953 - 2007), Varlaam I h.s. (1956-2005), Comandău h.s. (1968-2005) and of the Bâsca Mică River at the Brebu h.s. (1959-1974) and Varlaam II h.s. (1973-2005) (Table 1); discharges during the main floods; the hydrological data were provided by the "Romanian Waters" National Administration, Buzău – Ialomiţa Water Basin Administration (BI BWA), and the National Institute of Hydrology and Water Management (NIHWM);
- qualitative data: physical status of hydrotechnical works (from the Forest Research and Management Institute - FRMI) and
- quantitative data: number of hydrotechnical works (by the Aquaproiect and FRMI).

Table 1 Data about the hydrometric stations from the Bâsca River Catchment

River	Hydrometric station	A* (km^2)	H_B** (m)	Stream length (km)	Analysed period
Bâsca Mică	Brebu***	185	1240	36	1959-1974
	Varlaam II	235	1171	43,7	1973-2005
Bâsca	Comandău	111	1252	24	1968-2005
	Varlaam I	440	1142	53,5	1956-2005
	Bâsca Roziliei	759	1110	72	1953-2007

* - Catchment's area (upstream the hydrometric station),
** - Catchment's mean altitude (upstream the hydrometric station)
***- Hydrometric station was out of service in the years 1974.
Morphometrical data are according to Diaconu, 2005.

The main methods were represented by statistical analysis of the hydrologic and climatic data, field observations, expeditionary mapping and spatial analyzes using Geographic Information Systems (trial software, extensions of the ArcGis 10).

Factors generating and favouring floods

Floods generation is a highly non-linear process that depends on genetic and favourable factors such as the pluviometric regime, geological and morphometrical features (e.g. elevation, slopes, energy relief and drainage density), vegetation, soils and antecedent conditions of the catchment (e.g. land use) (Minea and Zaharia, 2010).

Precipitations

Precipitations represent the main factor generating floods in the Bâsca River Catchment.

Although in the catchment region, the mean annual amount of precipitation are relatively low (827.3 mm at Lăcăuţi w.s. and 664.3 mm at Penteleu w.s.), rainfalls can trigger floods especially during summer, when the rains have a torrential character. In the morphological features of the catchment, these rains can generate flash-floods.

At annual time scale, the highest average amount of annual precipitation was recorded in June at Lăcăuţi w.s. (130.2 mm in the period 1961-2000) (Fig. 2) and in July at the Penteleu w.s. (117.4 mm, in the period 1988-2007).

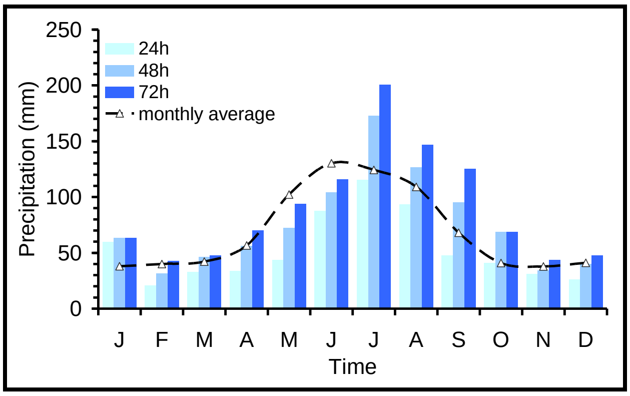

Fig. 2 Maximum precipitations (rain and snow) in short periods reached at Lăcăuţi w.s. (1961–2000)
Data source: *Clima României*, 2008

The maximum amounts of precipitation fallen in 24, 48 and 72 hours, at Lăcăuţi were recorded in July (Fig. 2). On July 12th 1969, at Lăcăuţi w.s. it was recorded: 115.4 mm in 24h (88.6% of monthly multiannual average), 172.8 mm in 48h (132.7% of the monthly multiannual average) and 200.7 mm in 72h (154.1% of monthly multiannual average) (Fig. 2).

At Penteleu w.s., on July 18th 1991, there were registered 155.5 mm in 24h (132.4% of monthly multiannual average), and notably 145.3 mm fell in only 6 hours, as it is mentioned in the "Special phenomena" rubric, of the Penteleu w.s. registry.

Morphometrical factors

Bâsca River catchment is drained by a network of torrential organisms, channels and valleys, with an average drainage density of 3.69 km/km^2.

DOI: 10.5775/fg.2067-4635.2011.034.i

Basic morphometrical characteristics of the Bâsca River catchment and its main sub-catchments inventoried in the Bâsca Catchment are synthetically exposed in Table 2.

Table 2 Morphometrical features of the Bâsca River Catchment and its main sub-catchments

River	River	Sub-catchment	
	Length (km)	Surface (km^2)	Shape
Ruginosul	5.14	11.8	C
Corongoş	5.32	12.8	
Slobod	6.18	9.22	Qc
Milei	6.43	15.8	C
Giurgiu	6.48	16.2	
Brebu	6.55	11.1	
Şapte Izvoare	6.62	15.6	Qc
Cernat	6.69	11.1	
Deluşor	6.88	20.9	C
Saroş	7.84	14.9	Qc
Popliţa	9.29	22.4	C
Ghiurca Mare	9.59	23.3	Qc
Păltiniş	9.69	25.1	
Pătac	10.0	18.5	E
Dârnăul Mare	10.6	21.5	
Cireş	11.1	19.6	Qc
Bâsculiţa	11.5	40.0	
Bâsca Mică	46.5	238	E
Bâsca Mare	64.2	440	
Bâsca	**81.0**	**785.1**	**E**

E= Elongation; Qc= Quasi-circular and C= Circular
Data source: Morphometrical data are obtained from processed GIS after Romanian Topographic Map, MTD, 1982 (scale 1:25,000).

The catchment's elongation degree was calculated with the shape ratio (Formula 1) proposed by Diaconu and Lazărescu (1965) quoted by Zăvoianu (1985). Transformation of the numeric ratio in qualitative estimation was made after the method specified by Diaconu (2005).

$$F_r = \frac{\sqrt{A}}{L_b} \qquad (1)$$

where: A is catchment area and
L_b is the mean catchment length.

Considering the qualitative aspect, 35% from sub-catchments have a shape tending to circular (e.g. Brebu, Păltiniş), 35% a circular shape (e.g. Giurgiu, Corongoş) and 26% are elongated (e.g. Bâsculiţa, Pătac).

The shape of the catchments can have a profound effect on the stream behaviour, especially in relation to the direction of storm movements, e.g. time of concentration (Black, 1991).

Orientation of sub-catchments with quasi-circular and circular shape to the main drainage axis of the Bâsca and the Bâsca Mică River is predominantly transverse. But the elongated shape and large area of sub-catchments (e.g. the Bâsca Mică), determine *"a diminution of floods because tributaries flow into the main stream at greater intervals in time and space"* (Zăvoianu, 1985).

Maximum flow and floods. Their consequences

We know that particularities of maximum flow present a major socio-economic interest, because they allow the identification and establishment of appropriate measures for flood risk mitigation.

General features

In the Bâsca River catchment, maximum instantaneous discharges have exceeded in many years the alert stages. Fig. 3 exemplifies the situation from Varlaam II h.s. on the Bâsca Mică River, where maximum annual discharge exceeded in 12 years the discharge corresponding to the attention stage[2].

Maximum instantaneous discharge (Q_{max}), on the Bâsca River, which caused major floods and flooding, occurred in the years: 1994 (212 m^3/s) and 1975 (204 m^3/s) at Comandău h.s.; 1975 (598 m^3/s) and 1969 (447 m^3/s) at Varlaam I h.s., and 1975 (960 m^3/s), 1969 (697 m^3/s), 1971 (586 m^3/s), 1991 (530 m^3/s) and 1985 (515 m^3/s) at Bâsca Roziliei h.s.

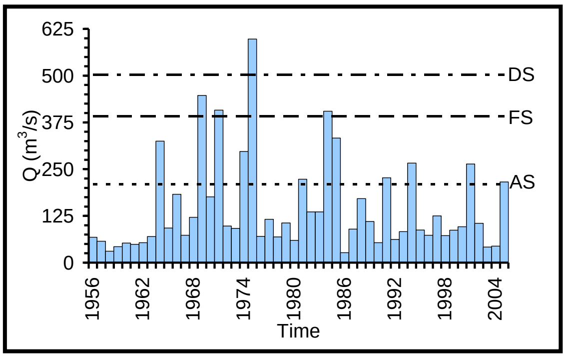

Fig. 3 Variability of the maximum annual discharge and alert thresholds (AS = 209 m^3/s; FS = 392 m^3/s; DS = 502 m^3/s) at Varlaam I h.s (1956-2005)
(Data source: BI BWA, 2009 and NIHWM, 2010

On the Bâsca Mică River, due to the small reception area, there were lower values of annual maximum instantaneous discharges. Thus, at the Brebu h.s., the highest annual maximum discharges were recorded in 1960 (150 m^3/s), 1961 and in years 1962 (87.2 m^3/s) and 1975 (392 m^3/s) 1991 (359

[2]Alert stages are gradual avertization forms, with local defence caracteristics. They are three stages of alert in Romania: attention stage (AS), flooding stage (FS) and danger stage (DS).

  DOI: 10.5775/fg.2067-4635.2011.034.i

m^3/s), 2005 (240 m^3/s) and 2001 (167 m^3/s) at Varlaam II h.s.

The analysis of the occurrence frequency of the maximum annual discharges exceeding the alert stages (in the periods mentioned in Table 1), shows that the most numerous overruns of the three alert thresholds were recorded on the Bâsca Mică River (Table 3).

Monthly frequency analysis of the largest floods indicates that the greatest potential for flood occurrence is encountered in June and July, respectively: July 2nd 1975 (960 m^3/s), July 13th 1969 (697 m^3/s), July 2nd 1971 (586 m^3/s), July 18th 1991 (530 m^3/s) and June 19th 1985 (515 m^3/s).

Table 3 Occurrence frequency of the maximum annual discharges higher than the ones equivalent to the AS, FS and DS in the Bâsca River Catchment

River	Hydrometric station	AS	FS	DS
Bâsca Mică	Varlaam II	18	6	4
	Comandău	18	9	-
Bâsca	Varlaam I	12	4	1
	Bâsca Roziliei	2	1	-

AS = attention stage; FS = flooding stage; DS = danger stage.
Data source: BI BWA 2009 and NIHWM, 2010

Floods and inundations produced in the Bâsca River Catchment caused socio-economic damages and environmental disturbances.

Such examples are the deterioration of some hydrotechnical works, partial destruction of the embankment and road elements (41 km of roads have been damaged by the flood and inundation from July 2nd 1975 and 51.2 km in July 18th 1991), bridges and road culverts (2 bridges and 10 platforms were destroyed in 1975 and 12 road culverts in 1991), houses and annexes (200 in 1975 and 45 in 1991). Between 1969 and 2002 there were recorded 16 human deaths due to these phenomena[3].

These are added to the biological consequences: significant implication for the "succession dynamics of riparian ecosystems" (Pautou and Decamps 1985 quoted by Richter and Richter, 2000).

Floods risk mitigation measures

Protecting areas vulnerable to inundation induced by floods require applying a set of structural measures[4] in interaction with non - structural measures[5] (Sorocovschi, 2004).

Structural measures

In the category of structural measures for flood risk mitigation floods, in the Bâsca River Catchment, there can be distinguished:

- stabilization of slopes (afforestation, correction of torrents);
- works for channel regulation and riverbank protection.

Slopes Arrangement

Slopes arrangements in the Bâsca River Catchment consists of afforestation, erosion control works, torrent correction (Table 4) and road culverts (Moţoc *et al.*, 1975). They aim at to:

- ensure water drainage on versants and access to road circulations;
- retain sediment load during the floods;
- reduce runoff velocity;
- strengthening versants without natural support (Arghiriade, 1953).

Culverts roads are used for crossing small courses of water ($Q_{max} = 0.3 \div 0.5$ m^3/s).

The slope from the Bâsca River Catchment generally has a high ratio of forestation (83.4%), constituting a moderating factor for superficial runoff.

Hydrotechnical works for torrent correction in the Bâsca River Catchment has a total length of 33.3 km. They are 28 longitudinal and 241 transversal pices (FRMI, 2007). The hydrotechnical works in the middle and lower parts of the Bâsca Catchment, where human settlements are positioned (Vadu Oii, Varlaam, Gura Teghii, Nemertea, Furtuneşti, Păltiniş, Vineţişu and Bâsca Roziliei Villages), are degraded in a proportion of 65%.

The Păltiniş River sub-catchment arrangements

The Păltiniş River sub-catchment (F = 25.4 km^2, L = 9.69 km), has a high forest cover, of over 70.7% (FRMI, 1994) and linear settlements on a length of 2 km in the lower third sector (Păltiniş Valley Village). Maximum flow of the river Păltiniş with 10% exceeding probability is 77 m^3/s, with 5% exceeding probability is 114 m^3/s, and with 1% exceeding of probability is 210 m^3/s (Aquaproiect, 2006).

On June 29th 1991, at Nehoiu w.s. (adjacent to the Bâsca Catchment) considerable amounts of precipitation were recorded (108.9 mm in 24h), which generated a severe flood in the Păltiniş River Catchment, causing:

- total destruction of works for torrents correcting from the Păltiniş;

[3]Data regarding social and economic losses have been provided by Aquaproiect (2006).

[4]Structural measures refer to any physical construction to reduce or avoid possible impacts of hazards, which include engineering measures and construction of hazard-resistant and protective structures and infrastructure. (UNISDR, 2004).

[5]Non-structural measures 'concern reducing damages induced by inundation without hydrotechnical works (structures)' (Şelărescu and Podani, 1993).

DOI: 10.5775/fg.2067-4635.2011.034.i

- damage to the forest roads and settlements (FRMI, 1994).

After the hydrotechnical works restoration in 1995, a new strong flood was occurred on Saturday 20th of July 2002, with important geomorphological and socio-economic effects:

- landslide reactivatation and destabilization of slopes;
- destruction of some hydrotechnical works (Photo 1);
- affecting sections of the local road DC75;
- homes flooded in the area of the confluence with the Bâsca River and
- one human death.

Photo 1 Hydrotechnical work destroyed by the flood from July 20th 2002 (near the confluence of the Păltiniş with the Bâsca River)

These consequences are probably due also to the fact that the works were in most cases hydrologically (exceeded by flood values and channel shifting) and lithologically (alternating layers with hard resistance with friable rocks), limited.

River channel training (correction) works

Channel correction aim to the reduce land flooding (Podani and Şelărescu, 1993).

Hydrotechnical works for channel training (frequent on the Bâsca River and in smaller proportion on the Bâsca Mică River) are:

- dry-stone pitching/riverbanks (such works have been identified on the left bank of the Bâsca River, in Varlaam and Gura Teghii villages and in Vadu Oii village, on the Bâsca Mică River);
- embankments made by gabions on the right riverbank of the Bâsca River, between Păltiniş and Furtuneşti villages;
- groynes, on the Bâsca Mică River in Vadu Oii village and on the Bâsca Mare River, upstream of Varlaam I h.s.;
- bridges crossings the river they have the drawback that the pier from the river's channel may generate riverbed jams with wood materials and determine inundations).

The analysis of the physical state of the engineering works indicates that some are degradated by destructuration (groynes) and erosion at the base (brick riverbanks).

In the middle and lower part of the Bâsca river catchment, hydrotechnical works for protection against flooding have degraded in a percent of 65%, requiring rehabilitation, and development of new hydrotechnical works (Minea and Zaharia, 2010).

After 2007, in the lower sector of the Bâsca River, new longitudinal hydrotechnical works (dykes from gabion mattress) are started (Photo 2). On the Bâsca River the project "Hydropower Siriu – Surduc Development", has been developed (being now in construction stage). This project includes a permanent water reservoir "Cireşu" on the upper part of the Bâsca River and an underground derivation "Surduc - Nehoiaşu", from Cireşu Accumulation, The Bâsca River towards the „CHE Nehoiaşu II" hydroelectric power station. This reservoir will mitigate the water volumes contributing to flood effects diminution.

Photo 2 New hydrotechnical arrangements (gabion baskets) on the Bâsca River (august 10th 2010)

Non-structural measures

Non-structural measures are an alternative complementary to structural measures that may reduce the loss of human life and economics. These include: legislation, catchment managements, land and administrative urban planning, education, insurances, hydrologic forecasting and warning.

Legislation

Romania is currently in the process of implementing the existing UE legal framework on water resources and inundation risk management.

The most important EU legislation on this subject are the *Water Framework Directive*

  DOI: 10.5775/fg.2067-4635.2011.034.i

60/2000/EC (consolidated), which establishes a framework for Community action in the field of water policy, and the Directive on the *assessment and management of flood risks* 2007/60/EC (http://eur-lex.europa.eu).

In accordance with the previsions of the Water Framework Directive and with the Romanian legislation on water (Law no. 112/2006, Law no. 310/2004 for Water Law no. 107/1996 amendment), the main instrument for implementing integrated water resources management in Romania is *The Scheme for Water Settling and Management*, including a qualitative component, materialized in the *River Basin Management Plan* and a quantitative one, concretized by the *River Basin Arrangement Plan.*

The national policy of prevention, mitigation and flood risk management is coordinated by the government, the authorities and the subordinate institutions.

Regarding the Romanian legislative framework on inundation risk and its management, the following documents should be mentioned:

- *National strategy for flood risk management on medium and long time*;
- Law no. 107/1996 - *Law of waters,* (amendment);
- Law No. 575/2001, concerning the approval of the *National Territory Arrangement Plan – Section V, Natural Risk*;
- Emergency Ordinance of the Romanian Government (EOG) no. 21/2004, on the *National System for Urgency Situations Management;*
- Government Decision (GD) no. 1491/2004 *for the approval of the frame Regulation on the structure, attributions, functioning and endowment of the committees and operative centres for emergencies;*
- Common Order no. 638/420/2005 of Ministry of Administration and Interior and Ministry of Environment for approving the *Regulations regarding the management of emergency situations produced by floods, dangerous weather events, dam breaking accidents and accidental pollutions;*

According to the Appendix no. 5 – *Administrative territorial units affected by flooding* - of the Law no. 575/2001, Gura Teghii Commune as well as Vineţişu and Bâsca Roziliei villages are assigned to the type of fluvial flooding.

At local scale, in the Bâsca River Catchment, the *management of emergency situations* is provided by the *Local Committees for Emergency Situations* (LCES)[6]. In this catchment, hierarchically, LCES of Nehoiu town, Gura Teghii and of Comandău communes are subordinated to the *County Committees for Emergency Situations* (CCES) from Covasna and Buzău counties.

The main attributions of LCES are[7]:

- to establish measures and specific actions for emergency situations management and track their implementation;

- to declare with the Prefect’s agreement, *alert status* in the administrative-unit area;

- to analyze and approve the local plan for assuring human, material and financial resources necessary to manage the emergency situation, etc.

The legal act under which the LCES of Gura Teghii Village manages risk situations is defined by the *Analysis and convergent scheme of risk* (ACSR). It facilitates Gura Teghii Commune LCES choosing solutions - regarding material and human resources management – for risk management. ACSR contains tables with families and number of houses to be evacuated in case of flooding (Table 4), means of transport which can be used for peoples and goods evacuation.

Table 4 Number of houses which have to be evacuated in case of flooding in the Gura Teghii Commune

Locality (village/zone)	Affectability houses (no.)
Vadu Oii	5
Varlaam (Vişani)	6
Gura Teghii (Prund)	9
Gura Teghii (Brăgăi)	3
Furtuneşti (Bâsca Colţi)	4
Păltiniş (Vascu)	2
Păltiniş (Gura Păltinişului)	24

Data source: Gura Teghii Commune Hall, 2010

The Gura Teghii LCES is composed of 10 members and it is led by the mayor. In its structure, the Operational Centre for Emergency Situations and Technical Secretariat are included. It is served by Voluntary Service for Emergency Situations (Department of Prevention and different teams, e.g. Intervention Teams at Inundation), according to Gura Teghii Commune Hall, 2010.

Catchment management

For water resources management, BI ABA establishes the *Management Plan of River Basin*

[6]According to art. 4 (4) corroborated with art. 9 (3), (4), d) from GD no. 1491/2004 *for the approval of the frame Regulation on the structure, attributions, functioning and endowment of the committees and operative centres for emergencies.*

[7]According art. 24 let. a)…f) from the EOG No. 21/2004, regarding the *National System for Urgency Situations Management.*

DOI: 10.5775/fg.2067-4635.2011.034.i

(APRB) part of *The scheme for water settling and management*.

The APRB concerns quantitative management of water resources by reducing negative effects of extreme hydric phenomena (floods, drought, excess moisture, soil erosion). In the Bâsca Catchment APRB foresees hydrotechnical works for channel correction and Cireşu Dam Reservoir. In addition BI ABA elaborates the *Plan of defence against floods*[8]. It details the warning phases according to alert thresholds.

Warnings are successive started for h.s. from the river catchments, in relation to the alert stages and to precipitation thresholds for the sites without hydrometric stations.

Land and urban administrative planning

One of the reasons amplifying the negative effects of floods is human settlements exposure due to their location in the floodplains (Photo 3).

Photo 3. Houses located in the floodplain on the right river bank of Bâsca, downstream Păltiniş Village (August 10th 2010)

Urban planning policy, as an instrument for reducing associated effects of hydric risk is expressed by:

- zoning flooding areas and discouraging constructions in floodplains and
- technical advices regarding the land use.

The role of local public administration is to restrict approvals of new construction[9] in flooding areas and resettlement.

Insurances

An important factor for reducing the financial risk for individuals, enterprises, and even whole societies in case of natural hazards is the insurance (Kron, 2005).

In Romania, compulsory insurance of *dwellings* against the negative effects of *earthquakes, landslides or flooding* is a mandatory financial instrument binding from July 1st 2010. Insurance - stipulated by Law no. 260/2008 *regarding compulsory insurance of dwellings against earthquakes, landslides or flooding* (amended) - covers for obligatory insurance of € 10 or €20, depending on the type of construction and on the type of natural hazards (earthquakes, landslides and flooding). Cover limit is € 10,000 or € 20,000.

In the rural space, specifically to the Bâsca River Catchment, the basic problem in flood insurance is low financial power, underestimation and floods traditional cohabitation (a divine premonition).

Forecasting and hydrologic warning

Forecasting and warning systems must advance information allowing the population preparedness for the flood occurrence.

Monitoring of the Bâsca River flow regime is provided by 3 h.s. and of Bâsca Mică River by 1 h.s. Nowadays (2010), they are automated and integrated into the DESWAT (Destructive Water) project[10]. Thanks to flood forecasting and warning systems, it is possible to save human lives (Kundzewicz, 2002).

Hydrological warning at national scale is done through mass-media announcements. Informative Bulletins, Hydrologic newsletters (daily and monthly) and Warnings are elaborated by the NIHWM.

Pre-warning local systems and population warning in case of floods requiring evacuation consist of the audible alarm and church bells acting.

CONCLUSIONS

Floods are the most common natural hazard in the Bâsca River Catchment. Their genesis is mainly pluvial and it is favoured by geographical physical features of the catchment, mainly by the morphometrical parameters.

The lithological structure, consisting predominantly of impermeable rocks, plays an important role. Flooding risk is magnified by anthropogenic intervention (construction in floodplains, improper land use etc.).

In order to reduce the flood risk in the Bâsca River Catchment, especially in its lower and middle part, where there is the most concentrated

[8] Posted on the website of the "Romanian Waters" National Administration (http://www.rowater.ro).

[9] For a new construction *is mandatory* to obtain the *Construction Authorisation* according to Law No. 50/1991 (amended and supplemented), regarding the authorising and measures for construction.

[10] DESWAT aims diminishing the flood impact by assuring permanent hydrologic monitoring and floods prognosis.

  DOI: 10.5775/fg.2067-4635.2011.034.i

population, both structural and non-structural measures have been initiated.

Structural measures include anti-erosion and hydrotechnical works. Due to their relatively advanced status of degradation, many of them require rehabilitation and extending works.

Non-structural measures represent a complementary support to the structural ones. They need to be developed so as to allow the population's adaptation to the flood risk and *living with them.*

For this, an increased attention should be given to: extending insurances, proper use of floodplains, training and educating of the population, improving hydro-meteorological monitoring and alert systems.

ACKNOWLEDGEMENTS

The research was accomplished within the doctoral training programme and supported by a POSDRU grant, financed by the Social European Fund (SEF).

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 167-176
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.035.i

Observation of Unusual High Particulate Mass and Number Concentration during Traffic Ban Hours of the 2009 Car Free Sunday in the Brussels Urban Area

Peter VANDERSTRAETEN[1], Michael FORTON[2], Olivier BRASSEUR[3], Yves LÉNELLE[4], Annick MEURRENS[5], Zvi Y. OFFER[6]

1 IBGE-BIM, Brussels Institute for the Management of the Environment, Laboratory for Environmental Research, Gulledelle 100, B-1200 Brussels, Belgium, e-mail: pvd@ibgebim.be
2 IBGE-BIM, Brussels Institute for the Management of the Environment, Laboratory for Environmental Research, Belgium, e-mail: mfo@ibgebim.be
3 IBGE-BIM, Brussels Institute for the Management of the Environment IRCEL-CELINE, Belgian Interregional Cell for the Environment, Belgium, e-mail: brasseur@irceline.be
4 IBGE-BIM, Brussels Institute for the Management of the Environment, Laboratory for Environmental Research, Belgium, e-mail: yle@ibgebim.be
5 IBGE-BIM, Brussels Institute for the Management of the Environment, Laboratory for Environmental Research, Belgium, e-mail: ame@ibgebim.be
6 Department for Solar Energy and Environmental Physics, The Jacob Blaustein Institute For Desert Research, Ben Gurion University, Sede Boquer Campus, 84990, Israel, e-mail: offer@bgu.ac.il

Received on <February, 4>, revised on <March, 7>, accepted on <April 29, 2011>

Abstract

Every year, since 2002, the Brussels authorities organize a car free day on the third Sunday of September. This very interesting experience has revealed some valuable information concerning traffic-related gaseous pollutants and particulates. On the car free Sunday of 2006 very high PM10 and PM2.5 mass concentrations were measured, along with very low concentrations for nitrogen oxides, carbon monoxide and dioxide. The car free Sunday of 2009 also showed very interesting results. During the traffic ban hours, particulate mass concentration and particulate number concentration peaked to one of the highest values for the whole year 2009. Black Carbon however was the only measured particulate component whose concentration continued to decrease during the traffic ban period.

Keywords: *car free Sunday, PM10, PM2.5, black carbon, particle mass concentration, particle number concentration*

Rezumat. Observaţii asupra masei şi concentraţiei neobişnuit de mari ale particulelor în suspensie înregistrate în duminica fără trafic a anului 2009, în aglomeraţia urbană Bruxelles

Începând cu 2002, autorităţile bruxeleze au instituit în fiecare an o zi în care traficul este interzis, în cea de-a treia duminică din luna septembrie. Această experienţă foarte interesantă a pus în evidenţă informaţii valoroase privind sursele gazoase de poluare, consecinţă a traficului intens şi particulele în suspensie. În duminica fără trafic a anului 2006, au fost înregistrate concentraţii extreme ale PM10 şi PM2,5, împreună cu concentraţii scăzute ale oxizilor de azot, monoxidului şi bioxidului de carbon. Duminica fără trafic a anului 2009 a evidenţiat, de asemenea, rezultate interesante. Pe parcursul orelor cu trafic interzis, masa şi concentraţia numărului de particule în suspensie au atins valori dintre cele mai ridicate din 2009. Carbonul elementar (funinginea) a rămas singurul component măsurat a cărui concentraţie a continuat să descrească pe parcursul perioadei de trafic interzis.

Cuvinte-cheie: *duminica fără trafic, PM10, PM2,5, carbon elementar (funingine), masa particulelor, concentraţia particulelor*

GENERAL SITUATION AND METHODOLOGY

The air pollution telemetric network in the Brussels Capital Region consists of eleven fixed stations, located in different types of urban environment (traffic, residential, industrial and urban background), measuring a selection of several pollutants: nitrogen monoxide and dioxide, ozone, sulfur dioxide, carbon monoxide, carbon dioxide, benzene, mercury vapor and the PM10 and PM2.5 mass fraction of the suspended particulates (particulates with an equivalent diameter up to 10 or 2.5 µm). The presence of nitrogen oxides is monitored in all 11 measuring sites, PM10 in 6 locations and the PM2.5 mass concentration is simultaneously measured in five of the six PM10 locations. PM10 and PM2.5 mass concentrations are measured by means of TEOM 1400Ab continuous instruments (*Tapered Element Oscillating Microbalance*), all equipped with FDMS 8500 modules (*Filter Dynamics Measurement System*). Nitrogen oxides are measured by ThermoFisher NO_X-analyzers, model 42C or 42i.

The EU air quality objectives from Directive 2008/50/EC are respected for most pollutants in most of the Brussels measuring sites. However, full compliance is still problematic for NO_2 at traffic oriented sites and for PM10 at sites along the industrial and economic axis of the Region. The NO_2 limit value, 40 µg/m^3 as the annual average, is to be respected from 2010 and since 2005 the PM10 daily limit value of 50 µg/m^3 may not be exceeded more than 35 times per year. Observations of the average NO_2 concentrations for Saturdays and Sundays and of the number of PM10 exceedings during the weekend, make clear that emission reductions, even as drastic as lowering the every day emissions to the actual average weekend emissions, will not enable to meet the air quality objectives in all Brussels measuring sites (Vanderstraeten, 2010b).

Over the past few years (2004-2010) the annual average NO_2 concentration level reached about 50 to 55 µg/m^3 in a street canyon, about 42 to 46 µg/m^3 in sites exposed to the traffic but situated in a better ventilated area, about 37 to 42 µg/m^3 in urban sites and 27 to 30 µg/m^3 in residential or urban background sites. On Saturdays the mean concentration is around 48 to 52 µg/m^3 in the street canyon, about 38 to 42 µg/m^3 in the exposed sites and about 24 to 28 µg/m^3 in the urban background sites. On Sundays the mean concentration is around 40 to 42 µg/m^3 in the street canyon, about 30 to 35 µg/m^3 in the exposed sites and about 20 to 24 µg/m^3 in the urban background sites (IBGE technical report, 2009a).

Over the past decade (1999-2010) a slow downward tendency of PM10 levels was observed. The PM10 annual average at the different sites in the Brussels area ranges from about 27 to 30 µg/m^3 for the urban background and suburban site to 30-35 µg/m^3 at the traffic site along the economic axis, to hardly less than 40 µg/m^3 at the industrial site of the naval Port. Although the EU limit value for the annual PM10 average concentration (40 µg/m^3) was respected in all Brussels sites since 2005, the limit value for the daily average concentration was systematically violated in two sites situated along the industrial and commercial axis, and occasionally, this was also the case at some of the other sites. For the years 2007 and 2009, due to several periods of poor dispersion during the winter months and the frequently observed formation of secondary aerosol during the spring, at the start of the agricultural season, this limit value was respected only in one, respectively in two of the six PM10 sites.

Since June 2008, at the Woluwe traffic site situated along a highway leading traffic into Brussels, the particulate number concentration is also measured, for 31 different particulate classes with equivalent diameters ranging from 0.25 µm to 32 µm, by means of a Grimm Laser light scattering spectrometer model 365. Since July 2009, at the same site, the mass concentration of ‘Black Carbon’ is measured by means of an aethalometer, Magee Scientific model AE22-ER. Over the past years air pollution by particles, the role of traffic, source appointment and the chemical composition were subject to numerous studies in Europe and the USA (Almeida et al., 2006; Hansen et al., 2010; Harrison et al., 2001; Holmes et al., 2007; Ruuskanen et al., 2001).

TRAFFIC RELATED GASEOUS POLLUTANT LEVELS DURING CAR FREE SUNDAYS

On all previous car free Sundays (2002-2008) a clear concentration decrease was observed for traffic related gaseous pollutants, but this was generally not the case for the PM10 and PM2.5 mass concentration. Unlike for the gaseous pollutants, relatively high PM mass concentrations were measured during the 2003 car free Sunday and in 2006 the daily PM10 limit value was even exceeded (Vanderstraeten, 2010a).

On Sunday, 20 September 2009, for the eighth time since 2002, a car free Sunday was organized by the Brussels Authorities. From 7:00 till 17:00 h UT (UT: Universal time or GMT), corresponding to 9:00 till 19:00 h local time in the summer, nearly all motorized traffic was banned on the roads over the entire Brussels Capital Region. The use of Public transport was free and besides the busses from the Brussels Public transport company, exceptions were given to a limited number of taxis, to emergency services and, on request, to a few thousands individuals. During the traffic ban hours the speed limit was set at 30 km/h.

The day was characterized by mild meteorological conditions: a temperature inversion close to the surface from midnight until 7:00 h UT, rather high relative humidity (85 to 90%) in the morning which decreased towards the afternoon (60 to 70%), weak wind (1-2 m/sec) until 9:00 h UT

  DOI: 10.5775/fg.2067-4635.2011.035.i

and moderate wind (2-3 m/sec) in the afternoon, with the temperature rising from 15°C in the early morning to about 21°C in the afternoon. Between midnight and 8:00 h UT the wind was mainly coming from the South, but then suddenly it changed direction and began blowing from north-northwest until late in the evening, importing polluted air masses with secondary aerosols already formed over the western part of Belgium. In Brussels the clear morning sky was replaced by a thin cloud cover and a reduced visibility for the rest of the day. The boundary layer height computed from ECMWF (*European Centre for Medium Range Forecast*) fields, was about 60 m until 6:00 h UT, then it increased progressively during the morning to reach about 950 m in the afternoon. Therefore, the meteorological conditions can be considered as relatively unfavorable to pollutant dispersion during the night and the early morning, but rather favorable during the late morning and the afternoon.

The results of the traffic ban can be read easily from the graphs representing the concentration evolution on the car free Sunday, an average Sunday and an average working day during the period May–September 2009 (Fig. 1). The concentration decrease is best seen in a road tunnel where the concentration levels are much higher than in the ambient air and where the influence of the meteorological conditions on the concentration is less important. Figure 1 represents the concentration of NO in a road tunnel leading to the centre of the city. Before and after the traffic ban hours the concentration on the car free Sunday (in the front graph) follows that of the average Sunday. A sharp and sudden decrease of the concentrations can be observed at 5:30 h UT, even before the official start of the traffic ban period. By the end of that period (17:00 h UT), when the traffic returns, a sudden increase of the concentrations can be seen. Similar trends are also obtained for NO_2 and CO, for any of the car free Sundays and for the average of all eight car free Sundays so far organized.

Similar, but less striking observations could be made in the past, for the traffic-related gaseous pollutants at traffic oriented ambient stations. Since the ambient concentrations on one particular day are strongly dependent on meteorological conditions, it is more appropriate to represent the average situation over all eight car free Sundays and to compare it to the average situation of all Sundays and all working days during the period May–September of the years 2002-2009, as illustrated in Figure 2. For this traffic site, similar trends are obtained for the other traffic-related gaseous pollutants NO, CO and CO_2.

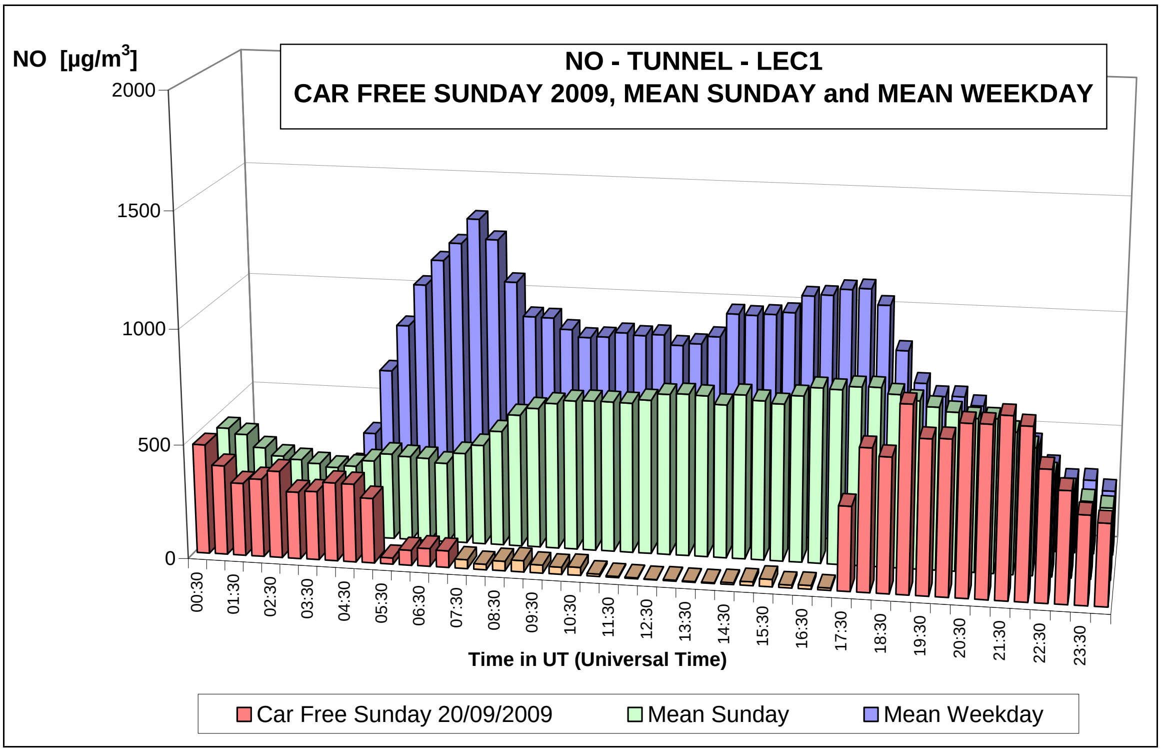

Fig. 1. Road Tunnel NO concentration – Car Free Sunday 20/09/2009, average Sunday and average working day during 'May-September 2009'

DOI: 10.5775/fg.2067-4635.2011.035.i

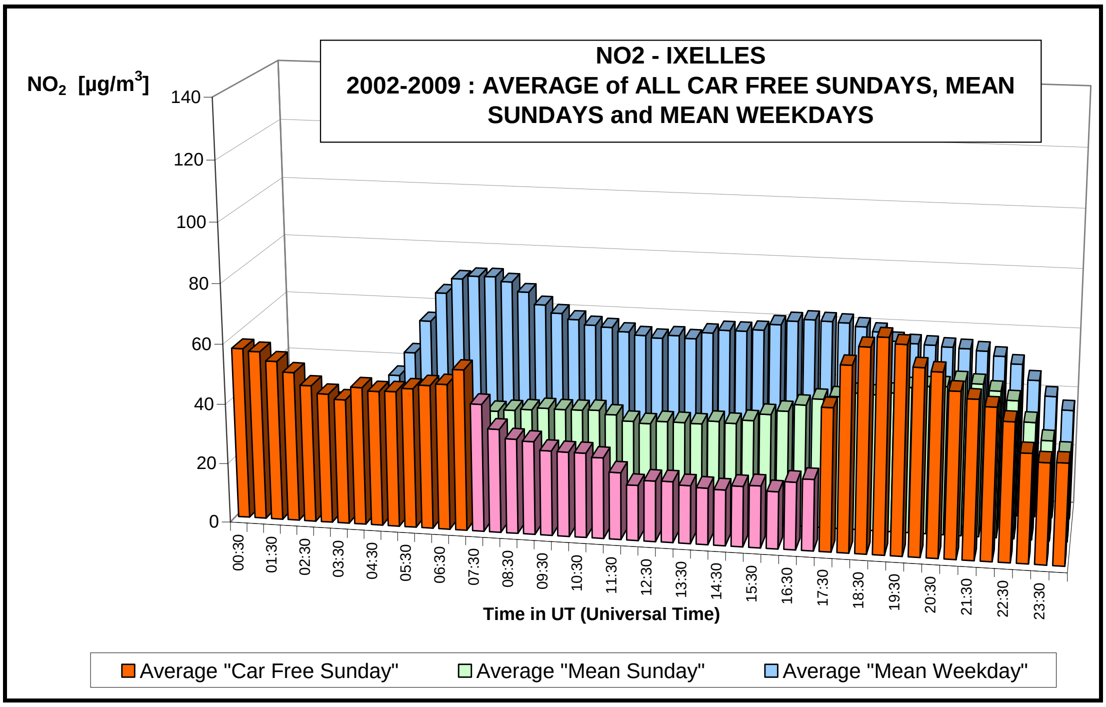

Fig. 2. NO_2 at a traffic oriented site - Average of all eight car free Sundays (2002-2009), average Sunday and average working day during May – September 2002-2009

In spite of the dependency on the prevailing meteorological conditions, the concentrations of the traffic-related gaseous pollutants were always found to be lower during the traffic ban period compared to the same period on an average Sunday or average working day, with an exception for the short peak at noon during the 2009 car free Sunday. A sudden concentration change always appeared at the beginning and at the end of the car free period with a clear sink of the concentration in between. Furthermore, a decrease of the NO_2 concentration was observed in all eleven Brussels measuring sites, in traffic oriented as well as in urban background and suburban sites (IBGE technical report, 2009b). This observation makes clear that the NO_2 problem with respect to the EU limit value could be solved if local traffic NO_X emissions were to be reduced drastically.

PM10, PM2.5 and Black Carbon during the Car Free Sunday

The PM10 and PM2.5 concentrations on the car free Sunday of 20 September 2009 were higher than on an average Sunday or average working day during the period May–September 2009. Most surprising however was the sharp concentration increase during the traffic ban hours, peaking at around 10:00h UT, followed by slowly decreasing but still elevated concentrations until the end of the interdiction time. This can be read from the Figures 3 and 4 representing, for the Molenbeek site, the concentration evolution respectively for PM10 and PM2.5 on an average Sunday, an average working day and the 2009 car free Sunday. For the readability of the graph the high concentration levels of the car free Sunday are moved to the back. Although the individual half hourly values of the car free Sunday are compared to computed average values for the mean Sunday and working day, these values are exceptional high.

Similar results were obtained in all Brussels sites measuring PM10 or PM2.5. The car free average daily PM10 and PM2.5 values respectively ranged from 47 to 64 µg/m³ and from 38 to 52 µg/m³ with daily PM10 averages exceeding the 50 µg/m³ limit value in five of the six PM10 sites. On a total of eight car free Sundays, the daily PM10 limit value was exceeded twice, in 2006 and 2009, and it failed to do so in 2003. During the interdiction hours, the PM10 and PM2.5 levels were about two times higher than during the rest of the day: the traffic ban average concentration at the different sites ranged from 66 to 93 µg/m³ for PM10 and from 58 to 76 µg/m³ for PM2.5. As it was the case during the 2006 car free Sunday, the PM2.5 mass concentration represented about 80 to 90% of the total PM10 mass concentration. For all stations, the maximum half hourly values measured during the traffic ban hours, were ranging between the 99.3 and 99.8^{the} percentile of the whole year 2009 (IBGE technical report, 2009b).

  DOI: 10.5775/fg.2067-4635.2011.035.i

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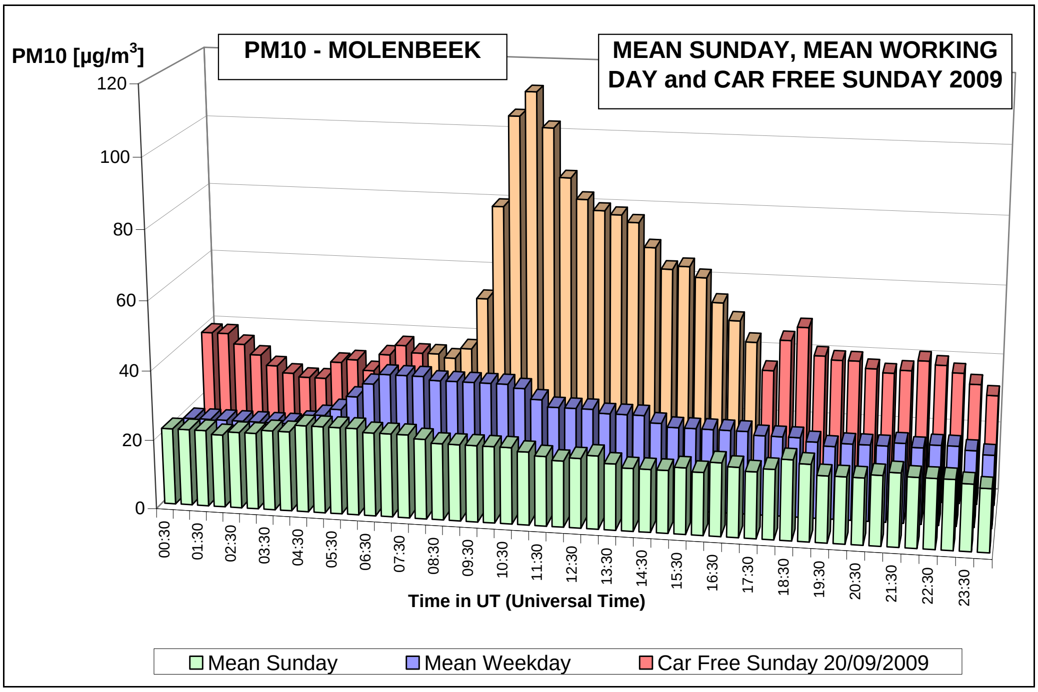

Fig. 3. PM10 mass concentration at Molenbeek - Average Sunday and average working day during 'May-September 2009' and Car Free Sunday 20/09/2009

At the beginning and at the end of the car free period one cannot observe a sharp or sudden concentration change, no concentration drop at the start nor a concentration increase at the end of the traffic free period, as is the case for traffic related gaseous pollutants such as NO, NO_2, CO and CO_2. These very high concentrations were obtained despite the absence of motorized traffic during that part of the day, with only minor contributions of domestic heating (15 to 21°C ambient temperature) and restricted industrial and commercial activities (Sunday).

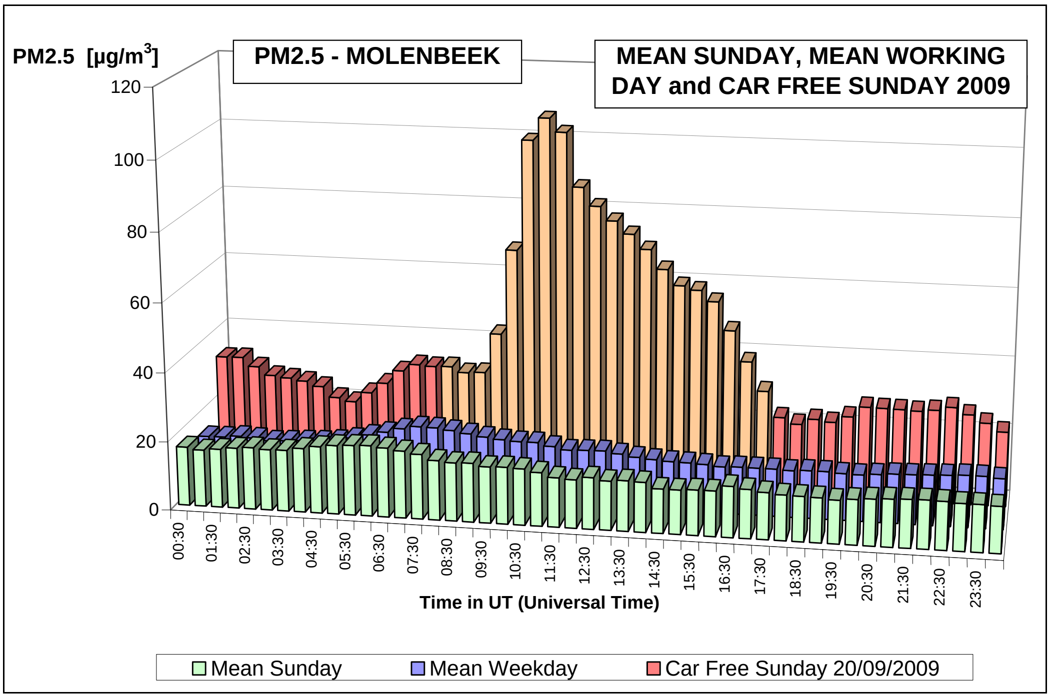

Fig. 4. PM2.5 mass concentration at Molenbeek-Average Sunday and average working day during 'May-September 2009' and Car Free Sunday 20/09/2009

High PM10 values and a high PM2.5/PM10 mass to mass ratio have already been observed several times under comparable conditions, also on Sundays or official holidays with far less traffic as usual, a limited contribution of domestic heating and industrial activity and even in the presence of low concentrations for the gaseous pollutants. Common factors seemed to be a mild temperature (8 to 20°C) and a high humidity range (75 to 90%). As in the case of this car free Sunday, the elevated PM10 concentrations cannot be explained by a poor dispersion (IBGE technical report, 2009a). The average concentration computed for all eight car free Sundays (2002-2009) organized so far is of the same order or slightly higher than the average concentration on all Sundays or all working days. Figure 5 represents the evolution of the average PM10 concentration for all the Car Free Sundays, the average Sundays and the average working days in the different periods May–September 2002-2009. Unlike it is the case for the traffic related gaseous pollutants, one cannot observe a sharp or sudden change in the PM10 concentration neither at the beginning nor at the end of the traffic ban period, nor a clear sink of the concentration during traffic ban hours.

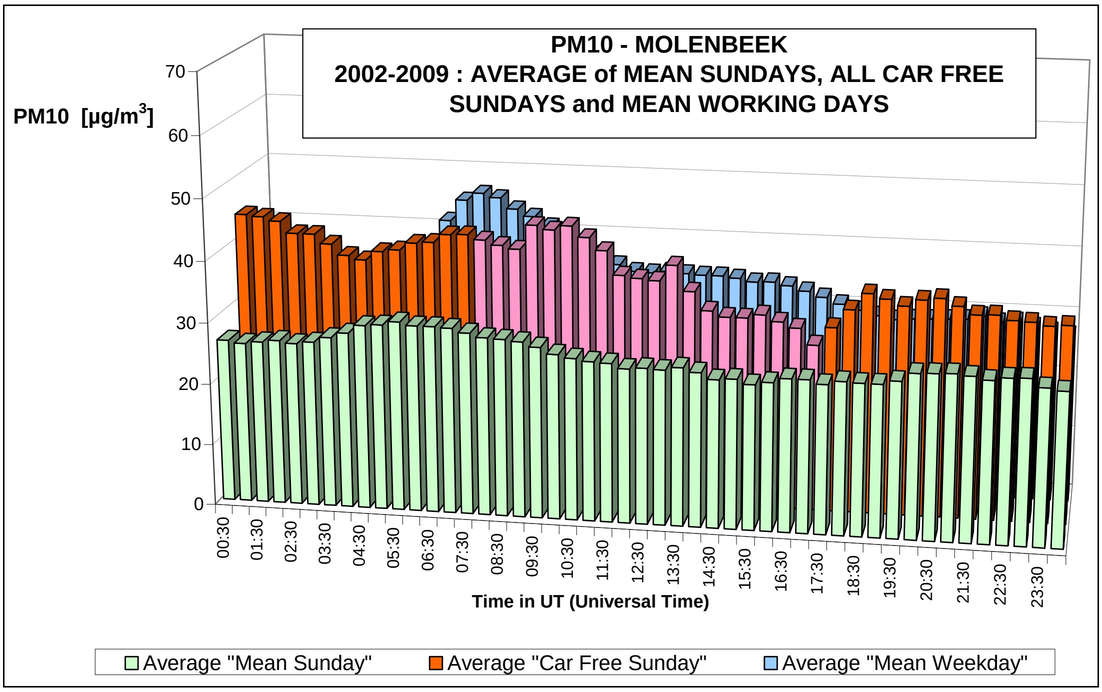

Fig. 5. PM10 mass concentration at Molenbeek - Average Sunday, average of all eight car free Sundays (2002-2009) and average working day during May – September 2002-2009

The evolution of the PM10 and PM2.5 concentrations was quite similar in all Brussels measuring sites, traffic as well as background stations (IBGE technical report, 2009b). At the Woluwe traffic site, the Black Carbon concentration however showed a continuous decrease during the traffic ban period, with a sharp decrease at the start and a sudden increase of the concentration as soon as the traffic returned. Figure 6 represents, for the period 18-22 September 2009, the half hourly values for PM10, NO and Black Carbon. During the traffic ban hours (centre of the graph) the evolution of the PM10 concentration is quite in opposition with that of Black Carbon, reflecting their different origin. The Black Carbon concentration does not always follow the PM10 pattern, rather it follows the pattern of the traffic related NO, as can be seen from the results on Saturday 19 and during the rush hours of Monday 21 September. Over a longer period, July 2009–June 2010, Black Carbon represents about 10% of the total PM10 mass concentration (IBGE technical report, 2010).

The TEOM-FDMS mass system also enables to register the loss of mass due to the presence of volatile or dissociating components, indicated as VO10 in the graph. The presence of a non-negligible quantity VO10 supports the idea that, as it was the case during the 2006 car free Sunday, the formation of secondary aerosol is responsible for the high PM mass concentration. Analysis of additional taken filters revealed that ammonium, nitrate and sulfate accounted for about 30% of the PM2.5 mass fraction. The mild temperature and high humidity are in favor of a stable ammonium nitrate aerosol (Stelson, 1982)

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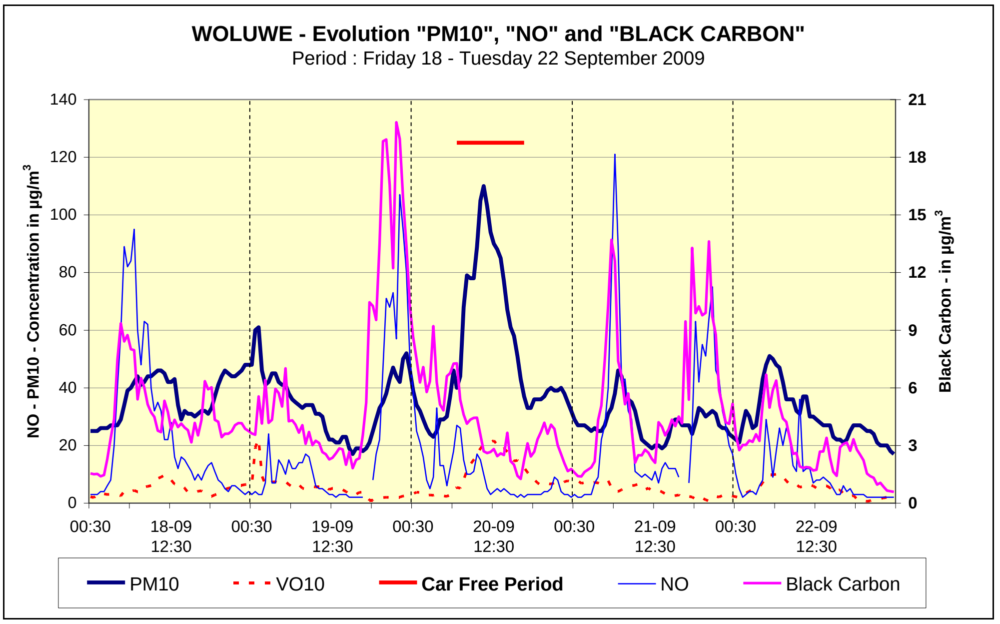

Fig. 6. Woluwe-Dynamic evolution for Black Smoke, NO, PM10 and the loss of volatile fraction (VO10) during sampling. Period Friday 18–Tuesday 22 September 2009

Particulate Number Concentration

At the Woluwe highway site, the number of particulates are counted and classified into 31 categories with equivalent diameters between 0.25 µm and 32 µm. For the classes with a diameter below 2.5 µm there is a striking increase of the particulate number concentration, especially during the traffic ban hours. For the smallest particulates, ranging between 0.25 and 0.28 µm, the increase of the numbers is most apparent at the beginning of the traffic ban, between 7:00 and 10:00 h UT (Fig. 7).

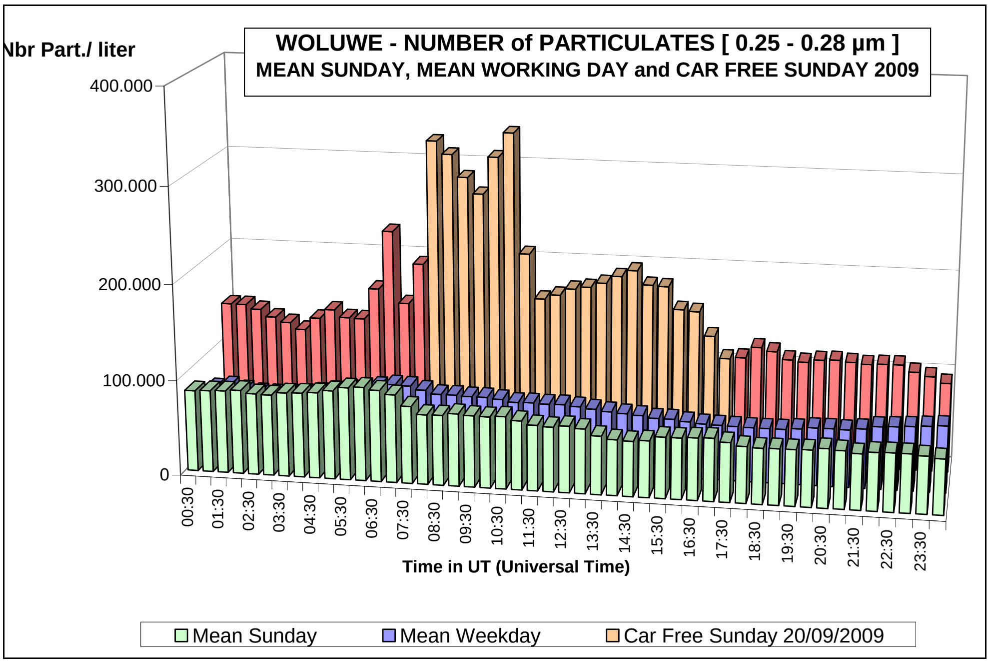

Fig. 7. Particulate Number concentration [0.25 – 0.28 µm] - Average Sunday and average working day during ‘May-September 2009’ and Car Free Sunday 20/09/2009

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For the particulates of a slightly larger size, with an equivalent diameter between 0.50 and 0.65 µm, the maximum number is reached only two hours later, between 10:00 and 12:00 h UT (Fig. 8). For a still larger particulate size, with diameter between 1.00 and 1.60 µm, the highest number concentration is observed between 10:30 and 13:00 h UT, collectively suggesting a time-dependent particulate growth process. The total number of all particulates greater than 0.25 µm reached a maximum of 1,200,000 (1.2 million) particulates per litre of ambient air between 9:30 and 10:00 h UT and represents one of the highest half hourly values (99.8^{the} percentile) of the year 2009 (IBGE technical report, 2010). High particulate numbers, above 1 million particulates (>0.25 µm) per litre air, are regularly observed during periods with formation of secondary aerosol. The record value since the start of the measurements end June 2008, is about 1,690,000 particulates per litre. This case proves, once again, that high particulate mass concentration, as well as high particulate number concentration may not automatically be associated with particulate emissions originating directly from traffic.

For the coarser fraction, particulates between 2.5 and 10 µm, the evolution of the particulate numbers of the 2009 car free Sunday follow that of an average Sunday. No peak value is observed during the interdiction hours (IBGE technical report, 2009b). In the absence of traffic and turbulences created by the traffic, there is less (re)suspension of the coarser particulates already deposited near or on the road surface.

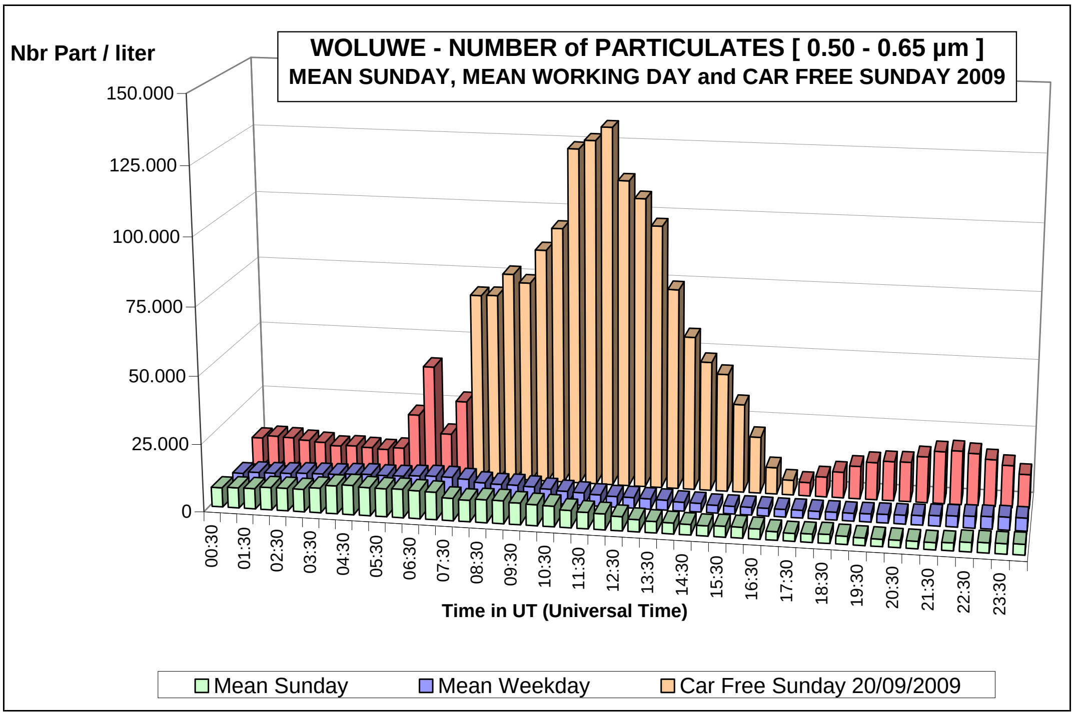

Fig. 8. Particulate Number concentration [0.50 – 0.65 µm] - Average Sunday and average working day during 'May-September 2009' and Car Free Sunday 20/09/2009

DISCUSSION AND CONCLUSION

For the organization of the different Car Free Sundays the Brussels Authorities achieved the maximum possible for banning the motorized traffic in the entire Brussels Capital Region. During the interdiction hours, the concentration of traffic related gaseous pollutants, mainly nitrogen oxides, decreased significantly in road tunnels. Generally this is also true for traffic oriented ambient measuring sites. Sharp and sudden concentration changes are normally observed at the beginning and at the end of the traffic ban hours. In the past, similar observations could be made for any of the car free Sundays, organized under different meteorological conditions. Averaged over all car free Sundays, the NO_2 concentration decreased at all measuring sites of the Brussels Capital Region, in the traffic stations as well as in the suburban and background stations. This observation makes clear that compliance with the EU limit value for the annual average concentration can and will be achieved, but only provided that further drastic NO_X traffic emission would be reduced.

During the car free Sunday of 20 September 2009, and especially during the traffic ban hours,

  DOI: 10.5775/fg.2067-4635.2011.035.i

very high PM10 and PM2.5 concentrations were observed in the whole Brussels urban area. During the interdiction hours and due to the importation of air masses polluted with secondary aerosol, PM concentrations levels were two times higher than those outside that period, when traffic was allowed. The absence of a sharp and sudden concentration change at the beginning and at the end of the traffic interdiction period seems to indicate that direct particle emissions from traffic only contribute to a slight extent in the total PM10 or PM2.5 mass concentration.

As it was the case for the 2006 car free Sunday, the daily average PM10 concentrations exceeded the EU limit value of 50 µg/m^3 in several PM10 measuring sites. This happened despite the absence of traffic during part of the day and a limited contribution of domestic heating and commercial or industrial activities. In both cases the formation of secondary aerosols was the main reason for the presence of these high PM concentrations. A strong indication for the non-negligible role of secondary aerosol is found in the fact that the PM2.5 to PM10 mass to mass ratio ranged as high as 80 to 90% and that the presence of volatile material, mainly inside the PM2.5 fraction was confirmed with about 30% of the total PM2.5 mass concentration identified as ammonium, sulfate and nitrate.

At the urban highway station the Black Carbon concentration seems well correlated with the traffic related NO concentration and hence to reflect the presence of traffic. Black Carbon is the only PM component showing a continuous concentration decrease during the traffic ban hours. A sudden concentration change was observed at the start of the traffic ban and a concentration increase as soon as the traffic returned. Averaged over a period of several months Black Carbon at this urban highway station represents about 10% of the total PM10 mass concentration.

Together with the PM10 and PM2.5 mass concentration, also the particle number concentration showed a sharp increase at the beginning of the traffic ban period. At its maximum, at 10:00 h UT, in the middle of the traffic ban hours, the total number of particulates with equivalent diameter above 0.25 µm reached one of the highest values of the year 2009. High number concentrations were obtained for all classes with diameters between 0.25 and 1.60 µm. For the coarser particulates, with diameter between 2.5 and 10 µm, no such increase was observed. The absence of turbulences created by the traffic put a limitation on the (re)suspension of that fraction.

Observations on car free Sundays lead to the conclusion that a traffic ban has an immediate and important beneficial effect on the concentration of traffic related gaseous pollutants and on the presence of Black Carbon in the ambient air, especially at traffic oriented measuring sites. A traffic ban has only a limited effect on the PM10 and PM2.5 mass concentration. The experience with the car free Sundays also helped to understand that the frequently occurring very high PM mass concentration are not necessarily caused by the particles directly emitted by the local traffic. Other phenomena, such as the presence of secondary formed aerosols may have a much greater contribution to the total particle mass and number concentration.

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 177 - 186
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.036.i

Land Use Change in the Bucharest Metropolitan Area and its Impacts on the Quality of the Environment in Residential Developments

Maria PĂTROESCU[1], Gabriel VÂNĂU[1], Mihai Răzvan NIȚĂ[1], Cristian IOJĂ[1], Annemarie IOJĂ[1]

[1] Centre for Environmental Research and Impact Studies, University of Bucharest
[1] Blvd. Nicolae Balcescu, sector 1, Bucharest, 010041, Romania,ccmesi@yahoo.com

Received on <January 13, 2011>, revised on <March, 1, 2011>, accepted on <April 24, 2011>

Abstract

The Bucharest Metropolitan Area (BMA) is undergoing a major and alert phase of reorganisation as a response to changes in the political, institutional, administrative, economic and social environment. Over the last 20 years land use has profoundly changed in the area under study, mainly by means of agricultural land conversion and the subsequent formation of residential and commercial areas. These two kinds of land uses were also expanded over industrial spaces in the Bucharest Metropolitan Area. Residential areas are showing a large quantitative increase and extremely non-concentrated dispersion, as well as complex and diverse typology. The present study analyses the possible direct and indirect consequences of land use change regarding the quality of the environment in the residential areas of the Bucharest Metropolitan Area (focusing on new residential districts). The results show that agricultural and forested areas are decreasing in surface and suffer from fragmentation, while residential areas are expanding in a chaotic manner, thus indicating the possible areas of conflict regarding the quality of the environment. The lack of coordination in the numerous institutional or private projects in real estate is the main cause of this situation. Public authorities administered the real estate projects between 1947 and 1990 (Communist Era) as the majority of the land and the constructed property were state-owned by law. After 1990, in the era of private property, in absence of legislation and convenient decision-making, the consequences of the privatization were difficult to manage (spreading of residential districts, overused and insufficient infrastructure in many areas, poor accessibility and waste management problems).

Keywords: *land use, agricultural land conversion, residential areas, quality of environment, Bucharest Metropolitan Area, Romania*

Rezumat. Modificări ale modului de utilizare a terenurilor în zona metropolitană Bucureşti şi impactul acestora asupra calităţii mediului din noile arii rezidenţiale

Spaţiul metropolitan bucureştean se află într-o fază de reorganizare cu dinamică rapidă şi complexă, ca răspuns la modificările ce survin în contextul politic, instituţional, administrativ, economic şi social. În ultimii 20 de ani, modul de utilizare a terenurilor din zona analizată a înregistrat profunde schimbări, îndeosebi prin conversia terenului agricol în spaţii rezidenţiale şi comerciale. Ultimele două categorii de utilizare a terenului au înregistrat de altfel o dinamică ascendentă şi în detrimentul spaţiilor industriale. Spaţiile rezidenţiale manifestă în zona metropolitană bucureşteană o extindere cantitativă importantă, larg diseminată teritorial, şi calitativ extrem de diversificată. Studiul analizează modificările în modul de utilizare a terenurilor care au impact asupra calităţii mediului din aceste spaţii rezidenţiale. Rezultatele analizei indică fragmentarea şi reducerea zonelor cu utilizare agricolă şi împădurite, dar şi extinderea dezorganizată a rezidenţialului,, cu efecte directe şi indirecte asupra calităţii mediului nucleelor rezidenţiale implicate. Explicaţia derivă din lipsa coordonării între extrem de numeroasele proiecte de investiţii instituţionale sau private în domeniul construcţiei de spaţiu locativ şi incapacitatea autorităţilor publice de a îşi exercita corespunzător noile atribuţii de reglementare şi decizie (în perioada 1947-1990 proprietatea imobiliară era administrată în cea mai mare parte de stat, iar după 1990 a urmat un vid decizional care a determinat disfuncţionalităţi în organizarea teritoriului care vor fi rezolvate extrem de dificil).

Cuvinte-cheie: *mod de utilizare a terenurilor, conversia terenurilor agricole, spaţii rezidenţiale, calitatea mediului, zona metropolitană Bucureşti, România*

INTRODUCTION

Land use change is a complicated problem in several respects: the balance between the natural (particularly forests) and the anthropogenic surfaces (urban areas at a different level of utilization and soil coverage); the organization and layout of various components of the environment in areas with high population density; the economic value and performance of various categories of land use, and others. Currently, more attention is given to the conservation of areas with well-preserved natural features, while the anthropization process of space is an on-going process (Sârbu, 2005).

It is worth noting the increased importance given to agriculture (and implicitly to farmland), as the consequence of the population's dependence on this sector, but also related to the increase of the market value of food production (as the population grows).

In densely populated areas, land planning have to ensure the co-existence of different land uses and solve the problem of the demand of land, which in many cases exceeds the physically available surface (Pontius, 2004).

The quality of life in human settlements largely depends on the use of land. This is true for either the smallest settlements with tens of people, or to megalopolises with tens of millions of people (Bogart, 2006).

The avoidance of the functional incompatibilities and the maintenance of the balance between privately used lands and those with social and economic usages, is a pressing concern in metropolitan areas, since here land use change occurs more often and faster (Verburg *et al.*, 2006, 2009).

On the European continent, the question of land use is a complicated issue due to the high density of population, settlements, road infrastructure, industrial facilities, logistics platforms and commercial areas (Bicík *et al*., 2001).

In addition, certain categories of land have an extremely severe system of administration and restricted use, for example those included in the area of protected sites, historical heritage sites, or areas having environmental and anthropogenic risk (Rufat, 2004).

In this context, any change that actually occurs in the use of land in metropolitan areas may have an impact on the quality of the environment.

THE AREA UNDER STUDY

The Bucharest Metropolitan Area (Fig. 1) represents a complex space still not under the coordination of a unified authority. BMA's administrative units are none the less related through a complex network of relations. Several scientific studies and political-administrative projects (Rey *et al.*, 2006) have demonstrated its factual existence. Geographically, it is situated in the Romanian Plain and bordering on Bulgaria to the South, along the Danube.

The Bucharest Metropolitan Area consists of 95 administrative-territorial units (ATU), of which 10 is a town (including the Bucharest Municipality) and 85 is a commune (CPUB, 2004-2005).

In terms of land organization, subsequent to the inflexibility of the Communist Era, rapid and unpredictable developments followed after 1990 (Bourdeau-Lepage, 2002, 2004) all over Central-Eastern Europe.

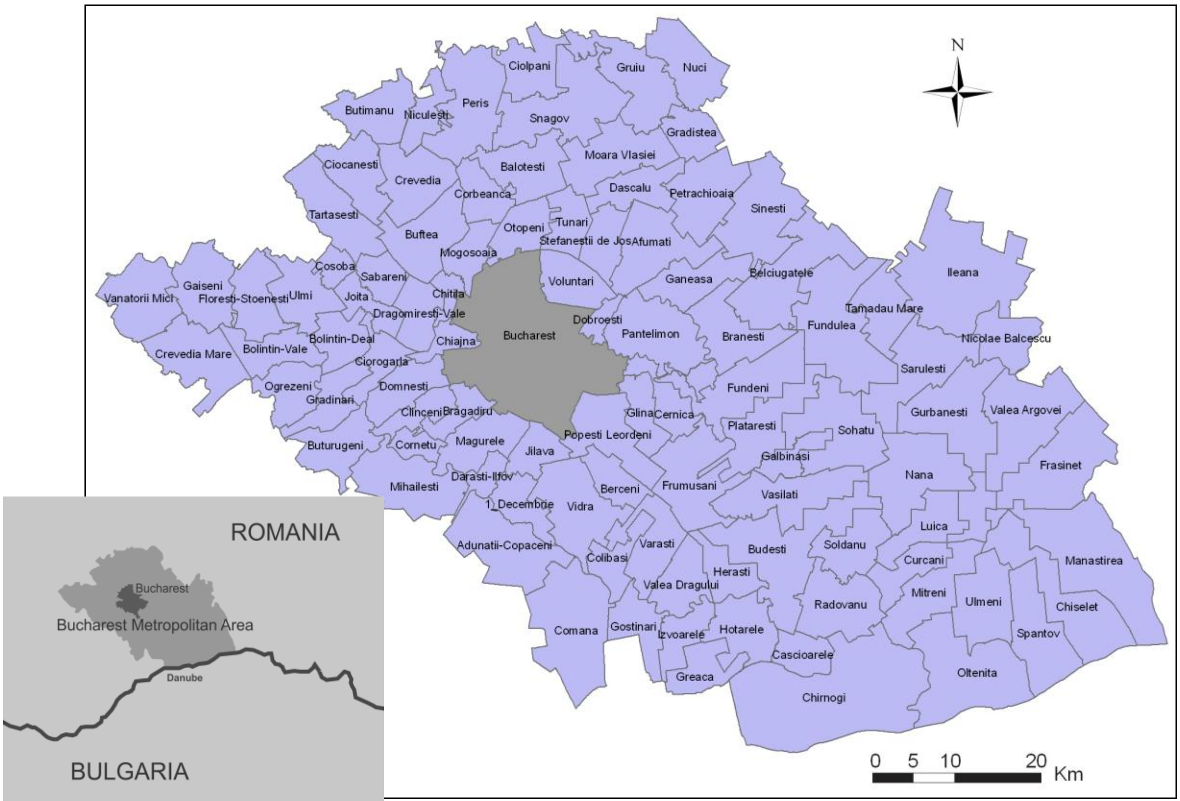

Fig. 1. The geographical location of the Bucharest Metropolitan Area and its administrative-territorial units

  DOI: 10.5775/fg.2067-4635.2011.036.i

The development model of Bucharest is very interesting and original. As the administrative centre of Romania and the largest urban centre in Southeast Europe (2 million inhabitants, 228 km^2) it would logically have been specialized in the service sector (Ianoş and Humeau, 2000; Ianoş, 2004). But the city also developed into a concentrated and complex centre in the industrial sector (heavy industry and chemical industry) in a planned communist type economy.

At the same time, the supply territory of the city is an agro-industrial area (Info Agricultural Sector). The expansion of the agricultural land to the detriment of unproductive areas was the consequence of the state policy. The wooded areas were nonetheless among the land uses vigorously protected by the communist state.

This land-use pattern is differently reflected in the living standard of the communities. The ATUs, in the vicinity of Bucharest, were characterized by traditional or modified rural lifestyle (even most of the citizens in cities like Buftea or Olteniţa), which then resulted in a specific organization of the space. The hearths of towns and villages formed a relatively compact housing unit, surrounded by farmlands, vineyards, orchards, meadows, forests and lakes.

At present, agricultural land use has been completely disarranged around Bucharest and it is correlated closely with the distance from the city. In the proximity of the capital there have been developed numerous residential projects, which have fragmented the farmland (Pătroescu *et al.*, 2009). Areas of strong rural character have been maintained by the use of land, while their accessibility has reduced.

According to the National Institute of Statistics (NIS), in 2006, the administrative-territorial units of the Bucharest Metropolitan Area totalled approximately 524 000 ha, of which 23 787 ha was for Bucharest. Population was estimated at about 2.6 million inhabitants, from which 2 million lived in Bucharest.

DATA AND METHODS

The present study is based on statistical data generated by the National Institute of Statistics, and it is aimed at how to quantify land use changes that have occurred in the period 1990-2007. A correlation is assumed between the reduction of the weight of arable land and the expansion of residential areas, although not directly proportional.

The amendments made, for example the establishment of new communes or the redrawing of boundaries, etc., in the organization of administrative-territorial units of the Bucharest Metropolitan Area, should also be considered. This explains the differences in total area between 1990 and 2006.

The ESRI ArcMap 9.3 software package was used to highlight the difference between the communication channels, especially between roads and residential areas (the areas which are poorly covered by road network), and to represent the position of the new residential developments regarding the unorganized dispersion of the housing units, the fragmented nature of the new settlement nuclei and the changes in the use of land.

A review was conducted about the information related to new residential projects around Bucharest and it was based on data obtained from the developers, from statistics on the number of housing units and areas, and as well as from the completion date and the means of access. Field observations were made on the distribution and structure of residential areas by team members during the period 2006-2010 and it proved to be also useful. The European reference datasets for land use (Corine Land Cover 1990 and 2000) have also been used for comparison.

RESULTS

In relation to the land use in the Bucharest Metropolitan Area, the results primarily reveal the existence of distinct categories of development in rural and urban areas.

The defining phenomena for rural areas in the Bucharest Metropolitan Area, in terms of land use, were the decrease of agricultural areas, the fragmentation of agricultural property, the reduction of forest cover, forest fragmentation and the expansion of urban areas (especially through residential areas).

In urban areas, related to the use of land, the increase of coverage with artificial surfaces and the reduction of green areas were observed.

The reduction of the agricultural land is a primary consequence of the specifically destructuring land recovery system of the Communist period.

Characterized by a certain economic inefficiency hidden by inaccurate statistical reporting, the Communist system promoted an agriculture developed on large areas. After 1990, the centralized system of land management was abolished and most of the equipment lost functionality. The average farm size reduced to approximately 2.5 hectare.

The analysis of data, generated by the NIS, demonstrates the reduction of the agricultural land in the area under study, with approximately 4 594 hectares (representing approximately 0.88% of the

DOI: 10.5775/fg.2067-4635.2011.036.i

total metropolitan area) during the period 1990-2006 (Table 1).

Table 1. Categories of land use within the Bucharest Metropolitan Area

Land use (ha)	1990		2006	
	BMA	**Bucharest**	**BMA**	**Bucharest**
Farmland (total)	391411	4788	386817	4356
Forests	52534	680	52118	611
Water	25672	906	26029	908
Roads and railways	16211	3240	16858	3212
Courtyards and constructions	36211	14025	39465	14607
Unproductive land	1230	21	2612	93
Non-agricultural land (total)	131858	18872	137082	19431
Total	**523269**	**23660**	**523899**	**23787**

Source: the National Institute of Statistics

In 1990, the ratio of agricultural land in the metropolitan area stood at 74.80%, indicating the suitability of natural environmental conditions for this activity, but also the feature of rurality, specific to most of the administrative-territorial units.

In the administrative area of Bucharest, but actually outside the city, a considerable surface of land was in agricultural usage. In 1990, this area was 4,788 hectares and by the year of 2006 the area reduced to 4 356 hectares. The decreasing ratio of the agricultural land in Bucharest in the period 1990-2006 is more significant than in the metropolitan area as a whole, amounting up to 1.82%.

The decrease of the agricultural land continued untill 2008, the period of 2006-2008 being considered the peak of a real estate boom, after which several real estate projects foiled, although the land had been purchased. Most lands, acquired for property development in the Bucharest Metropolitan Area, are green areas and have agricultural potential, but their cultivation was unlikely until the actual phase of construction came (sometimes after years), because companies or individuals, who have purchased them, were not specialized and were not willing to invest in agriculture. They waited only for an opportunity to sell.

The fragmentation of the agricultural land is an general feature in Romania at national level. The average farm size was reduced immediately after 1990 to approximately 2.5 hectares. Then it was followed by a very long process of consolidation of the agricultural land (especially arable lands) under the pressure of economic efficiency and profitability factors (Tofan, 2006). This process of consolidation was promoted by the subsidies granted by the Romanian state but it's still an undergoing process.

The accession of Romania to the EU gave a strong impetus even from a political and economic point of view (Bruna Zolin, 2007), and drew significant number of investors in agriculture, attracted by the extremely low price of land. In addition, most small farms are actually consisting of separate plots (Fig. 2).

Fig. 2. The fragmentation of agricultural land (in the commune of Săbăreni)

In 1990, forests represented 10.04% (52,534 hectares) from the total area of the Bucharest Metropolitan Area. The evolution of the forests in the Bucharest Metropolitan Area shows a reduction of 416 hectares in the period 1990–2010, for the whole analyzed area. The reduction has a particular importance, especially for urban areas, where forest was planted. Such areas are for example Bucharest or the administrative territorial units adjacent to it.

In Bucharest, the reduction of the forest cover, during the period 1990–2006, was 69 hectares, which represents a significant area converted into an area for real estate developments (Table 2).

The fragmentation of forest areas has occurred not only for the reason of building new arteries of communication (for example the Bucharest-Piteşti highway), but also of the investments of real estate

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developers in lands located near the forest (for example the Băneasa forest).

Statistics, provided by the NIS, for the use of land within the Bucharest Metropolitan Area were also confirmed by the analysis performed on data sets by Corine Land Cover 1990 and 2006 (Table 2).

There are a number of differences resulting from the different methodology and data acquisition. While statistical data were provided by local and central authorities to the NIS, CLC data are descended from the analysis of satellite images. The two data sources have a different typology and CLC data are characterized by higher number of land use classes.

Table 2. The categories of land use within the Bucharest Metropolitan Area based on the Corine Land Cover data

Land use (ha)	CLC 06	CLC 90
Artificial surfaces	59666	56574
Agricultural areas	386817	389511
Forest and semi-natural areas	59932	60933
Wetlands	3839	3630
Water bodies	13048	13020

Table 3. Details of artificial surfaces according to land use categories in the Bucharest Metropolitan Area based on Corine Land Cover data

Details of artificial surfaces (ha)	CLC 06	CLC 90
Urban / rural tissue	48908	46557
Industrial and commercial units	7660	7309
Transport infrastructure (roads and railways)	494	119
Airports	954	735
Parks and public gardens	1088	1346
Sport and recreation infrastructure	562	508

The obtained data was analysed by using the program ArcGIS 9.3 (ESRI), after the databases of Corine Land Cover (CLC) 2006 and 1990 were made equivalent to each other by the help of a system of equivalent classes for 1990 and 2006. The occupied area by each class was determined by using the Hawth's Tools extension. The results confirm the statistical data generated by the NIS. The farmland is reduced with 2 694 ha and the difference observed when comparing to statistical data results appears by withdrawing of large areas from the agricultural circuit, just in the records of local authorities, but without such changes to occur also in fact (by changing the effective use).

In addition, the 2006-2008 period is a blooming period of effective property development by building residential areas in the Bucharest Metropolitan Area, while previous years have served to land acquisition and project preparation.

As for forest areas and semi-natural areas, the approximate reduction, based on CLC data, is of 1001 hectares.

The analysis of the data, referring to the detailed artificial surfaces according to land use categories, is quite relevant. The surface of settlements (residential urban/rural tissue) increased from 46.557 hectares in 1990 to 48.908 hectares in 2006 (Table 3).

The increase of 2 351 hectares within 16 years is considerable (147 ha/year), especially regarding that in most cities there are major areas of abandoned land (industrial space, vacant land, etc.).

The growth of the population in the Bucharest Metropolitan Area has been considered insignificant (coincides with the national average), while the rate of natural increase has a reduced dynamics.

Residential expansion, in these conditions, reflects the imbalances in the housing market related to the price of land available in the city and outside city, and also the disappearance of public authorities, as a factor of regulatory and land planning.

Industrial and commercial areas in the period under review had increased by 351 hectares, while numerous commercial platforms were developed. The conversion of the former industrial sites to other categories of land use was extremely slow, and was preceded by a long period to arrange the transfer of ownership.

There is a significant increase in the transport infrastructure, which was not the result of great road or rail infrastructure projects, but of building access roads required for new residential, commercial or logistics projects.

It is to note a significant reduction of green areas within the city area, Bucharest Metropolitan Area, as a whole, amounting 258 hectares. This reduction is explained by the improper management of the available land (green spaces were seen as the first solution to solve the problem of parking, for example), but also by the returning of land to former owners, followed by allocation to a more profitable use (residential, commercial and mixed).

DOI: 10.5775/fg.2067-4635.2011.036.i

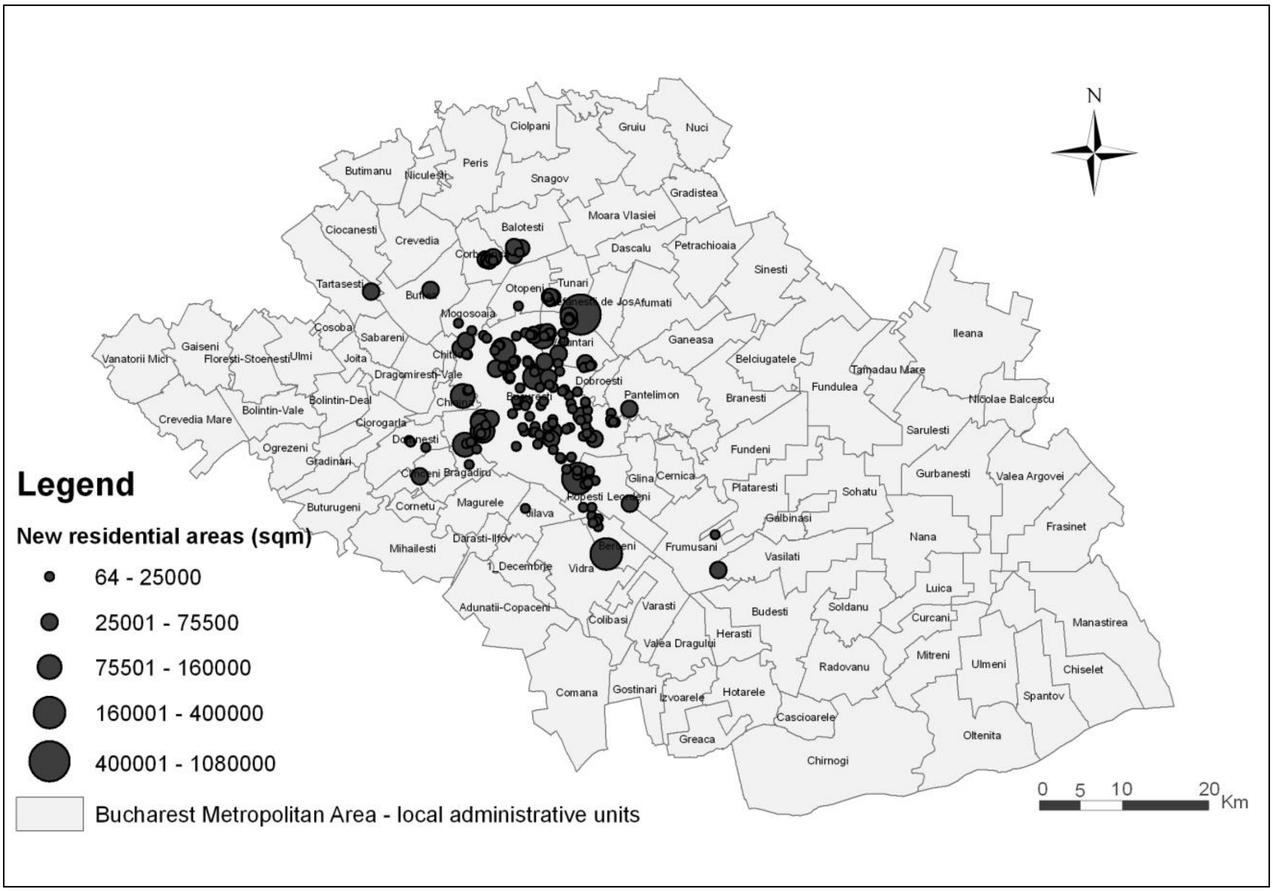

Fig. 3. New residential nuclei in the Bucharest Metropolitan Area (built after 1990 and ongoing)

Inventory of new nuclei and residential areas in the year 2009 has identified a number of 271 projects, completed or in progress (Fig. 3). Their size varies from 6 residential units and 309 m^2 (Prelungirea Ghencea) to 4600 residential units and 1.08 million m^2 (Cosmopolis). They are generally located close to Bucharest or even inside the capital giving some important extra densification to space, but there are also projects carried out at 30-40 km distance. In these institutional residential projects, the added buildings were constructed on direct labour and costs.

The major residential groups are outlined in the North of Bucharest (Vânău, 2009), where the area is more balanced in terms of environmental suitability (presence of oxygenated areas – lakes on Colentina and Herastrău Park, the forests in the North of the capital). As this area was covered and led to an overload of infrastructure (not only the road infrastructure), the southern part of Bucharest has also started to become a target for developers.

New residential areas have an organic connection to Bucharest, which provides them most of the residents, but they produce mutations in the use of land adjacent to territorial administrative units.

In the cities and communes in the first ring of settlements around Bucharest land owners have largely abandoned the agricultural use of land and seek fast profits by selling to real estate developers.

In terms of the typology of these new residential areas, related to the use of land and especially the occupation of the soil, field observations have revealed an extreme diversity, as evidence of their lack of concern for a judicious and uniform spatial organization.

One can still make a classification methodology of the new residential areas in terms of land use in three major categories: **unorganized residential areas**, **planned residential areas of expanded type** and **planned residential areas of compact type**.

Unorganized residential spaces (Fig. 4) are those, that were made by individual initiatives, by means of financial and material availability of the owner and they are usually built for their own use and not for recovery on the housing market. These are also characterized by fragmentation in some huge areas of land in relation to the land actually occupied by buildings. In most cases, there is only permission for construction and a master-plan document across administrative units is lacking.

  DOI: 10.5775/fg.2067-4635.2011.036.i

The road network is in the initial phase of land consisting roads and has an improvised character. Building adequate roads is considered only a problem to solve afterwards.

Planned residential areas of expanded type (Fig. 5) are ways of using land more efficiently, creating the premises for carrying out an existence in an area of rural settlement type (pollution, private green space), but with urban lifestyles and standards. Some are close gated communities (Rufat, 2003).

The institutionalized feature is given since the design phase and special attention is paid to effective use of land, since it was bought for great amounts of money, and after the sale it is expected to refund these amounts. At the core of this type of housing there are many examples of overloading the space with residential functioning, but examples of a lack in operating other functions and utilities (medical, educational, utility networks).

Residential nuclei of compact type actually represent transplantations of urban-type housing in rural areas. The land cover is the maximum and usually multi-storied buildings were built, including only small green areas.

DISCUSSION

Before 1990, there was a consistent homogeneity of different uses of land, regarding the territorial reorganization, decisions were initiated, evaluated and implemented unilaterally by the government, with the advantage of a uniform and timely approach.

After 1990, there followed a period of reorganization, including the organization in terms of land areas of the Bucharest Metropolitan Area, unfinished until 2010 and extended indefinitely under the impact of economic crisis.

The phenomenon with the strongest dynamic in the metropolitan area is represented by real estate development at the expense of agricultural, forested or semi-natural land. This leads to significant consequences regarding the quality of the environment in the metropolitan area as a whole, but especially regarding the environment quality in residential areas and in their proximity.

The expansion of residential areas determines the reduction and fragmentation of forested surfaces. These forests have multiple and important roles in the life of the neighbouring communities, especially when they were placed near large urban agglomerations, such as Bucharest.

Fig. 4. Unorganized residential space (Chiajna)

Fig. 5. Planned residential nucleus of expanded type (Paradisul Verde, Corbeanca)

Fig. 6. Planned residential nucleus of compact type (Domus Stil, Voluntari)

The establishing of a green belt around Bucharest is again a subject of debate (Pătroescu and Cenac-Mehedinţi, 1999; Pătroescu and Borduşanu, 1999), around patches of former large forests (Codrii Vlăsiei – Forests of Vlăsia), but effective actions are missing.

Forests represent one of the initial attractive factors in locating new housing projects. During the construction phase and afterwards, forests are fragmented in the beginning, and then their surface is gradually and continuously decreasing under the pressure of new residential units.

Fig. 7. Conflictual land usage in the Bucharest Metropolitan Area

Also, taking out important land areas from the agricultural production is an environmental problem, as the impact of agricultural land is lower than of residential areas (Pătroescu *et al.*, 2009). The conservation of these lands until a subsequent transaction is not likely to determine their ecological restoration, because the vicinity with residential areas and roads turns them frequently into non-compliant waste storage areas (CCMESI, 2008; Vânău, 2009).

The high productivity of agricultural lands has lost indiscriminately, because there is no rule in place addressing this mater. Once built, open spaces and farmlands cannot be reclaimed, unless extremely costly and specialized measures are implemented on a long timeframe.

Agricultural land use in areas dominated by residential space is also an environmental problem, especially if the activity of stock breeding and its potential in polluting the water sources is considered (Fig. 7).

Since many of the new residential projects are isolated from the main public infrastructure grids, they pressure, deteriorate and pollute local natural resources. One example is water resources. Both ground and surface water are increasingly used and polluted around the residential spaces in the Bucharest Metropolitan Area.

Sprawl-type development also brings habitat and biodiversity loss. Air and water pollution linked to new residential areas degrade the environment and further reduce biodiversity.

New constructions also steps up the erosion of land cleared for development. This consequently increases sediment suspension in bodies of water. As the land for natural ecosystems shrinks, there is less natural capacity to filter pollutants and detoxify waters and less capacity to recycle nutrients and compost organic wastes. As urban sprawl-type development increases in the Bucharest Metropolitan Area, the diversity of species and ecosystems is reducing. The loss of habitat and biodiversity are often irreversible.

Within settlements in the Bucharest Metropolitan Area, land use category change typically occurs at the expense of green spaces, replaced with residential and commercial areas. Inner-city green spaces have a key role in balancing the city in terms of climate and air quality characteristics, but have also well documented and important social functions (Pătroescu and Iojă, 2004; Marinescu, 2006; Nae, 2006; Iojă, 2008) .

Former industrial sites, present in the Bucharest Metropolitan Area, are important land reserves, where the industry has been deconstructed (Rufat, 2003, Rufat, 2004) and there is only a few major construction projects on ex-industrial units sites. The former industrial land could be an efficient alternative to reduce green spaces by covering them with other uses of land, but the process of reconversion of industrial sites has started only lately. The world economic crisis affecting Romania since 2008 will further slow the process.

The matter of residential space expansion determines adverse effects on the environment, not only per se, but also through its non-organized and non-regulated way of progression. A more compact and population growth related type of residential development in the Bucharest Metropolitan Area would be a better solution, but presently there is not awareness from the communities and the public authorities towards this phenomenon.

The areas of surfaces actually occupied with built space are often extremely low in comparison with the territory they fractured because of poor planning and unbalanced layout of the buildings. In addition, the unorganized expansion of residential space draws consequently an increase in vehicular traffic (Stanilov, 2003) and it is blamed as one of the major sources for the air pollution in metropolitan areas.

  DOI: 10.5775/fg.2067-4635.2011.036.i

Residential space expansion in Bucharest metropolitan area is a reality, but more research in understanding its consequences is necessary.

CONCLUSION

The restitution of property initiated after 1990 meant the revival of private initiative in the economy, including agriculture, land transactions and real estate market.

The period 1990-2010 represents a dynamic phase in terms of land use in the Bucharest Metropolitan Area, characterized by numerous transformations: speculative buying followed by non-use of land, extension of the built space, uncontrolled expansion of residential areas, development of business and logistics platforms which require intensive land consumption.

The consequences of the land use change in the Bucharest Metropolitan Area have had some negative effects on the environment through the conversion of areas with natural or close to natural features into residential nuclei, without efforts to try to control or make the process more efficient.

Further studies on these phenomena are extremely necessary in order to develop awareness and to provide appropriate solutions.

ACKNOWLEDGEMENTS

This article was conducted in the framework of **PN II IDEI 1925 project – Methodology of assessing environmental quality in residential spaces from metropolitan areas** (contract 1012/2008) funded by the Ministry of Education and Research - CNCSIS.

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  DOI: 10.5775/fg.2067-4635.2011.036.i

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 187-194
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.037.i

Quantifying Forest Ecosystems Fragmentation in the Subcarpathians between the Râmnicu Sărat and the Buzău Valleys, Romania, Using Landscape Metrics

Mihăiţă-Iulian NICULAE[1], Maria PĂTROESCU[2]

[1] Centre for Environmental Research and Impact Studies (CCMESI), University of Bucharest, 1 N. Bălcescu Ave., 010041 Bucharest, e-mail: *iulian_198@yahoo.it*
[2] Centre for Environmental Research and Impact Studies (CCMESI), University of Bucharest, 1 N. Bălcescu Ave., 010041 Bucharest, e-mail: *mpatroescu@yahoo.com*

Received on <January 11, 2011>, revised on <February 28, 2011>, accepted on <April 28, 2011>

Abstract

The Romanian Subcarpathian space has been the subject of continuous transformation during the last 2 centuries under the double impact of human activities and disruptive natural factors. Time and spatial dynamics of land use and coverage determined a major impact on the structure and functionality of the Subcarpathian landscape. In the Subcarpathians between the Râmnicu Sărat and the Buzău, the main tendencies in land use changes are highlighted by the decrease of forestry areas and increase of agricultural terrains, especially pastures and orchards, a consequence of the deforestation undertaken to answer local human needs. The fragmentation and the pronounced decrease of forestry ecosystems has been quantified by calculating and analysing landscape metrics, using land use and coverage maps derived from the Corine Land Cover 1990 and 2006 database. In the Subcarpathians between the Râmnicu Sărat and the Buzău, there has been registered a deforestation rate of 10.09% in the analysed period, but also an increase in landscape fragmentation. Thus, the number of forest patches increased by 10.96% and their average size decreased by 13.73%, while the shape remained unchanged. Landscape patches became more isolated, as the value of the average proximity index decreased by 42.07%. The study underlines the necessity of elaborating a strategy of protection and preservation for these ecosystems, aimed at increasing the reforestation rate and decreasing the fragmentation degree. A sustainable planning system of land use must be enforced in order to increase forest productivity and the uniformity degree of the Subcarpathian landscape.

Keywords: *landscape ecology, fragmentation, clearcutting, landscape metrics, Subcarpathians Curvature, Romania*

Rezumat. Utilizarea metricilor peisajului în cuantificarea fragmentării ecosistemelor forestiere din spaţiul Subcarpaţilor dintre Râmnicu Sărat şi Buzău, România

Spaţiul subcarpatic din România a fost supus în ultimele două secole unei continue transformări sub impactul activităţilor antropice, care s-au coroborat cu cele induse de factori naturali perturbatori. Dinamica spaţio-temporală a modului de utilizare şi acoperire a terenurilor a exercitat un impact major asupra structurii şi funcţionalităţii peisajului subcarpatic. În Subcarpaţii dintre Râmnicu Sărat şi Buzău, principalele direcţii privind schimbările modului de utilizare a terenurilor sunt evidenţiate de reducerea suprafeţelor forestiere şi creşterea în suprafaţă a terenurilor agricole, în special păşunile şi livezile, consecinţă a defrişărilor efectuate în scopul satisfacerii nevoilor umane. Fragmentarea şi reducerea accentuată a suprafeţei ecosistemelor forestiere a fost cuantificată prin calcularea şi analiza metricilor peisajului, utilizând hărţile de utilizare şi acoperire a terenurilor derivate din baza de date Corine Land Cover 1990 şi 2006. În Subcarpaţii dintre Râmnicu Sărat şi Buzău s-a înregistrat o rată de defrişare a pădurilor de 10,09% în intervalul analizat, concomitent crescând şi fragmentarea peisajului. Astfel, numărul patch-urilor a crescut cu 10,96%, iar dimensiunea medie a scăzut cu 13,73%, forma fiind nemodificată. Fragmentele de peisaj au devenit mai izolate, valoarea indicelui mediu de proximitate diminuându-se cu 42,07%. Rezultatele studiului subliniază nevoia de elaborare a unei strategii de protejare şi conservare a acestor ecosisteme, în scopul creşterii procentului de reîmpădurire şi reducerea nivelului de fragmentare. În scopul creşterii productivităţii acestora şi a gradului de omogenitate a peisajului subcarpatic trebuie implementate acţiuni de planificare durabilă a modului de utilizare a terenurilor.

Cuvinte-cheie: *ecologia peisajului, fragmentare, defrişare, metricii peisajului, Subcarpaţii de Curbură, România*

INTRODUCTION

Landscape transformation represents a consequence of human activities (Dumitraşcu, 2006) and of disruptive natural factors (Hansen and di Castri, 1992; Farina, 1998; Uuemaa et al., 2009).

The time diversification of land use generated contrasting landscapes, with a significant impact on species distribution (Primack et al., 2008).

The main human activities with a major impact upon the structure and functionality of landscape are: the intensification of agricultural activities, deforestation, the abandonment of agricultural lands in under-developed areas, but also the chaotic development of local communities (Farina, 1998; Burel and Baudry, 1999).

Habitats fragmentation induces negative effects upon a large number of animals and plants species (Farina, 1998), especially by increasing the isolation degree of habitats (Debinski and Holt, 2000; Watson et al., 2004).

Fragmentation implies the dissolution of habitats or large terrain units in smaller size units (Forman, 1977), the quantification of landscape fragmentation being the main method of analysis used for landscape structure dynamics (Bunce et al., 1993; Burel and Baudry, 1999).

The present study analyses land use and coverage changes in the forestry areas from the Subcarpathian region between the Râmnicu Sărat and the Buzău, during the 1990 – 2006 period.

MATERIALS AND METHODS

Study area

The study area is located in the Curvature Subcarpathians, in Buzău and Vrancea Subcarpathian units (Posea and Badea, 1984), overlapping Buzău and Vrancea counties (Fig. 1).

The analysed space is characterised by a deep rural character induced both by the absence of urban poles, the development of settlements with rural functions and aesthetics (Pătroescu and Niculae, 2010), but also by the prevailing agricultural land use (Pătroescu, 1996).

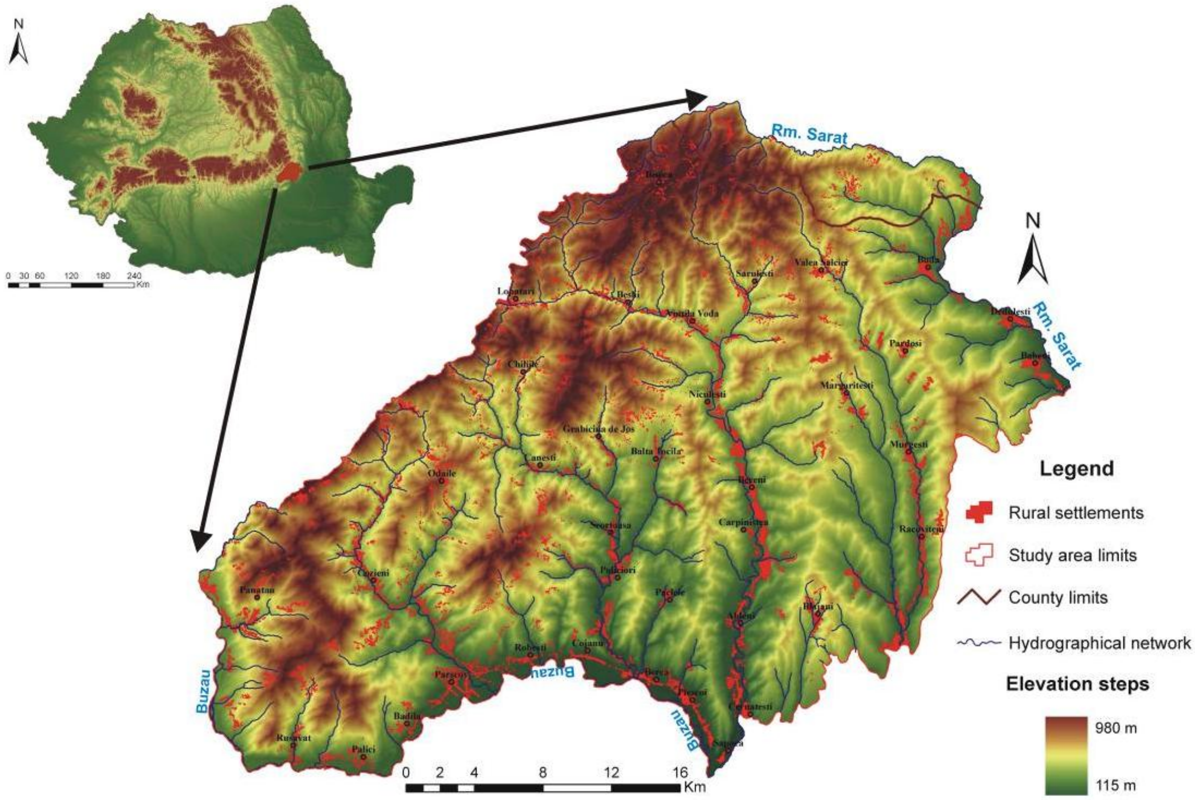

Fig. 1. Study area

Approximately 30% of the total area is represented by forests, while pastures and orchards cover about 33% of the area.

The main activities with direct impact on the fragmentation of Subcarpathian rural landscapes are: pasturage, orchards development and wood processing (Pătroescu, 1996).

Land use and coverage is conditioned by the morphologic and morphometric features of the relief, corroborated with the geological structure of

  DOI: 10.5775/fg.2067-4635.2011.037.i

the Subcarpathian area. Altitudes are between 115 and 980 meters, with the highest values being concentrated in the Northern and North-Western areas, at the contact with the mountainous Carpathian units.

Data

In the analyse it has been used the spatial database of the European Environmental Agency (EEA) as part of the Corine Land Cover (*CLC*) project, for the years 1990-2006, (*CLC 1990* and *CLC 2006*, data available at http:// www.eea.europa.eu/ data-and-maps /data/ corine -land- cover-1990 - raster and http:// www. eea.europa.eu/ data-and-maps/ data/ corine- land-cover-2006- raster).

Initial data have been reprojected in the Stereo 70 projection system, using ArcGis 9.3.

The 20, and respectively 19 classes, of land use and coverage specific to the studied area, resulting from the 1990 and 2006 CLC models have been reclassified in 5 main classes according to the system terminology for the CLC model, level 2 (Geri et al., 2010) joining polygons with the same land use (Table 1).

Table 1. Description of the land use and cover classes

Land use and land cover class	CLC 1990-2006 Level 2	Description
Forest	3.1	Broadleaf forests, evergreen forests and mixed, associated with shrubs, trees canopy covering >50% of the area
Seminatural areas	3.2-3.3	Natural pastures, shrubs, temporary water courses, beaches along the river beds, lands affected by erosion, bare rocks, badlands with rare vegetation
Agriculture areas	2.1-2.2-2.3-2.4	Arable lands, pastures, orchards, vineyards
Water areas	5.1	Water-courses, natural lakes
Urban areas	1.1-1.3-1.4	Built areas, transport infrastructure, extraction sites

Source: Bossard et al., 2000

Fragmentation analysis

Landscape fragmentation, as well as land use and cover changes in the analysed time period were studied using three different methods: 1) landscape metrics calculation and analyse; 2) analysing changes in the number of small units, specific to forestry surfaces and 3) quantification of land use/coverage changes for forestry surfaces.

The first method used for quantifying landscape fragmentation requires the calculation and analyse of landscape metrics (Apan et al., 2000). A series of 8 indices (Table 2) were selected for analysing landscape configuration (Turner et al., 2001). The indices quantify class surface, the number, shape and size of landscape units. Patch Analyst 4 (Grid), an extension for ArcGis 9.3, was used, as it includes in the analyse the FRAGSTATS program, elaborated by (McGarigal and Marks, 1994).

Table 2. Landscape metrics

Landscape indices	Symbol	Description	Range
Class area (ha)	CA	Total surface of the forests class	CA >0, no limits
Number of patches	NumP	Total number of forest patches	NumP ≥ 1, no limits
Mean patch size (ha)	MPS	Average size of forest patches	MPS > 0, no limits
Largest patch index%	LPI	Percent of the largest forest unit from the landscape	0 <LPI<100
Mean shape index	MSI	Average ration between perimeter and surface	MSI ≥ 1, no limits
Mean patch fractal dimension	MPFD	Average fractal dimension; indicates the complexity degree	1<MPFD<2
Mean nearest neighbour distance (m)	MNND	Average distance between a forest unit and the nearest forest unit; indicates the isolation degree	MNND>0, no limits
Mean proximity index	MPI	Measures the isolation degree of units and the fragmentation level	MPI ≥ 0

Source: McGarigal and Marks, 1994

DOI: 10.5775/fg.2067-4635.2011.037.i

The second method requires analysing changes in the number of small surfaces units, covered by forestry vegetation and their quantification. By applying this method, it was compared the number of units with a surface of one, two, three, four and five hectares between 1990 and 2006.

This method assumes the grouping of adjacent regions using the ArcGis program and the four orthogonal neighbours rule, defining the connectivity between cellules characterised by forestry vegetation, only on horizontal and vertical, and not including diagonal cellules.

The third method evaluates land use/cover changes in the analysed period. A cross tabular analyse was realised using the ArcGis 9.3 program, and the Tabulate area function (Spatial analyst). The two datasets were transformed in 100x100 grids and were compared by overlapping land use maps, for 1990 and 2006 (Fig. 2).

The rate of changes for surfaces with forestry vegetation and their directions were identified: the transformation of forest vegetation in other land use/cover classes (e.g. forests into artificial surfaces, agricultural lands, etc.), and the conversion of other land use/coverage classes into forestry vegetation.

RESULTS

Landscape metrics

The values obtained from landscape metrics calculations (Table 3) evidence that in the analysed period, the total surface of forestry vegetation terrains decreased with 1 566 ha (4.28 %), to a total value of 35 015 ha in 2006. The number of patches recorded a small increase, from 146 to 162 units. The Mean patch size index records a decrease in 2006 compared with 1990, and the Largest patch index expresses an obvious decrease, from 11.71 % in 1990 to 5.91 % in 2006.

The value of the Mean shape index is improper in the two analysed years, indicating that the average form of units with forestry vegetation isn't a square one. The two values, 1.94 and respectively 1.98, indicates an insignificant increase of patch form complexity in the case of forestry vegetation from 2006.

The Mean fractal dimension in the two years is 1.08, indicating a reduced complexity for the perimeters of vegetation units.

The Mean nearest neighbour distance decreased by 10.77 m, reaching a value of 163.32 m in 2006. The mean proximity index records a significant decrease, from 1,660.17 in 1990, to 961.69 in 2006.

Table 3. Landscape metrics calculated in the Subcarpathians between the Râmnicu Sărat and the Buzău for the forest class

Indices	**Year**	
Class level: forest	1990	2006
Class area (ha)	36 581	35 015
Number of patches	146	162
Mean patch size (ha)	250.55	216.14
Largest patch index %	11.71	5.91
Mean shape index	1.94	1.98
Mean patch fractal dimension	1.08	1.08
Mean nearest neighbour distance (m)	174.09	163.32
Mean proximity index	1 660.17	961.69

Changes in the number of small units

With the exception of forestry units with a surface of 3 ha, the number of units from the other 4 classes of size evaluated increased in 2006 in comparison with 1990 (Table 4).

Table 4. Number of patches with forestry vegetation corresponding to units with small surfaces

Patch size	Number of patches	
	Year 1990	Year 2006
1 ha	79	91
2 ha	40	47
3 ha	17	17
4 ha	3	8
5 ha	8	9

Quantification of changes in land use/coverage

Analysing the transition matrix (Table 5) it can be observed that in the analysed period *forestry surfaces* converted in other land uses represented 3,692 ha (10.09%), with an average of approximately 230 ha/year, while the conserved surface represented 32,889 ha (89.91% from the total surface in 1990).

In 1990, forestry vegetation covered 31.69 % (36,581 ha) from the total surface of the analysed Subcarpathian area (115 432 ha), with 1.36 % (approximately 1 556 ha) larger than in 2006 (35 015 ha).

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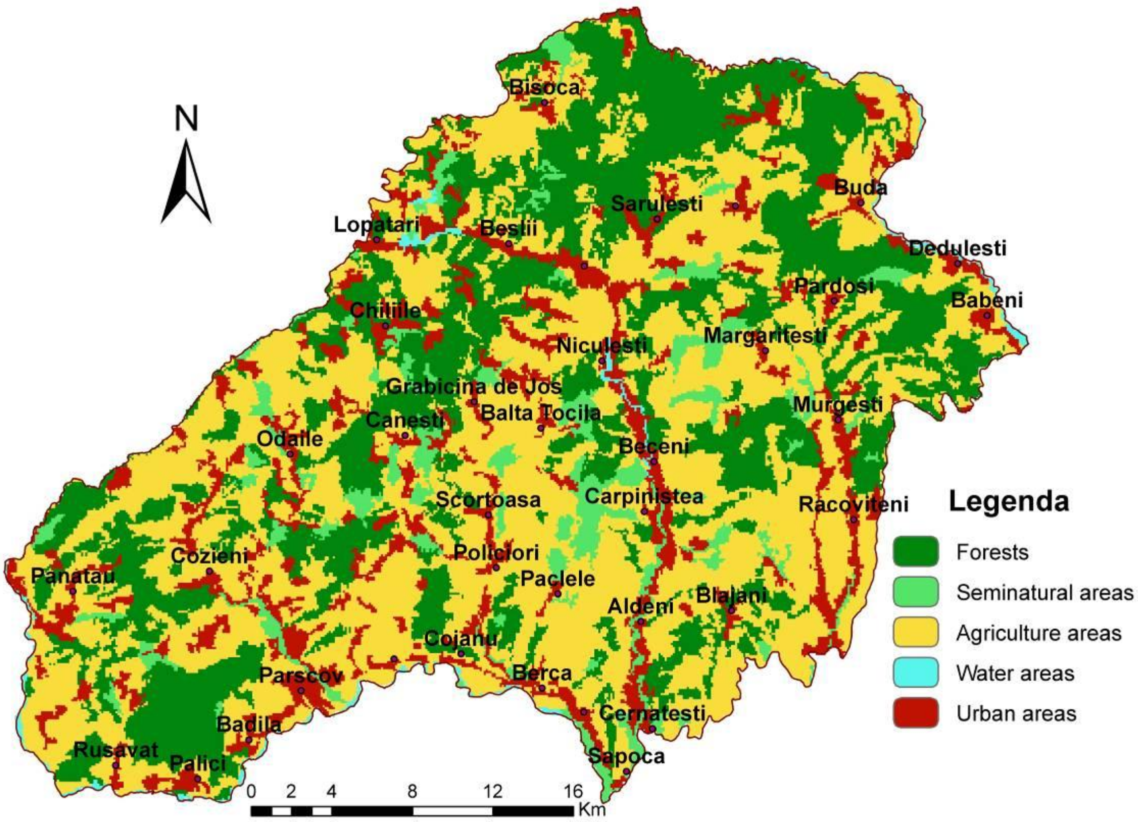
a.



b.

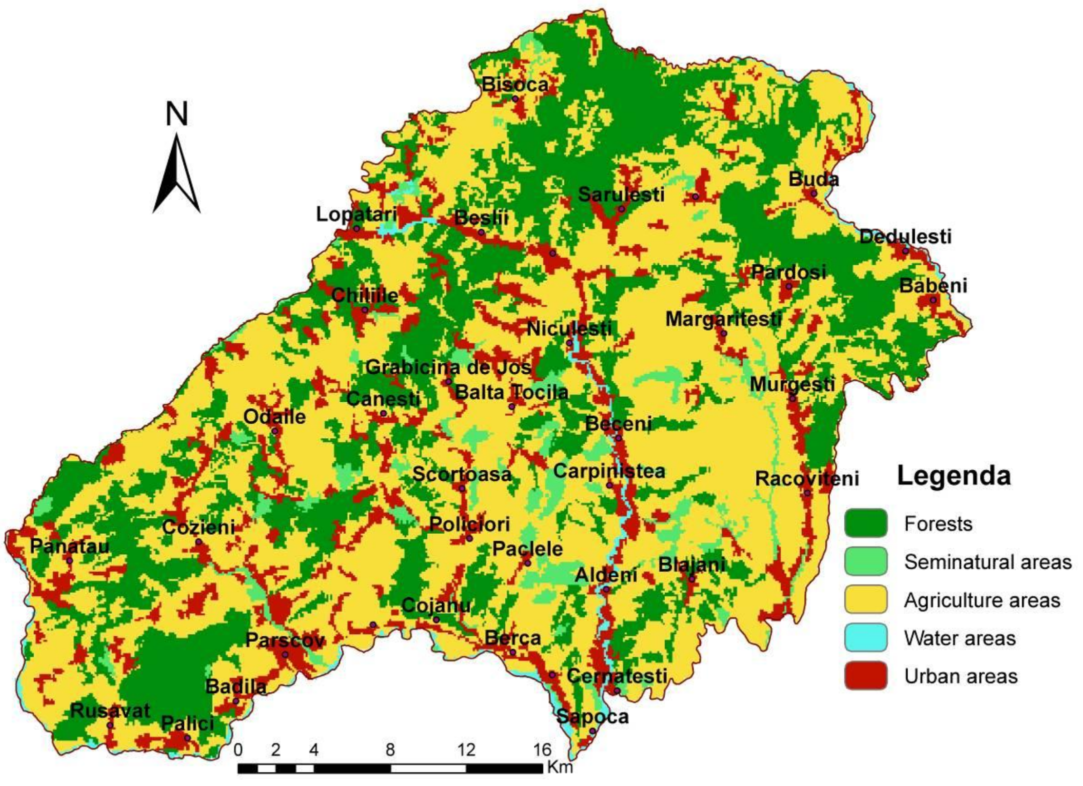


Fig. 2. Land use map in the Subcarpathians between the Râmnicu Sărat and the Buzău (a. Year 1996; b. Year 2006)

DOI: 10.5775/fg.2067-4635.2011.037.i

Table 5. Contingence matrix (values in ha and %) corresponding to the two datasets

	1990 ha (%) Class	Forest	Semi- natural areas	Agriculture areas	Water areas	Urban areas	Total
2006 ha (%)	Forest	32889 (89.91)	709 (10.07)	1344 (2.39)	4 (0.41)	69 (0.47)	**35015**
	Semi- natural areas	***59 (0.16)***	3367 (47.84)	908 (1.62)	15 (1.54)	165 (1.13)	**4514**
	Agriculture areas	***3500 (9.57)***	2459 (34.93)	53707 (95.4)	57 (5.87)	1319 (9.04)	**61042**
	Water areas	*4 (0.01)*	496 (7.05%)	53 (0.09%)	895 (92.08%)	26 (0.18)	**1474**
	Urban areas	***129 (0.35)***	8 (0.11)	239 (0.42)	1 (0.1)	13010 (89.18)	**13387**
	Total	**36581**	**7039**	**56251**	**972**	**14589**	**115432**

The data from Table 6 express that the largest surface from the total forest surfaces converted in other land uses was transformed into agricultural fields, approximately 3,500 ha (9.57%), and built up surfaces, approximately 129 ha (0.35%). The rest of the transformations, into seminatural and aquatic surfaces, are insignificant (0.17%).

From the total seminatural surfaces existent in 1990 (7,039 ha), 709 ha (approximately 10%) were transformed in forests, while approximately 1,344 ha (2.39% from agricultural fields existent in 1990, respectively 56,251 ha) of agricultural fields were converted into forest surfaces.

Table 6. Forest surfaces conversion in other land uses, in the 1990- 2006 period

Thematic change		Area (ha)	Area %
A.	No change	32 889	89.91
B1.	Forest to seminatural areas	59	0.16 (1.60)*****
B2.	Forest to agriculture areas	3 500	9.57 (94.80)
B3	Forest to water areas	4	0.01 (0.11)
B4	Forest to urban areas	129	0.35 (3.49)
Total B1-B4		**3 692**	**10.09**
Grand total (A and B1-B4)		**36 581**	**100**

* *the numbers in brackets represent percents of the total forest surface converted in other land uses*

DISCUSSIONS

The present study reveals a fragmentation of forestry surfaces during the analysed period, process which obviously contributed to the modification of the Subcarpathian landscape structure. This aspect is clearly emphasized by the temporal dynamics of landscape metrics and the values from the transition matrix.

The evaluation of land use and land cover changes in the analysed period allows a better understanding of the landscape fragmentation process (Apan et al., 2000), prioritizing both its causes and possible effects.

Landscape indices represent a tool for identifying and characterising spatial differences in landscape structure (Echeverria et al., 2006) and time changes in the landscape mosaic.

Changes in the number of forest units, their shapes and size, and the increase of the isolation degree for forestry vegetation, reveal an intensification of the fragmentation process, beginning with 1990.

The increase of forest units with small surfaces, between 1 and 5 ha, confirms the increase of fragmentation, as also demonstrated by increases in the total number of patches and decreases in the total surface of the forests.

The decrease of the Mean patch size index, from 250.55 in 1900 to 216.14 reveals an obvious surface reduction of most of the forest units, and corroborated with the decrease of the Largest patch index (from 11.71% to 5.91%), and with the Largest patch dimension which decreased in 2006, demonstrate that the fragmentation of the Subcarpathian landscape represents an active process.

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Fragmentation intensification is also revealed by an increase in the irregularity of patches, evidenced by the increase of the Mean shape index in the analysed period, the fractal dimension of units maintaining at 1.08.

The decrease of the Mean nearest neighbour distance of the closest patch from the same class reveals that in 2006, forestry units are more isolated than in 1990, decreasing the interconnectivity between units, a fact also sustained by the value of the Mean proximity index, diminished in 2006 compared with 1990.

The obtained transition matrix following the cross tabular analysis for the two thematic maps, exemplified for forestry surfaces all changes directions and rates, into agricultural lands, seminatural surfaces, water bodies and built surfaces.

The largest forest surfaces were transformed into agricultural fields. The enforcement of territorial legislation allowed retrocessions with lands in the old emplacements for the inhabitants, amplifying the fragmentation degree of habitats and subsequently, the Subcarpathian rural landscape.

Forestry surfaces were clearcutted in favour of agricultural land, especially of surfaces for pasturing, the main activity of local inhabitants, but also in order to obtain fuel needed in domestic use (Muică et al., 2000).

Alongside clearings realised by permanent residents, the Subcarpathian area suffered a reforestation process, both with natural determinant, but also as a result of the activities of local authorities which aimed at increasing the naturalness degree and revitalising degraded areas.

CONCLUSIONS

The present study quantifies and analyses major changes in forestry surface from the Subcarpathian area between the Râmnicu Sărat and the Buzău valleys, in the 1990–2006 period, identifying the directions of landscape transformation.

The causes and effects of changes were evidenced, being induced mainly by human factors, following the pursuit of satisfying human needs, and adjusting activities to the specificity of the Subcarpathian area.

Landscape fragmentation, and subsequently that of forest surfaces was, and continues to be induced by the local rural population, especially by amplifying and diversifying human activities, and materialised by an increase density of settlements, wood exploitation, expansion of pasture surfaces etc. Landscape structure changes were induced mainly by the intensification of forestry fragmentation in time, reflected especially by shifts in the forest units' number, form, size and degree of isolation.

The total surface occupied by forests decreased from 1990, simultaneously with the increase of landscape fragmentation. The largest forest surface was replaced by agricultural fields, respectively pastures, evidencing the specific of the Subcarpathian local communities.

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 195-206
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.038.i

Ecological Status Assessment of the Water Bodies Located in the Lower Sectors of the Jiu and the Motru Rivers (Oltenia, Romania)

Sanda Adina ŞERBAN[1], Oana IONUȘ[2]

[1] Jiu River Basin Administration, adinaserban22@yahoo.com.
[2] University of Craiova / Geography Department, oana_ionus@yahoo.com.

Received on <January 11, 2011>, revised on <February 10, 2011>, accepted on <April 15, 2011>

Abstract

By means of the Water Framework Directive methodology, the present study identifies the valid indicators used for evaluating the ecological status of two natural water bodies (the first located on the Jiu river between Bratovoieşti and the Danube confluence, and the second on the Motru river between the Jirov and the Jiu confluence): hydromorphological indicators, physico-chemical indicators and biological indicators.

The quality parameters deviated from the norm are: Shannon-Wiener Diversity Index – 2.87 for the Motru WB and Functional groups index – 0.68 for the Jiu WB (biological Indicators); modified water-cross section coefficient (depth) (1.22) – the Motru WB, impoundment coefficient (0.91) – the Motru WB and Coefficient of major streambed reduction (1.24) – the Jiu WB (hydromorphological indicators).

The quality parameters (physico-chemical indicators) of the water drainage systems deviated from the norm are: Biochemical Oxygen demand BOD_5 (40.78 mg/l) and Ammonium Nitrogen $N\text{-}NH_4^{\ +}$ (6.96 mg N/l) for Strehaia settlement; Biochemical Oxygen demand BOD_5 (33.70 mg/l), Ammonium Nitrogen $N\text{-}NH_4^{\ +}$ (19.66 mg N/l) and Total Phosphorus P_T (8.96 mg/l) for Craiova settlement.

The target is to validate the ecological status for the two water bodies, respectively „moderate status" for the lower Jiu and „good status" for the lower Motru, related to the Class II and Class III of the European process of intercalibration, ensuring thus the compatibility at European level.

The relevance of the paper consists in the assessment of the ecological status of two natural water bodies located downstream with respect to a major punctiform polluting source (two major settlements, Craiova on the Jiu, respectively Strehaia on the Motru), impacting heavily the achievement of environmental objectives set by the Water Frame Directive.

Keywords: *WFD, water body, reference conditions, quality elements, urban settlements, ecological status*

Rezumat. Evaluarea stării ecologice a corpurilor de apă din cursurile inferioare ale râurilor Jiu şi Motru (Oltenia, România)

Prin folosirea metodologiei propuse în DCA, prezentul studiu identifică indicatorii valabili pentru definirea stării ecologice (parametrii hidromorfologici, fizico-chimici şi biologici) a două corpuri de apă naturale (pe râul Jiu corpul de apă: localitatea Bratovoieşti - confluenţă Dunăre şi pe râul Motru corpul de apă: confluenţă Jirov - confluenţă Jiu).

Valorile parametrilor de calitate înregistrate în secţiunile de monitorizare sunt: 2,87 pentru Indicele de diversitate Shannon-Wiener - corpul de apă Motru şi 0,87 pentru Indicele grupe funcţionale - corpul de apă Jiu (în cazul indicatorilor biologici); 1,22 pentru coeficientul de modificare a secţiunii transverale (adâncime) – corpul de apă Motru, 0,1 pentru coeficientul de îndiguire - corpul de apă Motru şi 1,24 pentru coeficientul de reducere albie majoră - corpul de apă Jiu (în cazul indicatorilor hidromorfologici).

Parametrii de calitate (indicatorii fizico-chimici) ai apelor uzate evacuate sunt: consumul biochimic de oxigen (40,78 mg/l) şi azotul amoniacal (6,96 mg N/l) – oraşul Strehaia; consumul biochimic de oxigen (33,70 mg/l), azotul amoniacal (19,66 mg N/l) şi fosforul total (8,96 mg/l) – oraşul Craiova.

Obiectivul ţintă îl constituie stabilirea stării ecologice pentru cele două corpuri de apă, respectiv „stare moderată" pentru cursul inferior al râului Jiu şi „stare bună" pentru cursul inferior al râului Motru, stări ce corespund claselor a II-a şi a III-a de calitate conform procesului european de intercalibrare, ceea ce le conferă compatibilitate la nivel european.

Importanţa lucrării de faţă constă în determinarea stării ecologice a două corpuri de apă naturale amplasate aval de o sursă punctiformă de poluare majoră (aşezările urbane Craiova pentru Jiu, respectiv Strehaia pentru Motru) cu impact în neatingerea obiectivelor de mediu prevăzute de către Directiva Cadru Apă.

Cuvinte-cheie: *Directiva Cadru Apă, corp de apă, condiţii de referinţă, elemente de calitate, aglomerări urbane, stare ecologică*

INTRODUCTION

The European Parliament and European Council Directive 2000/60/CE, generally known as the Water Framework Directive (WFD), defines in article 2 the ecological status as an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters, by using biological, hydromorphological and physical-chemical quality elements as support functions for the biological ones.

The same article of the WFD defines a water body as a discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, transitory water or a stretch of coastal water. Thus, at European level, it is introduced a new notion in hydrology – „water body as a basic unit in water management, in analysis of human pressure and human impact on water as well as in risk assessment of failing to achieve the environmental objectives" (Şerban and Gălie, 2006).

The new concept of ecological status evaluation promoted by the WFD differs fundamentally from the previous approaches in the field of water quality. In fact, this new approach is based on a principle stating that biological elements represent the integrator of all types of pressures and the general physical-chemical indicators are only elements of support in determining the ecological status.

The characterization of water body types proposed by the directive is based on regionalization (Cohen et al., 1998). Ecological regionalization has been widely used in the context of river ecology to study biological communities (Van Sickle et al., 2006), to define quality goals (Prat and Munné, 2000) or to assign reference conditions (Dawson et al., 2002; Carballo et al., 2009).

In order to analyze hydromorphological conditions, the hydrological regime was considered. The hydrological regime is determined by natural flow regime, river continuity and WFD morphological conditions (Leopold and Maddock, 1953, Bizjak and Miko, 2004). The elements used as indicators for the morphological conditions were river depth and width variation, structure and substrate of the river bed and structure of the riparian zone (Munné et al., 2003, Wattage and Soussan, 2003). A number of authors (Hewitt, 1991, Rico et al., 1992, Birk and Hering, 2006, Ocampo-Duque et al., 2007) have used macro-invertebrates and fish fauna as bio-indicators to define the biological conditions of rivers.

Spatial variation of these indicators can be correlated with the human impact (from settlements) on the aquatic ecosystem (Naiman and Decamps, 1990): concentration of heavy metals in the Topciderska river load (one of the most polluted urban flows in Serbia) (Dragicevic et al., 2010); transport and transformation of nutrients (nitrogen compounds and total phosphorous) along the most polluted reaches of the canal Becej-Bogojevo, Serbia (Grabic et al., 2011).

From the legal point of view, the WFD was enforced in the Romanian law by means of the Law 310/2004 which modifies and completes the Water Law 107/1996. In Romania, beginning with 2004, the quality assessment of surface waters (according to WFD) is made at the level of river basins. The River Basin Management Plan represents the means to implement the WFD, readjusted through Article 13 and Annex VII, having as main objective the achievement of "a good status" for the water bodies corresponding to a balanced management of water resources.

Study areas

This paper proposes valid indicators for defining the ecological status of two water bodies, located in the region of Oltenia, South-Western Romania, according to the methodology proposed by the WFD. The physical-geographical framework is the general support for the evolution of the two water bodies. Thus, the physical characterization of the valleys and the administrative-territorial units' surfaces drained by the two water bodies impose as the first step in our study.

The Jiu River has a length of 339 km and a basin surface of 10,080 square km; it is a first degree tributary of the Danube and flows into it at 692 km upstream from the Danube's mouth. The lower catchment of the Jiu river basin (situated downstream Craiova settlement) is a space with an exceptional natural heritage that has been seriously transformed by man, the natural-human opposition becoming the key-element of the region (Licurici et al., 2011).

The water body located between Bratovoieşti and the confluence with the Danube is superposed to a sector of the lower Jiu (the Livadia stream – a right tributary, and the Gioroc stream – a left tributary), having a length of 57.3 km and a surface of the drained administrative-territorial units of 749.75 square km. The maximum altitude in this area is 59 m (on the right side) and the minimum altitude is 24.1 m at the confluence with the Danube.

Downstream Craiova, the valley of the Jiu River is asymmetrically developed having a width of 5–8 km, in which the floodplain has an average width of 4–5 km (Savin, 1990). Within this sector, the right slope remains steep and has a very active dynamics,

  DOI: 10.5775/fg.2067-4635.2011.038.i

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while the left slope generally occupies half of the valley's width (Fig. 1). On the left slope, in the Northern sector, five river terraces develop: 70–90 m (Cârcea terrace), 40–60 m (Şimnic terrace), 30–40 m (Bârza terrace), 15–22 m (Malu Mare terrace) and 5–12 m (Rojiştea terrace). These generally present a continuous development and fade into the Danube terraces downstream the alignment of Padea-Mârşani settlements (Coteţ, 1957).

The current shape has a historical age, being the result of climatic variations influencing the hydrologic regimen of the river, associated with the influence of neo-tectonic movements (Curcan et al., 2009). Except for the sectors with old anastomotic branches or marshland areas and pluvial sand banks, the geomorphology of the floodplain is rather unvaried. Downstream Rojiştea, on the left side, it can easily be observed an old branch of the Jiu – the Jieţ.

According to Corine Land Cover (2006), the significant diffuse sources of water pollution are shown in Figure 1, being represented by: non-irrigated arable lands (33.63%), pastures (8.09%), mainly agricultural lands (7.52%) and settlements (5.18%).

The Motru River (134 km length) forms the largest reception sub-basin (1,895 square km) of the Jiu hydrographic basin. The water body confined by the confluence of the Jirov and the Jiu river has a length of 45.1 km and a drained surface of the administrative-territorial units of 338.2 square km.

The main tributaries of the Motru river in this sector are on the right side (the Jirov, the Huşniţa, the Slătinic and the Tălăpan streams) while on the left side there is only one tributary, the Stângăceaua stream. The maximum altitude in this area is 362 m on the left slope and the minimum altitude is 102 m at the river's mouth (Fig. 2).

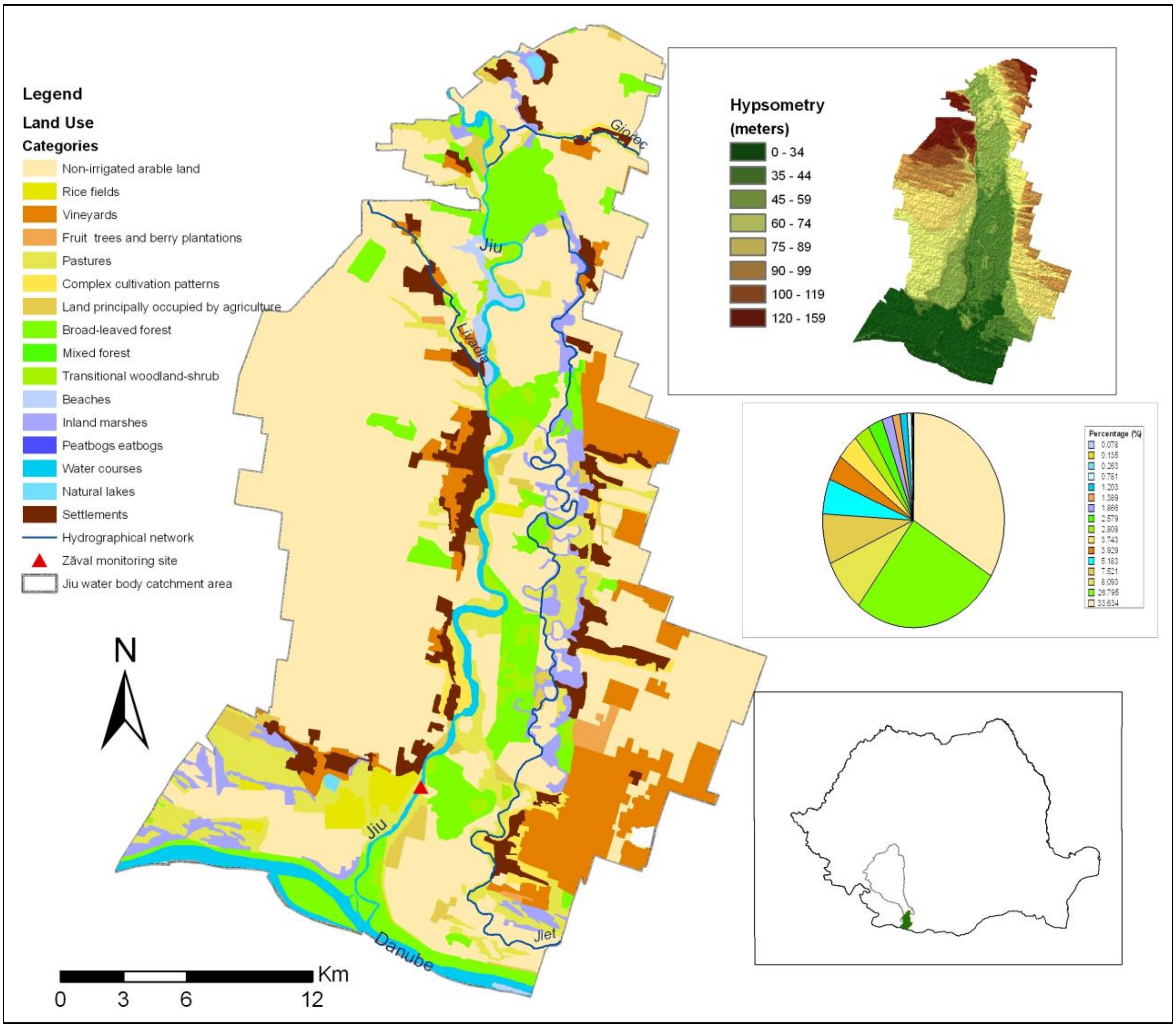

Fig. 1. Land use and hypsometric map of the drained surface of the water body corresponding to the lower sector of the Jiu river (Corine Land Cover, 2006 and SRTM elevation model)

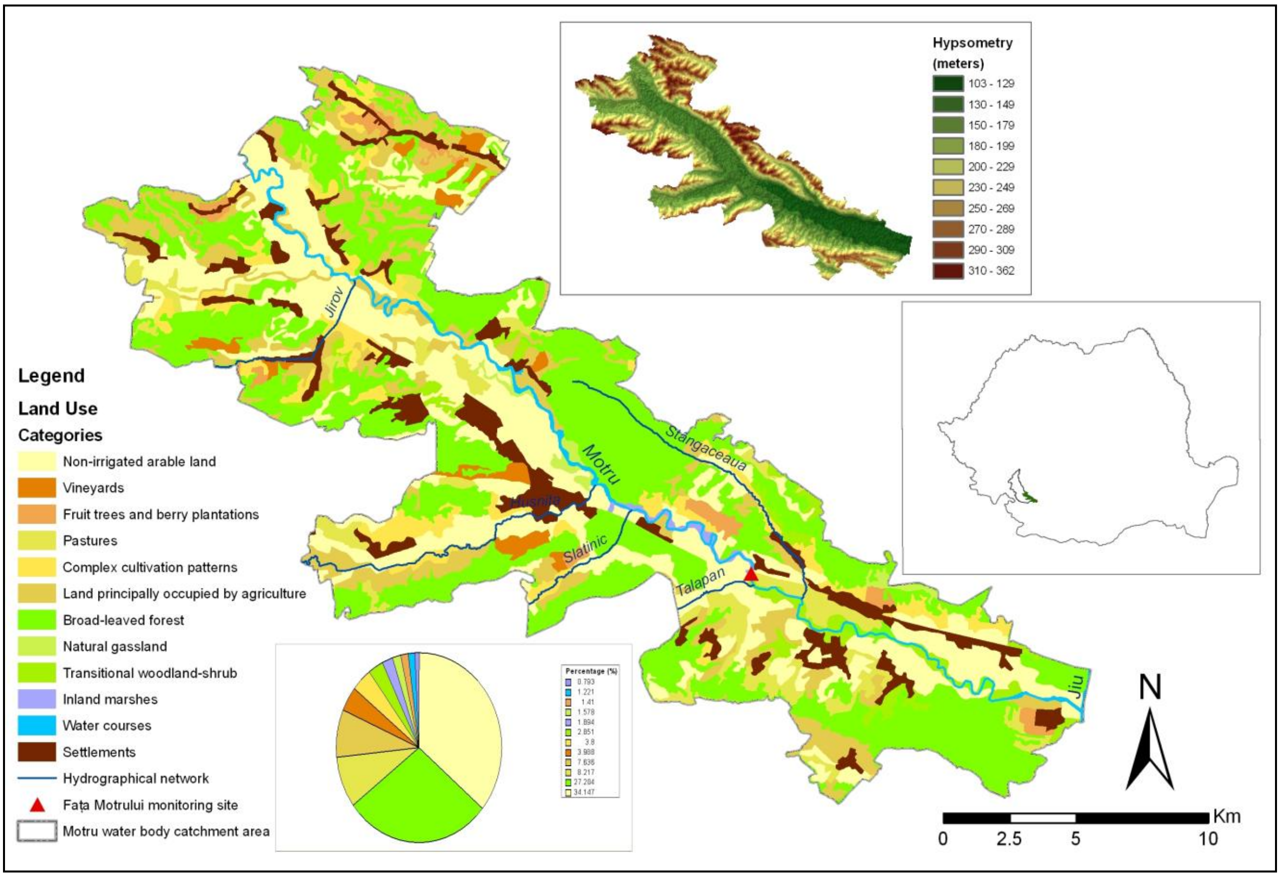

Fig. 2. Land use and hypsometric map of the drained surface of the water body corresponding to the lower sector of the Motru river (after Corine Land Cover, 2006 and SRTM elevation model)

The course of the Motru river, generally oriented on a North Western–South Eastern axis, closely follows the left slope downstream Faţa Motrului settlement; after that, it occupies a median setting within the floodplain, until Eastern Buiceşti settlement. The course further flows under the right bank until the confluence with the Jiu river (Ionuş, 2009).

For the lower sector of the Motru, the influence of the positive neo-tectonic earth movements that took place in the Southern area of the valley led to a Northward „shift" of the river. The floodplain of the Motru river is 1.6–2 km wide between Strehaia and Buiceşti, and 2 km wide downstream Buiceşti (Stroe, 2003).

Upstream Strehaia, the sector delimited by the confluence with the Jirov and the confluence with the Huşniţa, the Motru terraces on the right side (towards Coşuşta Hills) are mostly fragmented and destroyed by numerous tributaries and torrents, this process being amplified by the low resistance to erosion of the predominant sand deposits existing in this area (Şchiopoiu, 1982).

In 1982, Al. Şchiopoiu identified three terraces downstream Strehaia, having the following extent: 30–40 m (the terrace bridge on the right side shows a steep forefront), 50–60 m (presented as a step interrupted here and there by large torrent valleys, hundred meters wide) and 70–80 m (appearing as a rock erosion in shape of shoulders). The slopes are steeper on the left side, beginning with the entrance of the Motru in the piedmont and downstream the confluence with the Stângăceaua, where the river has gullies that are crossing the slope (Tomescu, 2004).

According to Corine Land Cover (2006), the significant diffuse sources of water pollution are shown in Figure 2 and are represented by non-irrigated arable land (34.15%), pastures (8.22%), mainly agricultural lands (7.64%) and settlements (5.26%).

DATA AND METHODS

In order to establish the ecological status of the analyzed water bodies, we took into consideration the typology and the reference conditions in conformity with the abiotic parameters of the B system in the WFD.

Hydromorphological elements for evaluating the ecological status are represented by the hydrological regimes and the morphological parameters.

The support physical-chemical elements used for the ecological status are represented by the nutrients

  DOI: 10.5775/fg.2067-4635.2011.038.i

group (Ammonium Nitrogen N-NH_4^+, Nitrites Nitrogen N-NO_2^-, Nitrates Nitrogen N-NO_3^-, Phosphates Phosphorus P-PO_4^{3-}, Total Phosphorus), by the thermal and oxygenation conditions (water temperature, dissolved Oxygen, salinity, pH-acid status) and by the group of specific synthetic and non-synthetic (Copper-Cu, Zinc-Zn, Arsenic-As, Chromium-Cr) pollutants group.

In evaluating the ecological status of Romanian rivers, the biological elements that are taken into consideration are the phytoplankton, macro-zoobentos (composition and plenty of the benthic invertebrate fauna) and fish fauna (composition, plenty and age distribution).

Starting from a list of species recorded within a monitoring station, we have reckoned each of the seven indices proposed for evaluating the status of the water bodies based on the macro-invertebrate communities that enter the composition of the multimetric index for bentic marcro-invertebrates: *Saprobic index* (SI), *Ephemeroptera, Plecoptera, Trichoptera insects index* (EPT_I), *Shannon-Wiener Diversity Index* (ISH), *Number of families index* (FAM), *Oligochaeta-Chironomidae index* OCH (OCH - IOCH/O), *Functional groups index* (IGF), *Preference index of flowing water* (REO/LIM).

The evaluation of the ecological status is based on a five-stage classification system (Fig. 3):

- ***Class I – very good status*** is characterized by values of the biological, hydromorphological, and physical-chemical elements associated to untouched water ecosystems (taken as reference) or areas with minor anthropic modifications;
- ***Class II – good status*** is characterized by minor deviations of the biological, hydromorphological and physical-chemical elements associated to untouched water ecosystems (taken as reference) or areas with minor anthropic modifications;
- ***Class III – moderate status*** is characterized by values that differ in a moderate measure from values of the biological, hydromorphological and physical-chemical elements associated to untouched water ecosystems (taken as reference) or areas with minor anthropic modifications;
- ***Class IV – poor status*** is characterized by major alteration of values of the biological, hydromorphological and physical-chemical elements associated to untouched water ecosystems (taken as reference) or areas with minor anthropic modifications;
- ***Class V – bad status*** is characterized by severe alteration of values of the biological, hydromorphological and physical-chemical elements associated to untouched water ecosystems (taken as reference). It is established when a large number of relevant biologic communities are absent compared to those present in untouched areas or areas with minor anthropic modifications.

The transposition of the WFD requirements, concerning the ecological status and the establishment of the 5 classes above, is based on a national study which is related to the European process of intercalibration, ensuring thus the compatibility at European level (ICIM, 2008).

The determination of the ecological status is achieved based on the values of the biological, hydromorphological and physical-chemical parameters recorded on two monitoring sites of the studied water bodies:

- Zăval monitoring site (Fig.1) for the water body Bratovoieşti – the Danube confluence;
- Faţa Motrului monitoring site (Fig. 2) for the water body the Jirov – the Jiu confluence.

RESULTS AND DISCUSSIONS

For the definition of the ecological status of the lower sectors of the Jiu and the Motru Rivers and assessment of the quality elements, the WFD provides assessment tables that classify each quality element through qualitative assessment (*high*, *good*, *moderate*, *poor* and *bad*).

Characterization of Water Body Types

In order to characterize water body types using system B, as described in Annex V of the WFD, the variables defined in the system that was adapted to the conditions of the Romanian territory were used. The proposed variables were determined based on data collected along the complete rivers, according to data collected during the study – the Jiu River Basin Management Plan, the study areas falls within the following categories.

Water body: Bratovoieşti – the Danube confluence (on the Jiu river) Type: water sector with wet areas flowing through a field area; Symbol: RO18; Surface (sq. km): > 5000; Geology: silicon, limestone, organic; Lithological structure: sand, ooze, clay; Altitude: < 200 m; Potential biocoenosis type: barbel and carp.

Water body: the Jirov confluence – the Jiu confluence (on the Motru river). Type: water sector with flowing through hilly and piedmont area; Symbol: RO14; Surface (sq. km): 1000–10000; Geology: silicon, limestone, organic; Lithological structure: sand, gravel; Altitude: 200 – 500 m; Potential biocoenoses type: barbel, *Chondrostoma nasus*.

DOI: 10.5775/fg.2067-4635.2011.038.i

Establishment of Specific Reference Conditions

The reference conditions were established in conformity with the WFD for each type of water body and represent values of biological, hydromorphological and physical-chemical elements untouched or with minor anthropic influences.

Table 1, 2 and 3 present the limits of the values for the quality parameters detailed with respect to the typology of the two water bodies (RO14–the Motru and RO18–the Jiu).

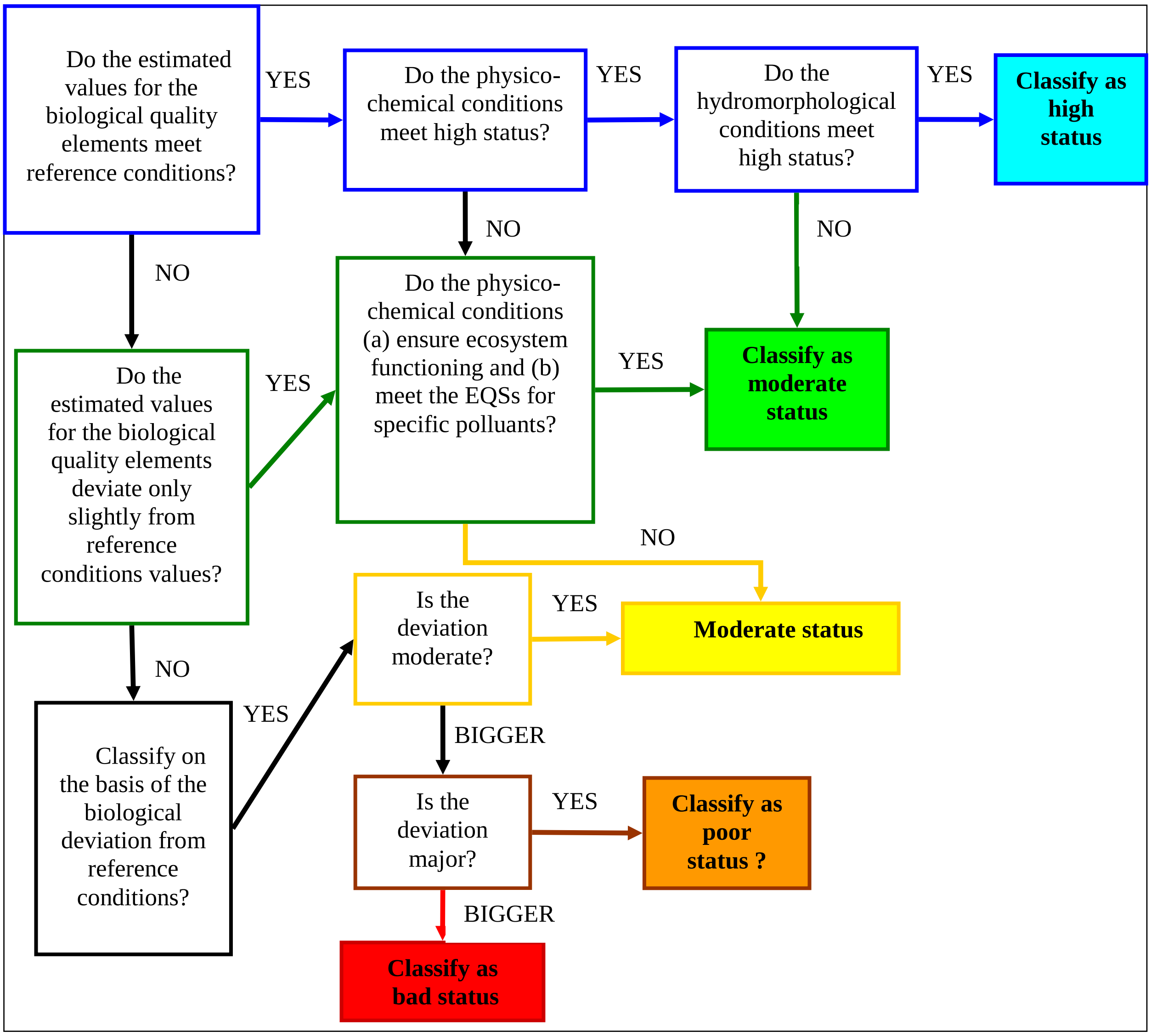

Fig. 3. Diagram of biological, hydromorphological and physicochemical quality elements in ecological status classification according the normative definitions in Annex V: 1.2. (WFD)

Types Ecological Status Indicators

Biological Indicators

Evaluation of the ecological status from the point of view of fish fauna was made only for the water body on the Motru river: the Jirov confluence – the Jiu confluence. For the water body on the Jiu river: Bratovoieşti – the Danube confluence the fish fauna was not analyzed due to the relatively high flow of the river in Zăval section (87.7 cubic meter/second – mean multi-year flow).

The initial analysis method started with the determination of the biological coefficients presented in the framework Specific Reference Conditions. Part of these coefficients recorded pozitive deviations from the reference values (Shannon-Wiener Diversity Index – 2.87 for the Motru WB and Functional groups index – 0.68 for the Jiu WB (Table 1).

After reckoning the multimetric index based on invertebrates, the ecological status of the two water bodies was evaluated as ***good***.

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Table 1. Results for the reference conditions and biological parameters assessed (2007)

Biological coefficients	Reference conditions R014/RO18 type	Faţa Motrului monitoring site (Motru WB)	Zăval monitoring site (Jiu WB)
European Fish Index (EFI+)	>0,912 (for Salmonicol waters) >0,94 (for Cyprinicol waters)	0,79	**
Saprobic index 30%	0,921/0,738	2,2	2,05
Ephemeroptera, Plecoptera, Trichoptera insects index10%	1,55/1,6	0,43	0,34
Shannon-Wiener Diversity Index 20%	0,3/0,3	2,87	1,44
Number of families index10%	1,9/1,9	13,33	5
Oligochaeta-Chironomidae index 10%	14/14	0,31	0,2
Functional groups index 10%	0,25/0,25	0,34	0,68
Preference index of flowing water 10%	0,3/0,3	0,97	1,00
Multimetric index for benthic macroinvertebrates	0,9/0,9	0,929	0,721
Ecological Status	-	**Good**	**Good**

*** for large rivers sample acquisition is still poor, reason for which on the Jiu river in Zăval section, no samples were available to determine the fish fauna coefficients.*

Source: Scientific study concerning the elaboration of classification systems and global evaluation of surface water bodies (rivers, lakes, transitory waters, coast waters) in conformity with the requirements of the WFD 2000/60/CE based on biological, hydromorphological, and physical-chemical elements - National Research and Development Institute for Environment Protection, Bucharest

Physico-chemical Indicators

The ecological status evaluated only via general physical-chemical elements and specific pollutants is determined by the worst-case scenario.

As seen in Table 2, the ecological status of the water body on the Motru river: the Jirov confluence – the Jiu confluence is evaluated as ***good***, while the status of the water body on the Jiu river: Bratovoieşti – the Danube confluence is evaluated as ***moderate***, the main cause being the lack of a treatment process for the waste waters of Craiova.

The interpretation of values corresponding to the Water Quality Index on the Motru river, on the basis of the scheme proposed by House and Ellis (1987) allows for the establishment of the usage domain for the river water as natural resource. During the years when values above 90 percent were registered, the water of the Motru river was good for all recreation activities and convenient for all fish species and aquatic fauna, while in the case of the values comprised between 74 and 90 percent, the water situation was uncertain for aquatic sports that imply the direct contact with the water and for fishing, only supporting the population with sweet water fish species (Ionuş, 2010).

In what concerns the water body on the Jiu: Bratovoieşti – the Danube confluence the drained surface corresponds to the following administrative-territorial units: Bratovoieşti, Drănic, Valea Stanciului, Dobreşti, Gângiova, Sadova, Ghighera şi Ostroveni. For the water body on the Motru: the Jirov confluence – the Jiu confluence the drained surface corresponds to the following administrative-territorial units: Văgiuleşti, Corcova, Strehaia, Butoieşti and Stângăceaua.

From the point of view of anthropic pressure on the two water bodies, although the administrative units are characterized by a majority of rural settlements, the urban population (Strehaia and Craiova settlements) through their water distribution and water drainage systems are the main punctiform polluting sources. Therefore, choosing the two water bodies as being representative is justified by the fact that the two urban settlements do not yet have waste water treatment plants, being thus heavy pollution sources for the two water systems.

The water drainage system of the city of Strehaia takes the waste waters of a population of 14098 equivalent inhabitants. The average evacuated flow is 4.5 litres/second, and the quality parameters deviated from the norm are: Biochemical Oxygen demand BOD_5 (40.78 mg/l) and Ammonium Nitrogen $N\text{-}NH_4^+$ (6.96 mg N/l), thus influencing the water body analyzed. The evacuation of the waste waters is carried out in the Huşniţa stream, with no treatment, and then again in the Motru river (the distance between the evacuation in the city and the confluence of the Huşniţa and the Motru being of 0.9 km).

DOI: 10.5775/fg.2067-4635.2011.038.i

Table 2. Results for the reference conditions and the physico-chemical parameters and specific pollutants assessed (2007)

Physico-chemical and specific pollutants	Reference conditions R014/RO18 type	Fața Motrului monitoring site (Motru WB)	Zăval monitoring site (Jiu WB)
Temperature (^oC)	21,5 ^0C (for Salmonicol waters) 28 ^0C (for Cyprinicol waters)	13,5	19,8
pH	6,5-8,5	8	7,9
Dissolved Oxygen (mg/l)	8/10	9,9	8,8
Ammonium nitrogen N-NH_4^+ (mg N/l)	0,66/0,09	0,172	0,33
Nitrites nitrogen N-NO_2^- (mg N/l)	0,08/0,011	0,015	0,04
Nitrates nitrogen N-NO_3^- (mg N/l)	2,6/0,7	0,708	2,37
Phosphates phosphorus P-PO_4^{3-} (mg P/l)	0,09/0,035	0,0368	0,08
Total Phosphorus (mg P/l)	0,23/0,11	0,0694	0,14
Copper (μg/l)	0,75/2/6	3,9	5,92
Zinc (μg/l)	7/35/50	5,5	7,55
Arsen (μg/l)	49	0,96	1,47
Crom (μg/l)	8,8	1,7	1,068
Ecological Status	-	**Good**	**Moderate**

Source: Scientific study concerning the elaboration of classification systems and global evaluation of surface water bodies (rivers, lakes, transitory waters, coast waters) in conformity with the requirements of the WFD 2000/60/CE based on biological, hydromorphological, and physical-chemical elements - National Research and Development Institute for Environment Protection, Bucharest

The main punctiform polluting source for the water body corresponding to the lower Jiu river is the city of Craiova and its waste waters. The city of Craiova still does not have a waste water treatment plant. The Craiova water drainage system serves a population of 385000 equivalent inhabitants, evacuating a mean flow of waste water of 1320.96 litres/second. The quality parameters that are deviated from the norm are: Biochemical Oxygen demand BOD_5 (33.70 mg/l), Ammonium Nitrogen N-NH_4^+ (19.66 mg N/l) and Total Phosphorus P_T (8.96 mg/l) (Fig. 4).

Hydromorphological Indicators

The ecological status evaluated by means of hydromorphological elements is considered relevant if only the ecological status is *very good*, both for the biological and the physical-chemical elements and also for the specific pollutants.

The hydromorphological parameters used to support the analysis of the ecological status and which record deviations from the reference values are (Tab. 3): Modified water-cross section coefficient (depth) (1.22)–the Motru WB, Impoundment coefficient (0.91)–the Motru WB and Coefficient of major streambed reduction (1.24)–the Jiu WB. This is due to the local physical-geographical conditions, to the influence of the basic level, to the shape of the valleys, to the evolution of the waterbeds, and implicitly to the floodplain dynamics of the two rivers.

Table 3. Results for the reference conditions and for hydromorphological parameters assessed (2007)

Hydrological regime and Morphological parameters	Reference conditions R014/RO18 type	Fața Motrului monitoring site (Motru WB)	Zăval monitoring site (Jiu WB)
Coefficient of Average flow variation	0,96-1,04	1,08	1,02
Level variations coefficient (m)	0,90 – 1,10	0,85	1,10
Modified water-cross section coefficient (depth)	0,95 – 1,05	1,22	1,00
Modified water-cross section coefficient (width)	0,95 – 1,05	1,00	1,00
Coefficient of major streambed reduction	1	0,91	1,24
Impoundment coefficient	0	0,91	0,532
River bank consolidation coefficient	0	0,009	0
Ecological Status	-	**Moderate**	**Moderate**

Source: Scientific study concerning the elaboration of classification systems and global evaluation of surface water bodies (rivers, lakes, transitory waters, coast waters) in conformity with the requirements of the WFD 2000/60/CE based on biological, hydromorphological, and physical-chemical elements - National Research and Development Institute for Environment Protection, Bucharest

  DOI: 10.5775/fg.2067-4635.2011.038.i

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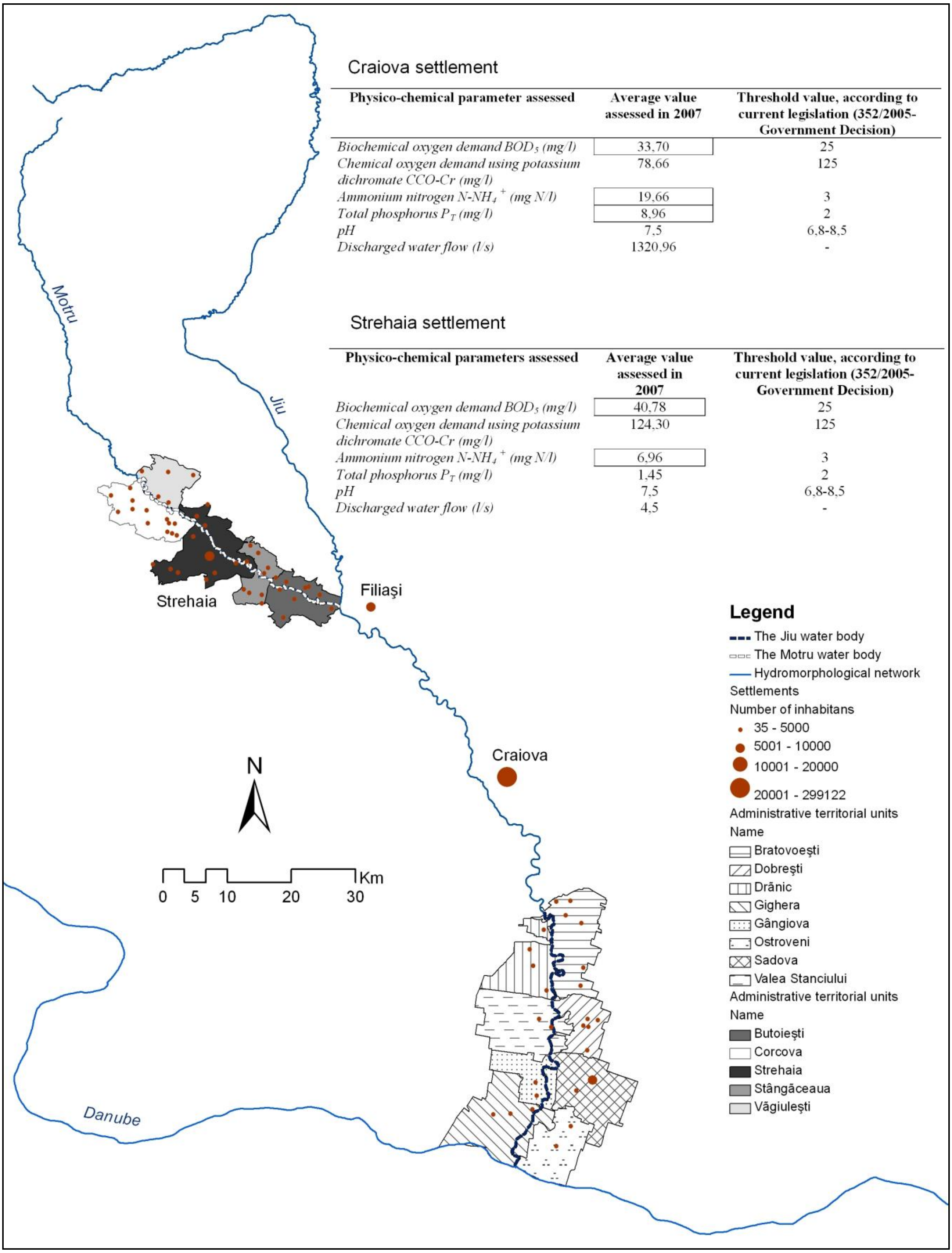
Volume 10, Issue 1/ June 2011, pp. 195-206



Craiova settlement

Physico-chemical parameter assessed	Average value assessed in 2007	Threshold value, according to current legislation (352/2005-Government Decision)
Biochemical oxygen demand BOD_5 (mg/l)	33,70	25
Chemical oxygen demand using potassium dichromate CCO-Cr (mg/l)	78,66	125
Ammonium nitrogen $N\text{-}NH_4^+$ (mg N/l)	19,66	3
Total phosphorus P_T (mg/l)	8,96	2
pH	7,5	6,8-8,5
Discharged water flow (l/s)	1320,96	-

Strehaia settlement

Physico-chemical parameters assessed	Average value assessed in 2007	Threshold value, according to current legislation (352/2005-Government Decision)
Biochemical oxygen demand BOD_5 (mg/l)	40,78	25
Chemical oxygen demand using potassium dichromate CCO-Cr (mg/l)	124,30	125
Ammonium nitrogen $N\text{-}NH_4^+$ (mg N/l)	6,96	3
Total phosphorus P_T (mg/l)	1,45	2
pH	7,5	6,8-8,5
Discharged water flow (l/s)	4,5	-

Fig. 4. The human pressure on the Jiu and the Motru water bodies (physical-chemical parameters assessed in waste waters discharged from urban Craiova and Strehaia settlements in 2007)

When the ecological status evaluated only through biological elements is superior to the status given by the physical-chemical elements, then it will prevail the status given by the physical-chemical elements. This rule is applied in the assessment of the ecological status of the water body on the Jiu river between Bratovoieşti and the confluence with the Danube.

CONCLUSION

The ecological status evaluation of the two water bodies corresponding to the lower parts of the Jiu and the Motru rivers was made by integrating all quality elements of flowing waters (biological, hydromorphological and physical-chemical), by applying the worst-case principle, except for the hydromorphological elements.

Therefore, if the evaluated ecological status in conformity with the hydromorphological elements is ***moderate***, and the evaluated ecological status in conformity with the biological elements is ***good***, then it will prevail the status given by the biological elements (the pressure of hydromorphological elements on the water body has no impact). This case is also met in evaluating the ecological status of the two water bodies in Table 4.

At the end of this study, the ecological status of the water body on the Motru river: the Jirov confluence–the Jiu confluence is evaluated as ***good***, meaning that in conformity with the WFD, the ecological status of this sector must be maintained (Vannote et al., 1980).

Table 4. Assessment of the ecological status of the Jiu and the Motru water bodies

Water body	Assessed quality elements			Ecological status
	Biological	Hydro-morphological	Physico-chemical	
Motru Jirov confluence – Jiu confluence	Good	Moderate	Good	**Good**
Jiu Bratovoieşti – Danube confluence	Good	Moderate	Moderate	**Moderate**

The ***moderate*** ecological status of the water body on the lower sector of the Jiu river: Bratovoieşti – the Danube confluence reflects an average degree of pollution, for which immediate actions must be taken to improve its quality in order to meet the objectives of the Water Frame Directive.

Taking into consideration the available set of analysis, the ecological status can be assessed with different levels of confidence (Şerban Adina, 2009).

The ecological status of the two water bodies was established with a medium confidence level, because less than twelve analysis per site were analised.

ACKNOWLEDGEMENTS

The research was achieved within the framework of a grant offered by the *Simion Mehedinţi Doctoral School (*Faculty of Geography, University of Bucharest), project co-financed through the *Sectoral Operational Programme for Human Resources Development 2007-2013*, POSDRU/6/1.5/S/24/7546 Contract.

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1 / June 2011, pp. 207-211
(www.forumgeografic.ro) **DOI**: 10.5775/fg.2067-4635.2011.040.i

Types and Sources of Underground Water Table Pollution in Sânmihaiu German Settlement (Timiş Country) – Preliminary Analysis

Alina SATMARI[1], Ana IANĂȘ[2]

[1] West University of Timişoara, Department of Geography, alina.satmari@cbg.uvt.ro
[2] West University of Timişoara, Department of Geography, ianasana@cbg.uvt.ro

Received on < December 29, 2010>, revised on < February 13, 2011>, accepted on <May 6, 2011>

Abstract

The drinking water of German Sânmihaiu, located at about 15 km South-Western from Timişoara city, is polluted. There are some small farms in the settlement, which pollute the underground water with sulphates, nitrites and ammonia. Waste thermal waters resulted as open discharges from the local swimming pool are added.

22 water samples constituted the basis of this study, accompanied by questionnaires. The chemical analysis of the test was performed in the laboratory. The study also uses digital cartography methods, which outlined the spatial disparities regarding the pollution of each underground water table. The concentration of ammonia and nitrites has considerably decreased as compared to the last two decades, when intensive agriculture at CAP level was based on chemical fertilizers. Yet, the pollution from unmonitored sources continues to represent a problem.

Keywords: *pollution, underground water, The West Plain, GIS*

Rezumat. Tipuri şi surse de poluare a pânzei freatice în localitatea Sânmihaiu German (judeţul Timiş) – analiză preliminară

Apa potabilă din satul Sânmihaiu German, situat la cca. 15 km SV de oraşul Timişoara, este poluată. Pânzele de apă freatică sunt contaminate cu sulfaţi, nitriţi şi amoniu de către micile ferme din localitate. Lor li se adaugă deversările libere de ape termale uzate ale ştrandului din localitate.

Studiul s-a bazat pe 22 de eşantioane de apă, însoţite de chestionare. Analiza chimică s-a făcut în laborator. Metodele de cartografie digitală au pus în evidenţă disparităţile spaţiale în ceea ce priveşte poluarea fiecărei pânze freatice în parte. Concentraţia de amoniu şi nitriţi din ultima perioadă este mai mică decât acum cca două decenii, când agricultura intensivă la nivel de CAP se baza pe utilizarea îngrăşămintelor chimice. Poluarea continuă însă din surse nemonitorizate.

Cuvinte-cheie: *poluare, apă freatică, Câmpia de Vest, SIG*

INTRODUCTION

Most Romanian villages lack basic facilities like drinking water supply, sewage, waste management etc. Water is an essential substance for human life and human activities. The alteration of water quality is one of the great problems of mankind, as a result of an increasing population density, but also because of the diversification of consumption and contamination ways. In Romanian rural areas, intensive agriculture, drainage or irrigation systems, use of chemical fertilizers, are only few “regular” causes of water resources degradation. There are other unusual situations, like thermal water discharge, as presented in this case study.

Premise

The village Sânmihaiu German belongs to the Sânmihaiu Român commune, both situated a few kilometers South-Eastern from Timişoara, in the divagation plain of the Bega river, subdivision of the Timiş low plain. In times of high humidity variations, this relatively flat relief form favors long-term floods and a sharp vertical movement of soil water, mobilizing other soil chemical elements too.

As a result of intensive agriculture practiced during the communist period, the soil has become a repository of chemical contaminants in fertilizers. In this category, ammonia and nitrite, basic compounds of the nitrogen cycle in soil, have been considered of a higher interest in the present study.

The accidental discovery of thermal waters in this area, lower than 2400 m deep, in 1977, after some searching of oil drillings, led to the construction of a thermal bath private property.

More than 20 years, this thermal bath discharged waste water in ditches adjacent to the property. We analyzed the surface and depth distribution of sulfates from this perspective.

Because the village water supply is provided from personal wells and boreholes, its quality is a major problem for the community.

DATA AND METHODS

Local dissatisfaction of the residents about the drinking water was our starting point for analyzing spatial quality disparities (ammonia long term pollution and strictly local contamination with sulphates).

Field work consisted of water sampling; 22 water test-samples were randomly taken. The information provided by the owners helped us group samples in 4 categories, corresponding to the water table depth: 15-20 m, 60-70m, 80-90m, over 100m (Fig. 1).

Laboratory chemical analysis was performed in terms of ammonia compounds, nitrites, sulfates and pH property. A series of written questionnaires were carried out concerning local water quality, but also its economic problems (namely health and hygiene).

The ammonia analyses were performed using Spectroquant NOVA 60 photometer with the special kits Spectroquant Amonium cell-test with 0.5-16mg/l measurement range. The work method has been ISO 7150/1 in analogy with EPA 350.1.

The laboratory analysis for nitrites was made using the product Aquaquant Nitrit, a kit for colorimetric determination of concentration by Griess reaction method with the color gradation scale: 0 – 0.005 – 0.012 – 0.02 – 0.03 – 0.04 – 0.05 – 0.06 – 0.08 – 0.1 mg/l (ppm).

The sulphate pollution was analyzed using Merckoquant strip tests that offer a quick estimation of the significant concentration of sulfate ions for the categories: less than 200 mg/l, 200-400 mg/l, 400-600 mg/l, 600-800 mg/l, 800-1200 mg/l and 1200-1600 mg/l.

Local data were interpolated using spatial analysis methods computer aided, in order to obtain a more complex view of surface and depth pollutants distribution. In a future study, this data will be completed with the results of opinion polls.

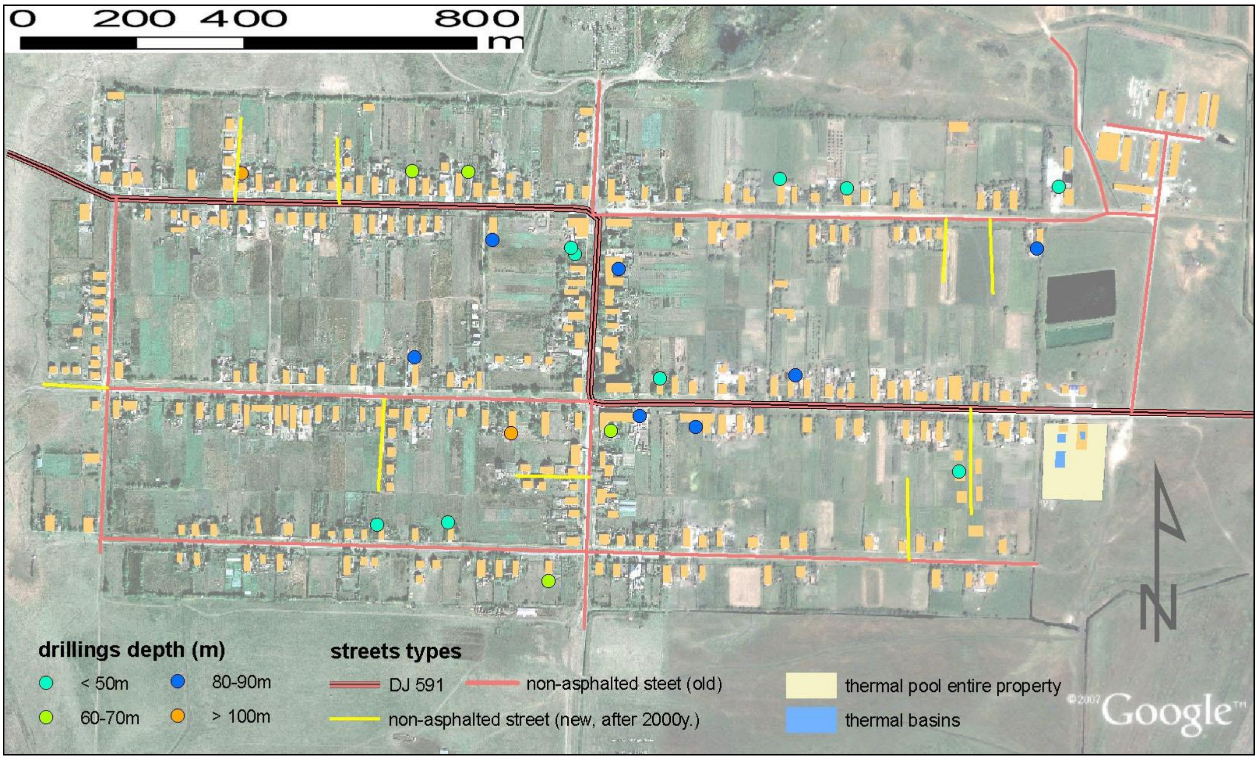

Fig. 1. Water sampling distribution and depth

DISCUSSIONS

Ammonia is an indicator of the dynamics of contaminated groundwater self-purification. Its values are no longer excessive in the proximity of the former CAP (because they do not function presently), but the pollution problem persists in case of groundwater.

Natural organic ammonia was neutralized in the upper soil horizons in the last 20 years because of the diminishing or even canceling inflows, as well as a pronounced soil washing.

The areas registering the highest values/concentrations are located in the proximity of small farms and septic tanks as leaking is quite frequent.

  DOI: 10.5775/fg.2067-4635.2011.040.i

In order to establish the classes of pollution, we used the STAS criteria for drinking water 1342/1991 and the international criteria proposed by EPA. In 1999, EPA introduced the notion of Continuous Concentration Criterion (CCC) for supplementing the Maximum Allowable Concentration Criterion (CMA). This is a chronic criterion testing ammonia, dependent on temperature and pH. The value of CCC for ammonium is 0.035 mg/l and CMA (acute criterion of maximum) is 0.233 mg/l. In the same context, EPA suggested to all specialized forums the development of some numerical criteria and the elimination of the narrative criteria for establishing the toxicity levels.

The analysis was individually performed for every groundwater intercepted by drilling, according to the depth classes: 15-20 m, 60-70 m, 80-90 m, less than 100 m. Because of the relative homogeneity of the sandy layers where the water quartered, the interpolation method is IDW (Inverse Distance Weighted) (Fig. 2). The alternating structure sand-clay justifies the presence of some groundwater with large continuity.

Depending on the drilling from which the samples were taken, the most relevant example for the ammonium analysis was the groundwater located at 15 m depth.

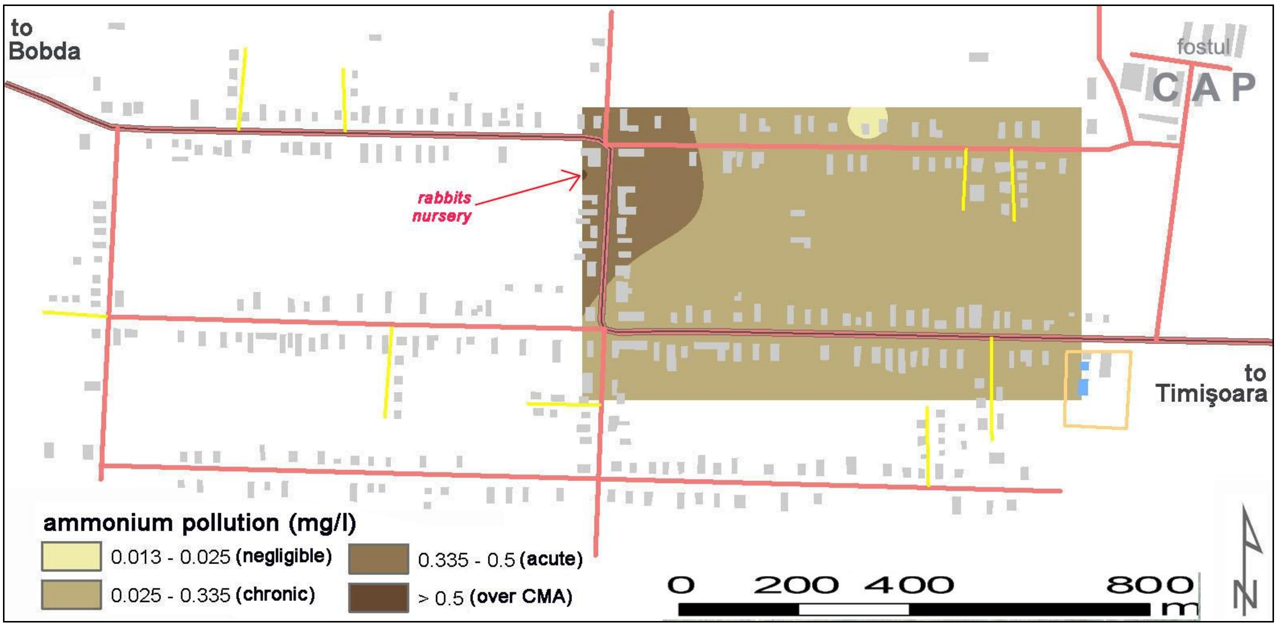

Fig. 2. IDW analysis for ammonium pollution sampling-test results

Nitrites are intermediate products in the continuous transformation process of nitrogen in the soil: denitrification (anaerobic) – nitrification (aerobic). Because of their poor stability in acid soil conditions, the nitrite can be a very important component in the process of loosing the nitrogen from soil. The soil's organic substance and its mineral phase have a stimulating effect on the decomposition of nitrite in acidic conditions (Van Cleemput, 1984).

Also, in the nitrogen transformation process in the soil, it is very important the presence of actinobacteria that record an optimum biological activity in the soil with a pH of 6 – 7.5 (Smith, 1990). From this perspective, we also accomplished the pH analysis for each groundwater, only two of these recording values outside the optimum.

The nitrogen concentration (Fig. 3) highly varies during the rainy periods, when there is an intense washing of the soil, the low temperatures blocking the working capacity of the nitrifying bacteria.

The sulphate pollution (Fig. 4) is a particular case, affecting more than a half of the analyzed drillings, respectively from the community's water resources.

The specific studies (Van Cleemput, 1984, 1996) have shown that the presence of the compounds based on iron in the soil represent a catalyst for the decomposition of the nitrite in weak acid conditions, this being a very important hypothesis in the studied area, where the groundwater has a high iron content, easily organoleptic perceptible but scientifically not analyzed yet.

According to sanitary regulations no. 934 of August 15, 2007, the sulphides content allowed in drinking water is about 150 mg/l.

DOI: 10.5775/fg.2067-4635.2011.040.i

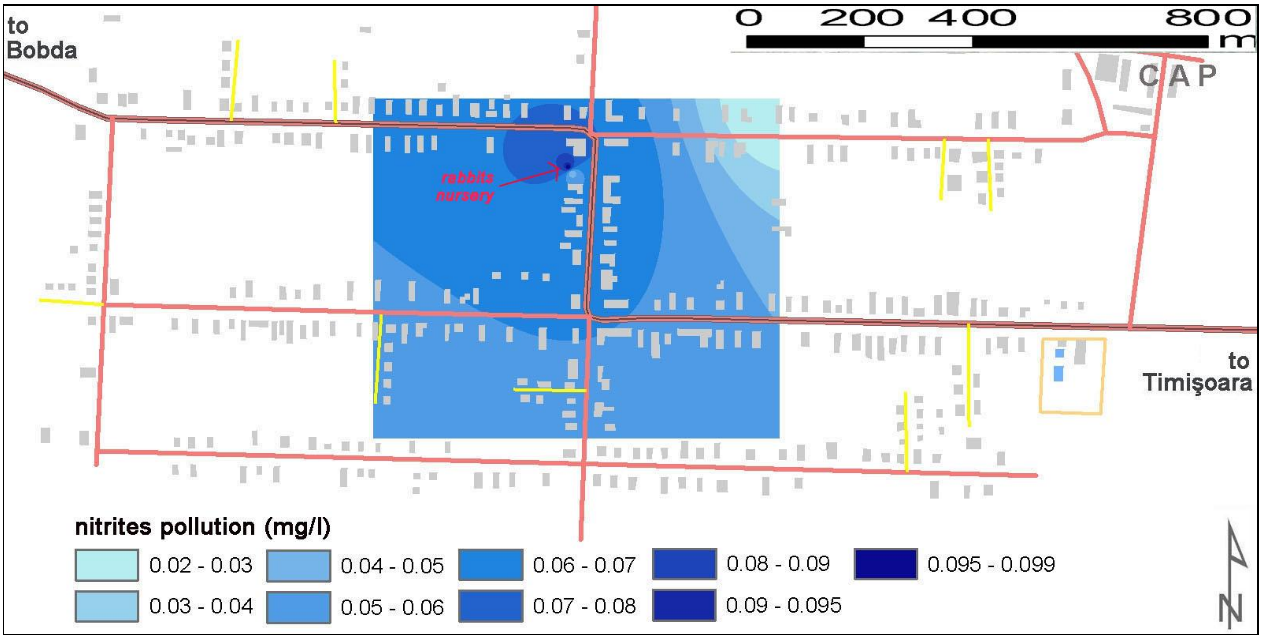

Fig. 3. IDW analysis for nitrites pollution sampling-test results

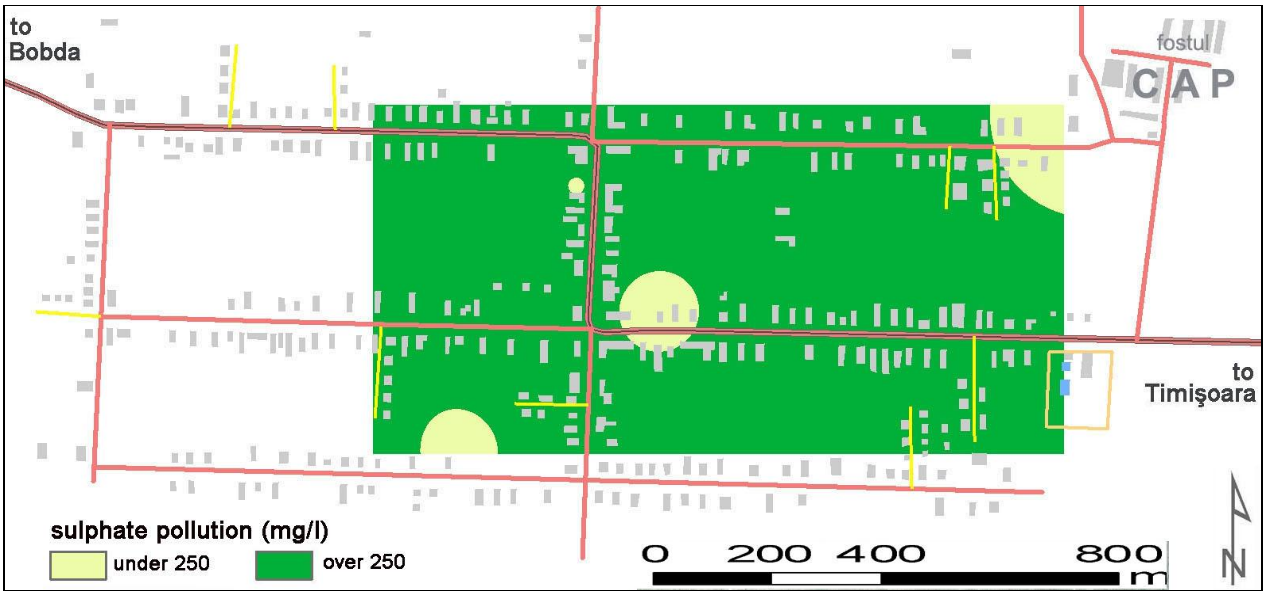

Fig. 4. IDW analysis for sulphate pollution sampling-test results

CONCLUSION

Although in the last two decades the ammonia and nitrites concentration in groundwater from the studied area is greatly reduced compared to the periods of the ex-agricultural cooperatives (C.A.P.), the groundwater pollution continues from unmonitored sources, some with a great flow, because of a reduced self-purification in the hydro-geological conditions of the accumulation area.

According to the data obtained by measurements, we made the reclassification of the monitored parameters and a cumulation of their favorability – unfavorability, resulting a partial map of the locality groundwater contamination. Where at least one of the chemical compounds analyzed proved negative quality (it is polluted over the maximum allowable), it has cancelled other positive values. In this situation, some of the underground water tables were highlighted as undrinkable.

The cumulative analysis (Fig.5) shows us a small area with drinking water in contrast with the large area of under-limit quality waters.

In the future, we plan to enlarge the database for drillings, both numerically and in terms of the compounds analyzed, for a better accuracy of the estimations.

  DOI: 10.5775/fg.2067-4635.2011.040.i

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume 10, Issue 1/ June 2011, pp. 207-211

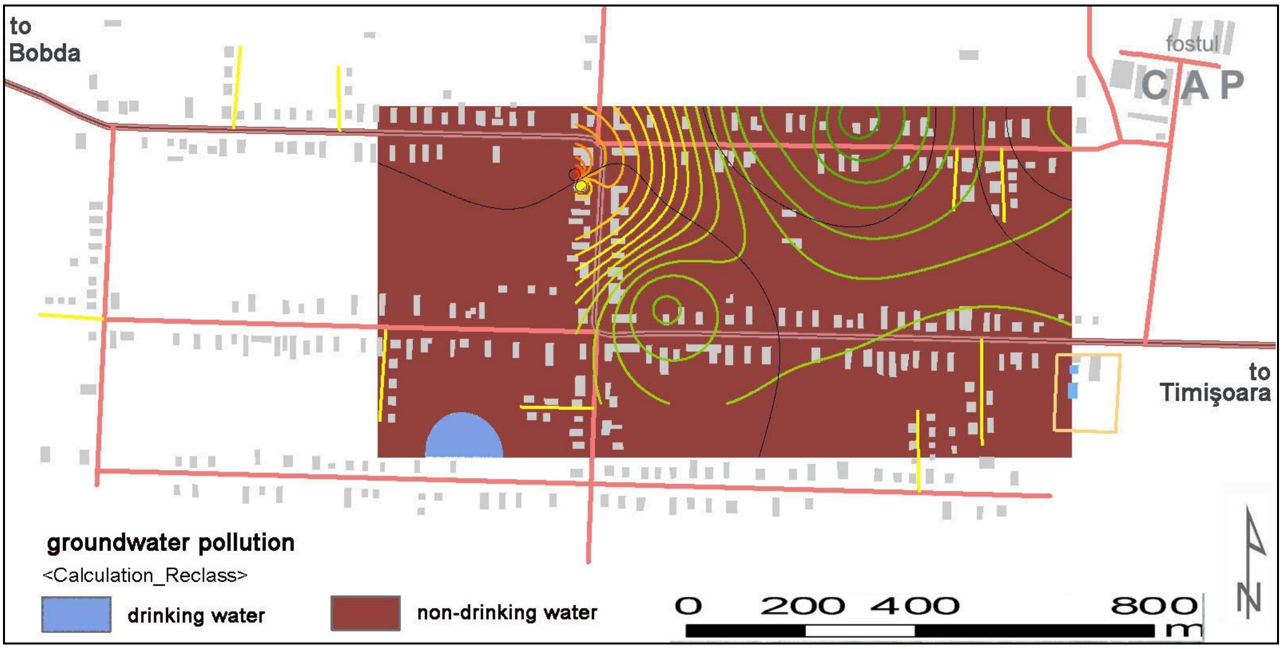

Fig. 5. Spatial distribution of drinking underground water in Sânmihaiu German village

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DOI: 10.5775/fg.2067-4635.2011.040.i