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Morphological Analysis of Topolog Basin Fluvial Terraces: A Valleys System Evolution Approach

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Abstract

The organisation of valleys network leads to the morphological identity of a territory, developing particular internal developmental models that take into account a number of parameters, such as the climatic, tectonic, eustatic and glacioeustatic ones, the local and regional basic levels or the local morphodynamics. Their highlighting is being reflected in the landscape by structural and quantitative differences resulted from the valley's evolution up related to each terraces level. In that sense, a probative example is the Topolog's basin which overlaps three morphostructural units having distinctive dynamics: the Făgăraş Mountains' Group, the Argeş and Vâlcea Subcarpathians and the Cotmeana Piedmont. The analysis of the position, number, features and structure of the current fluvial terraces, of the way in which the hydrographic network was imposed in the landscape by its evolution enables the identification and tracking of some models with different characteristics on the three sections drained by the Topolog river. Therefore, in the mountain sectorthe valley's evolution has imposed hydrographic disturbances, in the Subcarpathian one a deepening of the initialcourse and in the piedmont sector some changes through lateral dislocation determined by the amplitude of the elevation process and the thickness of the piedmontan deposits, concurrently with the existence of certain subsidence areas along the Olt river. The direct correlation between the structural features of terraces and the thickness of the deposits along the Topolog river wasaccomplished by an integrated interpretation of the data we have achieved from the electrical resistivity method (49 vertical electrical sounding) and geotechnical survey.

Keywords: *fluvial terraces, Topolog drainage basin, evolution of valleys system, hydrographical remoulding, geoelectrical interpretation*

Rezumat. Analiza morfologică a teraselor din Bazinul Topologului: un mod de abordare a evoluţiei reţelei de văi

Organizarea retelei de vai este cea care impune definitivarea morfologica a teritoriului, construind anumite modele de relatii, care iau in considerare o serie de parametri, cum ar fi cei climatici, tectonici, eustatici si glacioeustatici, nivele de baza locale si regionale, morfodinamica locala. Concretizarea lor se reflecta in peisaj prin diferentieri structurale si cantitative ale rezultatelor evolutiei vailor la nivelul teraselor. Un exemplu in acest sens este bazinul Topologului care se suprapune peste 3 unitati morfostructurale cu dinamica diferita: grupa Muntilor Făgăraş, Subcarpatii Argesului si ai Valcii, respectiv Piemontul Cotmeana. Analiza pozitiei, numărului, fizionomiei si structurii teraselor actuale, a modului in care reteaua hidrografica, evoluand, s-a impus in peisaj permite identificarea si urmarirea unor modele cu particularitati diferite pe cele trei sectoare drenate de raul Topolog. Astfel, in sectorul montan evolutia vaii a impus remanieri hidrografice, in cel subcarpatic, o adancire pe traseul initial, iar in sectorul piemontan modificari prin deplasari laterale impuse de amplitudinea înălţării şi grosimea mai mare a depozitelor piemontane in paralel cu existenţa unor arii de subsidenţă în lungul Oltului.

Cuvinte-cheie: *terase morfologice, bazinul Topolog, evoluţia reţelei de văi, remanieri hidrografice, interpretare geoelectrică*

Introduction

The Topolog River and its tributaries have locally created fluvial landforms and by their analysis and interpretation it can be deducted the evolutive stages of the hydrographic basin and the intermediate and current evolutive levels. The Pleistocene–Holocene evolution highlighted, through characteristic processes, landforms resulting either due to climate oscillation or tectonic uplift: terraces (Chang et al., 2006; Olszak, 2011). Because of the issue of this type of relief is vast and complex - can itself constitute an interesting subject of detailed research, in this paper we choose that the fluviatil morphology processing to be carried out on characteristic sectors.

The distribution of the terraces and their age provide important information about the quaternary evolution of the region and the hydrological basin they belong to, provided that their research consider connecting and mapping them in accordance with the situations within the neighboring hydrographic basins. (Viveen and co., 2013).Geographical Settings

The wide altitudinal expansion of Topolog basin between 2535.4 m (Negoiu Peak) and 184 m (Galicea - Ostroveni) is the primary factor of the complexity and great diversity of fluvial forms and processes. Topolog's hydrographic basin is determined by the geomorphological registers of the major geographic regions by developments within the hydrographic network and by quaternary and current modeling.

The three major geographic regions crossed by the Topolog River are morphologically required by ensembles of steps overlapped on the major types of relief: mountains in the north of the basin area, hills and subcarpathian depressions in the middle section and piedmont plateau in south, in the lower sector.

The morphostructural and tectonic units that the Topolog river drains are the Fagaras Mountains, Iaroslavele depression area – Manita, Frunti Mountains in the east and Poiana Spinului in the west, then Topolog Subcarpathians (Visan, 1998) and Cotmeana Plateau (Fig. 1).

Fagaras Mountains are the first reliefs in the Paleogene which were emerged and subdued to denudation in the hydrographic basin so that the first network of valleys was concomitant with the Borascu leveling complex (Eocene) (Sircu, 1958, Popescu, 1972, 1984, Posea, 1997, Posea, Armaş, 1999, Andra, 2002).

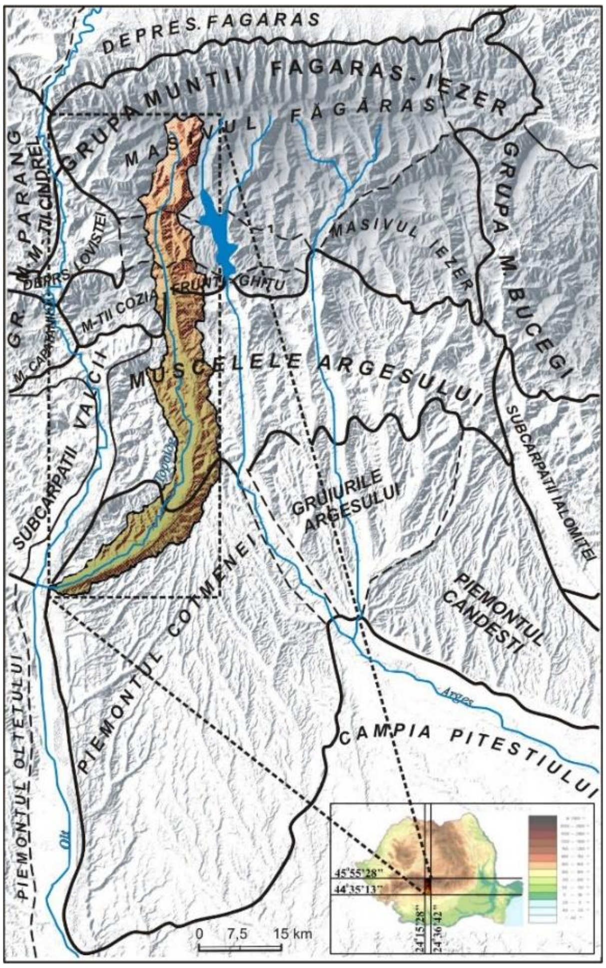

Fig. 1: Location of Topolog basin and geographical regions

Related to the subsequent intermittentelevation, the valleys paleo system, as modified and subjected to the influence of tectonic lines newly generated, it is responsible for the formation of the other correlated leveling complexes with both Miocene deposits submitted in the Getic Piedmont and Brezoi - Titeşti and with the Pliocene ones deposited in the Dacian Lake. During the next stage (Pliocene - Quaternary) the general features of the valley system that extends in the Subcarpathians are configured and lifted during the Wallachian movements (Dragos, 1959; Badea, 1983; Visan, 1998); the latter are responsible for the defining of the southern piedmonts; they will also be affected by emergence movements and transformed by the rivers' widening and cut in plateau units.

The hydrographic network structure is determined by the relationship between the main morphostructural units, tectonic lines and elements which condition the drainage (morphometric, climatic and hydrological factors). The Topolog's hydrographic basin is characterized by a dendritic type of network, in which the confluence angles record low values, the exceptions being tectonic, structural, petrographic and evolutive determined (confluence Scara – Modrugaz, Topolog – Topologel, Topolog - Sutu (in the mountain section), Topolog – Valea Satului (in the subcarpathian sector).

The Topolog valley is formed by the union of the river segments Scara and Negoiu Spring at an altitude of 1339.8 m and flows into its collector, the Olt river at 185 m (Table 1), being its left tributary.

Table 1: Topolog tributary valleys parameters

River	L [km]	A.s [m]	A.c [m]	S [m/km]	m.c.
Topolog	106,812	1339,8	184	11.345	1.404
Izvor Negoiu	4,738	2110	1339,8	162.558	1.196
Scara	4,581	2100	1339,8	165.946	1.088
Topologel	9,469	1970	963	106.347	1.137
Cumpăna	12,047	1430	712	59.6	1.088
Valea Satului	6,097	960	639	52.649	1.104
Cărpeniş	9,775	820	452	37.647	1.063
Bădislava	16,758	840	384	27.211	1.158
Momaia	5,933	550	381	28.485	1.187
Bălceasca	7,392	515	259	34.632	1.041
L – length; A.s. – altitude spring; A.c. – altitude confluence; S – slope; m.c. – meandering coefficient					

The Topolog's tributary valleys generally have reduced lengths and are structurally determined, often with a torrential character. Some of them, however, had experienced a more complex evolutive path reflected in the preserved terraces' fragments along them: the Topologel, the Cumpana, the Manita, the Valea Satului, the Cărpeniş, the Bădislava, the Valea Bălceasca.

Under the influence of the collector river's deepening rhythm, they had developed a system of 1-2 terraces, which are characterized by the following three aspects: they are monolateral, they have reduced widths and surfaces and have alluvial or rocky structure.

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Materials and methods

The morphological analysis was based on the cartographic documents, represented by topographic maps at 1: 25,000 and topographical plans at 1: 5000, 1: 10,000 made by the Military Topographic Direction, between 1964, 1977 and 1982, aerial photographs (1966), geological maps and orthophotoplans (2011).

For the inventory and correlation of the terrace fragments we have applied the chorology method, based on the data gathered in the field in several campaigns. The field investigations have consisted in running multiple shallow drillings in the lower terrace of the Sălătrucu, Galicea, the execution of 49 geoelectrical vertical soundings (ABEM SAS 300), 9 geoelectrical sections interpretative (Botezatu, 1987; Morris, 1997), in 5 districts of the Topolog Valley (Galicea, Tepsenari - Mănicioiu, Dedulesti, Ceaureşti, Suici and Sălătrucu), in the terraces' geomorphological mapping and the integrate interpretation of terraces information from the subcarpathic and plateau area.

The processing of cartographic resources and the thematic maps, the morphological profiles and geoelectrical sections acquiring were achievedusing the following tools: ArcGIS, Global Mapper - Blue Marble Geographics, Surfer - Golden Software.

The geotechnical analysis and the terrace deposits' mapping have locally shaped the structural characteristics of the terraces, but their extrapolation, in conjunction with the results of the others applied methods, allowed a uniform view achievement on the evolving model of the valley network from this basin.

Morphological analysis of terraces

The morphological, evolutive perspective's diversity, caught in cross and longitudinal section, is generated by the alternation of characteristic sectors from those of narrow valley to those of wide, mature valley. The Topolog's Valley is transversalon the geographical units which it pervades, with local epigenesis characters and a history, strongly tectonic influenced in the mountain area and locally elsewhere.

Linking the Topolog's fluvial system with neighboring systems

The complexity and difficulty of the research regarding the Topolog's river terraces are created by:

- the various morpho-litho-structural and tectonic units crossed by it;
- the altitudinal differencesof over 2,300 m;
- the affiliation and allegiance of erosive-accumulative regimen to the Olt's hydrographic basin; Olt – Topolog confluence represents a basic level lower than that of the Arges river from the neighboring area (Fig. 2);
- the presence and dynamics of the modeling floors carried out within the basin;
- the pronounced dynamics of the relief, which required strong fragmentation of the terraces;
- the anthropogenic interventions.

The specialty literature indicates a variable number of terraces in the adjacent space of the Topolog basin, which is why it is necessary, in a first phase, a comparison and putting in parallelof all available results until the present (Table 2).

The Topolog valley's evolution and the terraces' defining are closely linked to the Olt Valley during the Quaternary. The upper level of the Olt's terraces has a Middle Quaternary age and has a relative altitude of 210-240 m (Badea, 1983). Its position at the cut-water level off the confluence between the Olt and the Topolog indicates the role the two rivers had in the formation of this terrace level. The third terrace is widely developed in the plateau area and discontinuous in the subcarpathian one due to the evolution of the paleo-layer during the generation of the second terrace or because of the current morphodynamics; in the mountain area of this terrace level, fragments were found in the depression area Iaroslavele - Manita and in the lower section of the Topolog's defile.

The second terrace has a wide development, being highly fragmented by the Topolog's tributaries of order 4 and 5. The subjacent terrace is widely extended in the subcarpathian and plateau sectorsn, with a monolateral development, especially in the down subcarpathian, and bilateral in the piedmont (Fig. 3), but the elbow that the Topolog makes to SW caused this level's erosion on the left, near Ciofrângeni.

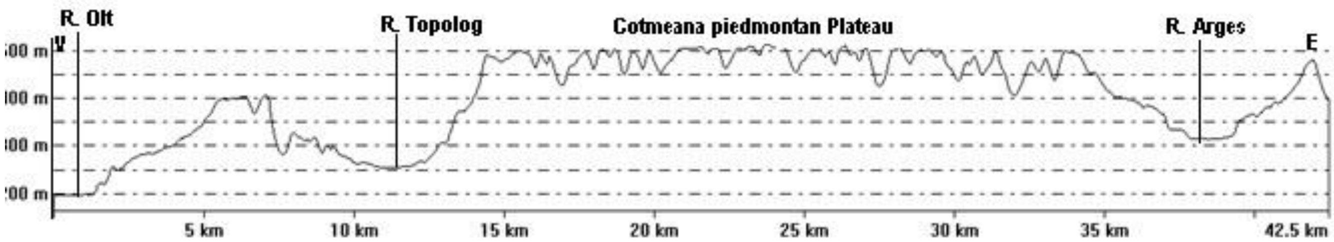

Fig. 2: Cross-section of the differentiated local base level of erosion in the Cotmeana Piemont

The characteristics of the terraces' system related to the regional geographical units

The terraces' system constitutes in 4 levels, one in bedrock, two alluvial and one fill-cut alluvial deposit. The terraces number and structure highlight the link between the form, the deposit and the type of evolution of the relief through phases of aggradation or sinking. These are the correspondents of the climatic and glacioeustatic changes (Merritts, Vincent, Wohl 1994) differently reflected in each region which is drained by the Topolog River.

Table 2: Briefly overview on the Romanian literature about the Olt, Topolog and Arges terraces

Authors, year	Floodplain	T_1	T_2	T_3	T_4	T_5	T_6
Mihăilă N., 1971	holocen	Pleistocen sup qp_3^3 Wurm III	Pleistocen sup qp_3^3 Wurm II	Pleistocen sup qp_3^1 Wurm I	Pleistocen med qp_2^2 Riss	Pleistocen med qp_2^1 Mindel II	?
		4 - 10	**15 - 22**	**30 - 40**	**60 - 70**	**80 - 100**	
Vişan, Gh., 1998 Mihăilă, N, 1971	holocen	W III	W	Pleistocen med	Pleistocen med.	?	Pleistocen inf
		8 - 12	**40**	**60**	**100 - 110**	**150 - 160**	**200**
Coteţ P, 1957 Liteanu, E, 1971 Parichi, M., 2001	Holocen sup	WIII	WII	WI	Pleistocen supW1	Mindel	?
		5 - 13	**20 – 30m**	**40 - 70**	**80 - 108**		
observations			Echivalentă T4 Vultureşti (Olt)	Echivalentă T5 Verguleasa Cp Govorei	Terasa Slatina		

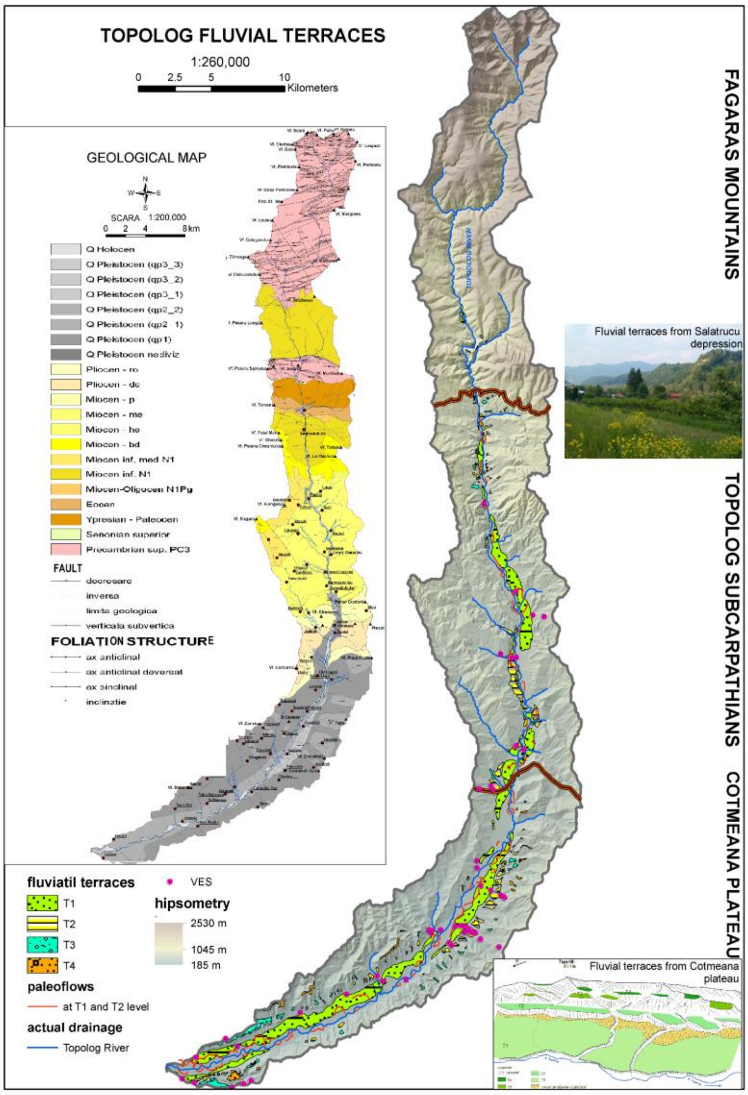

Fig. 3: Topolog drainage basin fluvial terraces and geological units map (source: *geological maps, 34. Piteşti and 27. Sibiu 1:200 000, 1968, 109 a, Negoiu, 126 b, Călimăneşti 1:50 000, 1977, 108 d, Titeşti, 1 : 50 000 (1982), 109 c, Cumpăna, 1 : 50 000,1985*)

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The mountainous sector

Within the pre-Mezozoic crystalline area from the Fagaras Mountains, some valleys sectors are formed by antecedent and superimposed genetic processes; this is also the case of the Topolog defile (Ielenicz, Tirla, 2012).

Between the confluence of the rivers Scara and Negoiu (the training point of the river Topolog) and the confluence of Topolog and Topologel, the valley is narrow, symmetric, with strongly inclined slopes, whose base has direct contact with the layer and falls in width, within 5-15 m. In horizontal plane, the valley looks tortuous being conditioned by the petrographic and fault systems. Cumpana's gneisses amphibolous formation, characteristic of this sector, is marked in fluviatil relief by strong elbows with angles from 90 ° to 180 °, being determined either by the fault system oriented NNW - SSE or by the amphibolites and gneiss bands oriented ENE - WSW. This sector of the valley, whose slopes have inclines of 35-55°, has the characteristics of a meandering valley; the valley meanders are kept on about 4 km distance, and they can be identified on slopes up to 200-250 m relative altitude.

The next sector of the valley – Iaroslavele - Manita depression compartmentfollows through a narrow key type valley segment, grafted onto the Cumpana granitoid.

The valley section from Iaroslavele – Manita Depression, the extension of Loviştei Depression, consists of two compartments, grafted on conglomerates and the Podeni's formation sandstones; the characteristics of the valley are determined by the differential erosion, which imposed an asymmetrical aspect in cross section, with slow and prolonged right slope, while the left one is steep and short and the wide layer (150 m). The longitudinal profile shows a decreasing cliff, especially in the right confluences (r. Ruzii, Manita - where a few patches of rock terrace can be identified).

The fault system Brezoi - Titeşti stands out in relief not only by steep slopes of the northern Poiana Spinului Mountains and Frunti, but by the refocusing of the Topolog's flow from NNE - SSW direction to ESE - WNW, on a length of about 1 km. This fault system from the north of the Cozia- Frunti - Ghiţu Mountains has implications in a regional morphohydrographic scale, by imposing the general flow directions and the basins geometric shapes of order 3 and 4 (Penes Valley, Carpenilor Valley – left tributaries of the Cumpana River by Topolog and Pietrosu valley right tributary of the Topolog River).

Between the two depression compartments, Iaroslavele and Manita, there are some geomorphological fluviatile differences; the morphology of the latter has recorded the effects of the lifting in block of the Horst located further south, Poiana Spinului - Frunti, by the deepening of the main hydrographic system and its interruption with about 100 m, above the Topolog's thalweg (Fig. 4) (Andra, 2009). The Topolog's defile (Grigore, 1989) lies between two low massives the Poiana Spinului and the Frunti Mountains, on a length of 5.14 km.

This sector is made up of two narrowing areas and a widening one. Genetically this sector has a tectonic and antecedent character, between the two Paleogene - Miocene sedimentary basins (Muthiac, 2004), from the north and south of the Cozia – Poiana Spinului – Frunti horst.

The ample, sinuous appearance indicates the existence of a valley's meanders, developed only in the lower half of the slopes, below 900 m absolute altitude. On the other hand, at the way out of the clough, the Topolog river has cut itself a gorge sector in Paleogene conglomerates and breccias, which are extending along almost the entire area of the southern slopes of the Frunti Mountains and including the Poiana Spinului Mountain's interfluves; this fact induces the idea either of a more marked elevation of both massifs, in the north, on the fault lines of the system Titeşti – Brezoi, or a mixed epigenetic and antecedent genesis- downstream.

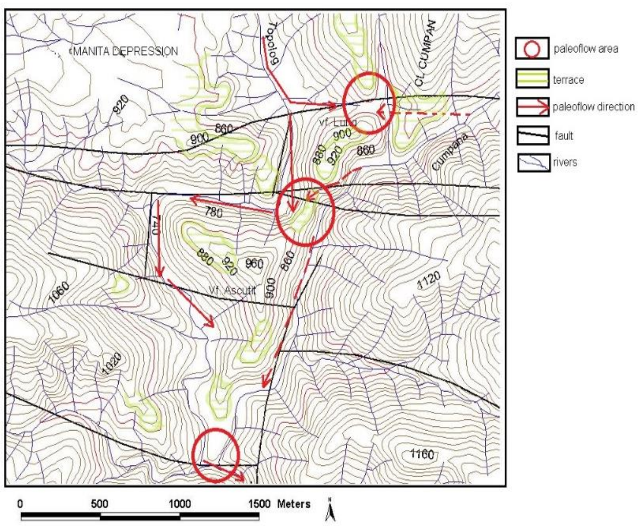

Fig. 4: The draft of the hypothesis of the valley system's evolution under the conditioning of the faults systems, in the mountainous depression Manita

In the slopes two levels have been identified. The first level is located at about 60-80 m relative altitude, being the level at which the intra-mountain depression area Iaroslavele-Manita was modeled, the second level being suspended at this level, above the Topolog current thalweg.

The second level is identified at about 35-45 m relative altitude, being the level of the terrace formed upstream the clough, where this river and Cumpana went deeper, along with the morpho-tectonic completion of the Topolog's clough. To all these, a terrace level of about 5 m relative altitude is added, together being correlated with the evolutive levels from Sălătrucu Depression.

An additional argument that indicates the state of deepening of the Topolog river during the clough's training and of successive confluences witnesses the Ascutit Peak erosion (979.5 m) (Fig. 4, 5), which binds by the two wide saddles and a short interfluves sector (Lung Peak, 935 m), from the Cumpana crest. This witness is framed by a first fault system oriented V - E, and a secondary N - S. It has the same altitude as the Manita's suspended depression compartment or as a level of beads retrieved just on the right side of the Cumpăna's valley. Moreover, the two saddles are altitudinal found under the mentioned witnesses and bear a gravel layer (mica schist with big, gross, rolled cement less garnet), which indicates the fact that both beads and two saddles belong to two levels of tectonic calm, where the two rivers have created a common channel.

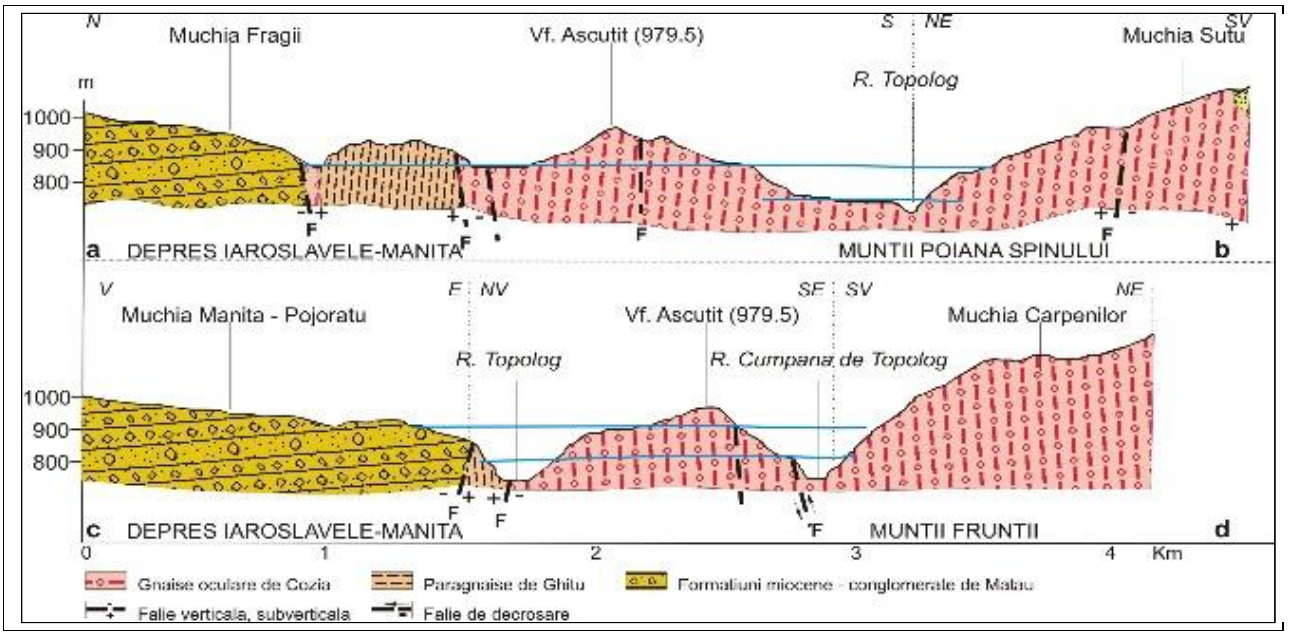

Fig. 5: The Topolog defile, relevant issues in the interpretation of the mountain area's evolution

The two erosion witnesses can only represent, according to this hypothesis, old popins, patches of terraces, detached by the rivers' deepening in the later stages. The morphological areas kept as erosion witnesses have relative altitudes of 60-80 m, which would connect them with T4 terrace (after Mihăilă, 1971) or with T_3 terrace (after Visan, 1998), while the two saddles are above the current thalweg by about 40-45 m relative altitude, thing what includes T_3 and T_2, according to the above cited authors.

The Subcarpathian sector

The internal Subcarpathian sector consists of the Salatrucu submountainous depression area, characterized by a strong asymmetry of the declivity, altitudes, type of relief and morphodynamics of the two slopes. The right side is milder, being subdued to the crossover from conglomerates and sandstones to marls and sandstones - the lower Paleogene, and to Miocene conglomerates, while the left side is characterized by structural landforms in the same lithological conditions (Murgeanu,1953, Dragos, 1959). The morphostructural and morpholithological differentiation is owed to the wide movements from the Frunti Mountains, relatively with the Poiana Spinului Mountains. The terraces are well represented being connected to the upstream ones.

Salatrucu depression is composed of two widening compartments (Salatrucu de Sus and Salatrucu de Jos) and two small narrowing areas, gorges-like, off the anticline drifting to the east of the sandstones and conglomerates: the narrowing of Alunis and the narrowing of Văleni - Dardari (Andra, 2007). The greater width is recorded on the left side of the river, in the northern section - Salatrucu de Sus - and on right side of the river, in the southern one.

This development of the terraces was also reflected in the structure and the occupancy of the two villages: Salatrucu de Sus and Salatrucu de Jos. Downstream, off La Rudari village, the lower terraces T_1 and T_2 have been shaped in piedmont cones that start from high peak Tămaş - La Măcluci, being strongly affected by torrential and areolar erosion processes.

In this area, a strongly anthropic meadow terrace has been identified, due to the construction of the power plant at Salatrucu de Jos by the liquid flow taking-over appliances from the river bed. The lower terrace is unilateral along the entire length of the Salatrucu Subcarpathian sector, with a few

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exceptions in the narrowing sectors at Aluniş and Văleni - Dardaria. The surface of the terrace is smooth, but heightened by the alluvial cones from valleys' bottom with torrential character: Tomeni, Clocotici, Valea cu Calea.

The external Subcarpathian sector consists in three depression areas: Şuici, Cepari and the interference sector Tigveni - Ciofrângeni. In Suici area the Topolog alley is relatively symmetrical, with long and mild slopes. The Cepari depression area is characterized by a strong asymmetry due to some fractural lines that led to the east extension of inferior - Miocene micro conglomerates, while the left side, short, mild and affected by a pronounced morphodynamic, is developed on marls, sands, clays and thin sandstones.

In the piedmont - Subcarpathian transition strip the asymmetry is reversed, as the right side is short and has low declivities, and the left one is long and with higher cliff's values. This morphographical change in cross section is due to the Vătăşeştii - Burlusi synclines structures. The middle and lower terraces are well represented, even affected by hydromorphodinamic and gravitational processes.

The terraces of the Suici – Cepari sector are monolateral, according with the Topolog's meandering directions. The lower terrace is extended over the entire length of the valley corridor, subject to anthropogenic pressure, representing the morphological support of the two communities. The lower terrace T_1 (8 m), in Rudeni locality, has an alluvial structure made up of dusty sands, gravels and clays, in bedding (Fig. 6).

The T_2 terrace is found as patches on the steep slopes' bottom, with the surface slightly inclined toward the valley's axis due to the coluvio - proluvial increased heights; its structure is given by the sandy, dusty clays and in bedding gravels, about 6-7 m, where the first hydrostatic level was identified.

The terraces of the Cepari – Tigveni sector are fragmented, predominantly on the left, for these to be identified more on the right side downstream Tigveni, due to the SE migration of the Topolog River at Burluşi locality. The structural variations of this area, induced by the Vătăşeşti - Burlusi sinclinal and the downstream sequence of the Pontian and Dacian deposits, had imposed the terraces' erosion on the left and their conservation on the right.

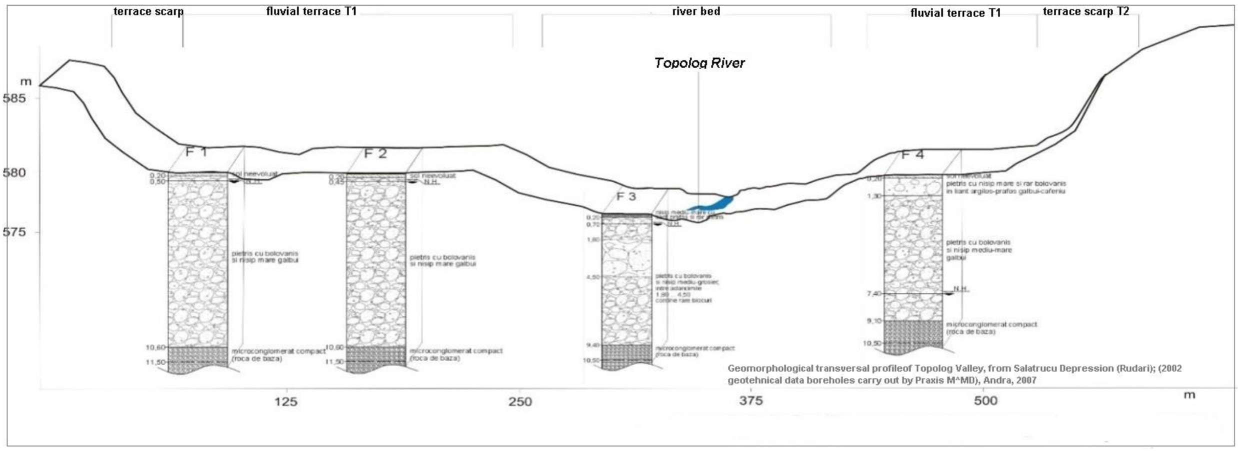

Fig. 6: Cross-section through the lower terrace and the Topolog river bed near to Sălătrucu de Jos and lithostratigraphic column which reveals the sequential formation of alluvial deposits

The piedmont sector

The newest exondated geographical unit in the Topolog's drainage basin is characterized by different amplitudes of the eustatic ascensions, by thicker piedmont deposits and by the existence of some areas of subsidence along the Olt, such as in Băbeni locality, causing the deviation of the Topolog's River bed to South-West (Dragos, 1959). On the Topolog's left side four levels of terraces were identified, near to Poienari village, dominated by the piedmont level and fragmented by the left side tributaries of the collector river. In the Deduleşti - Vărzaru area 12 geoelectrical interpretative sections were made, which revealed an asymmetric arrangement of the terrace's deposits sideways from the river's course.

The T_1 and T_2 terraces in Varzaru - Milcoiu village are covered with the sliding deposits, the entire right slope being affected by a series of deeper slides.

In Milcoiu town, on the right side of the Topolog River, the T_1 terrace (4-5 m) has an alluvial structure: coarse gravels, with the dimensions (major axis, minor axis, thickness) 8/5/3 cm, which have bigger roller gravel in base 13/9/4 cm, laid on a thin layer of 10-15 cm of sand, slightly cemented with oxidation traces; in bedding, the terrace shows small gravels (1.5 / 1 / 0.5 cm) which passes in average gravels 10/5/5 cm. This structure indicates a fluctuated evolution during the T_1 terrace's formation where the river's competence and capacity had variously manifested.

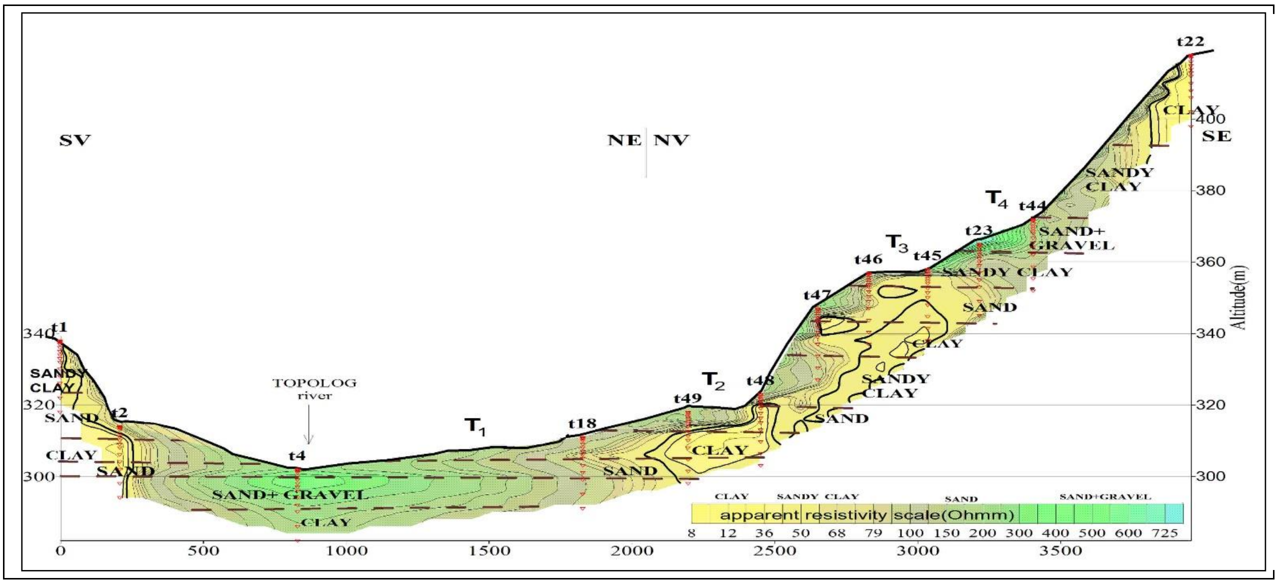

Fig. 7: Dedulesti – Varzaru. Interpretative geoelectrical cross section along geomorphological valley transversal profile regarding the terraces's structure. (scale 1:20000 / 1:1000)

The T_1 terrace (5 - 8 m) in Corbii de Vale locality is represented by a single fragment, identified on the valley's left, where the alluvial cone of a downstream tributary had determined the Topolog river's meandering on the right. The edge of terrace is pinked and the surface width of 200-250 m is used in agriculture.

Upstream the Bălceasca – Topolog confluence, the T_1 terrace, located on the right, is heavily covered by coluvio-proluvial deposits. Terrace T_2, whose scarp was reafforested,is fragmented by torrential organisms. It represents the morphological support for urbanexpansion in the recent years. Fragments from T_2 were also mapped on the left side, but the erosion and fragmentation is much higher than on the right one.Serbăneasa terraces have an equal progress on both sides, in the form of some narrowed strips on the left side and of patches on the right one.Galicea locality's terraces are common to the Topolog and the Olt.

The watershed between the two rivers is being represented by the confluence terrace T_4 on the right (210-240 m). The terraces of Galicea are relatively continuous, but fragmented by erosion such as the cloughs and gullies type. They are unequally distributed on the two slopes and they make, on several kilometers upstream, the basin's watershed.

Vlăduleşti T_4 terrace is formed on quartz sands, poorly cohesive, yellow rust with elements of gravel, and its surface is slightly inclined, without obvious edges, due to the prolonged erosion it went through.

Terrace T_3 has a structure made of gravel embedded in a mass of sand, and red clay in the base, which led to semi profound drifts to the scarp's bottom. These led to the formation of a sliding glacis on the T_2 surface of terrace, widely extended on the both slopes. The surface of terrace is very smooth, with gradients of up to 3º. The edge is clear, trenchant and the scarp is straight. The terrace's structure is described by the following sequence of deposits: 0-1.60 m soil, 1.60-2.90 (phreatic level) gravels and sands with low average granulometries of 2-5 cm and high average of 10-15 m, 2.90-5.20 m reddish loamy sands.

The T_1 terrace, where Galicea town and Cocoru village have expanded, is large, with sinuous contours, revealing the recent dynamism of the Olt's meanderings. It consists of sand and gravel, which repause on a fine clay found bed at depths of approximately 15-20m, possibly the result of the Wurm III deposits. In the recent decades, it has undergone a significant anthropogenic pressure, together with the floodplain, given the construction of Băbeni dam in 1978.

The meadow terrace is characterized by a slightly irregular aspect; its scarp is widely pinked.

Discussions regarding directions of Topolog paleoflows

In order to get a better insight into the morphological aspects of the terrace levels along the Topolog river, this paper was given proof of the necessary aspects for the interpretation of system evolution of river valleys by interdisciplinary analyzing of relative resistivity images which were compared with geotechnical data from boreholes and geomorphological mapping sheet terraces.

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Table 3:Terraces deposits set

	thickness of terraces deposits(m)			roa (omm)		terraces deposits at		numbers of layers
	Carpathians	Sub-Carpathians	Piedmont	max	min	surface	phreatic level	
T1	-	3	12	270	15	weak loamy sands	sandy clay	4 - 5
T2	-	10-12	16	230	15	gravels and cobbles	clay	3 - 4
T3	-	12-13	8-9	60	12	sandy clay		3
T4	-	12	12-15	300	10	gravels and pebbles		2

Thus, the thickness of all terraces levels range between 8 meters and 16 meters, usually increasing from the Sub-Carpathian region to the Piedmont region, as a result of different rate of up-lift of these geographical regions. An exception is given by the third terrace (T3) because it is 12 meters thick in the Sub-Carpathians and 9 meters thick in the piedmontan area, which would suggest an inverse of tectonic movements in the two geographic units when these deposits were filled.

By analyzing and adjusting the terraces' fragments from the Topolog catchments the following evolutive aspects emerged:

- the mountain course deepening's preponderance, as a local and regional reflex of the tectonic movements with some brief periods of calm evidenced by the existence of the twists meanders and the terrace's patches of rock

- the construction of the Fagaras Mountain South units imposed basin's disturbance

- a successive deepening of the Topolog River bed into the Subcarpathian sector with the constant deviation to the right, as demonstrated by the terraces' monolateral position;

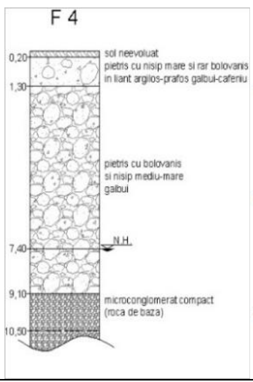
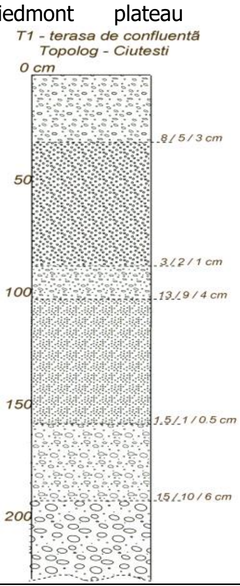
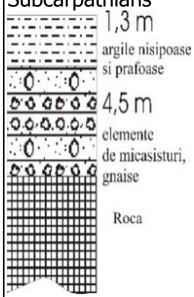
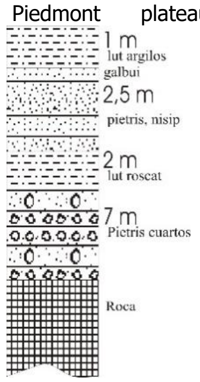
- a clear delineation and extension of the T_1 terrace, fragmented by torrential valleys;

- T_2 terrace, more fragmented, but better highlighted in relief through extensive surfaces as some sheets pervaded into torrential valleys about 100 - 200 m long;

- T_3 terrace borders the secondary interfluves' terminal parts, which are drawn from the piedmont level (ex: Tapa Hill, 611 m) and it represents the greatest fragmentation, sometimes lacking;

- the last terrace, T_4, was identified as a low-level width, but relatively continuous, located at about 70 m below the piedmont level.

Table 4: Summary characteristics of the Topolog river's terraces

Terraces	T_1	T_2	T_3	T_4
Rel. alt (m).	5 – 8	20 - 45	40 – 70 (60 – 80)	100 - 120
occurrence	Sălătrucu – Suici - Cepari Tigveni – Deduleşti,	Salatrucu, Cepari, Tigveni– Deduleşti	Iaroslvale Maniţa, Valeni, Tigveni - Galicea	Tigveni – Dedulesti. Galicea
type	Fill-cut and alluvial terraces in narrow sector	alluvial	alluvial	strath
structure	Subcarpathians Piedmont plateau  	Subcarpathians 	Piedmont plateau 	
width	1 – 3 km monolateral	1,4	2,3 km	3-4 km
toponymes	Rudari,Vărzari	Ceaureşti Galicea	Deduleşti	Galicea
equivalence	Dobrogostea (Argeş)	Vultureşti (Olt)	Verguleasa (Olt)	Slatina (Ot)

The T_4 level, totally isolated in the mountain and the Subcarphatian area, becomes an evident morphological surface in the plateau area, where downstream becomes the confluence terrace. Terrace T_3 is found as isolated patches, with rock or alluvial structure, covered by extensive glacis especially into the Internal Subcarphatian.

Terrase T_2 is generally fragmented, has the aspect of a confluence terrace in the Subcarphatians (Suici, Carpenis and Budislava); in the transition area between the Subarpathian hills and plateau (Tigveni) it is characterized by continuity.

Terrace T_1 has revealed the character of continuity especially in the Subcarpathian and plateau sectors. The lower terraces are alluvial in the Subcarphatians, from where the general trend of widening (continued) of the river during their formation in this area results. Horizontally, in Valeni – Cepari sector, the valley has evolved through lateral west side drifts of the Topolog River, a trend that is also kept in the river bed's evolution.

The Topolog River has created four bilateral terraces in the Cotmeana Piedmont, except the segment Varzaru - Dosu Raului, where they become monolateral as a result of the thrust to the left of the collector river through the cones by the torrential tributaries, at just 1 km from the watershed.

The T_3 terrace level is partly missing in the Poienari piedmont section, which indicates a lateral erosion on the left bank of the river, during the formation of T_2 terrace, with the destroying of a fragment of T_3 terrace; accordingly, during the formation of the terrace T_3, the Topolog presented a wide meander to the left. Although T_3 has a wide deployment along the Olt and on the left side of the Topolog, its absence on the right side of the river, downstream of the mouth (Galicea), indicates the position of the Topolog river during the training of T_2 at the right bottom side, which resulted the T_3 terrace's lateral erosion

Conclusions

The Topolog River basin was completed during the formation of the fluvial system in 4-5 steps of erosion linked to the glacial and interglacial climate's oscillations. All the terraces have sand and gravel (coarse) quartzic type deposits in their structure, with or without boulders and one, two argil or clays (yellowish, reddish) layers, which outlines the varying quality of the competence and capacity of the river during the formation of its own terraces.

Instead, the lateral erosion of the terraces has been driven by local tectonic and structural context (the fault system Brezoi – Titeşti, the synclines structures Vătăşeştii - Burlusi, the existance of conglomerates) and morphodynamic (cones, aprons and slides).

The hydrographic network from the Topolog basin during the completion of each terrace level is highlighted in the deposits' structure and thickness, indicating a stronger process of erosion on the T_1 and T_3 terraces level, lower in the case of T_2 and a more profound at the upper terrace level.

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References

Andra A. (2002). Suprafeţe şi nivele de eroziune în bazinul hidrografic montan al Topolgului. *Comunicări de Geografie*, Vol. VI, Editura Universităţii din Bucureşti

Andra A. (2007). Depresiunea Sălătrucu. Observaţii geomorfologice. *Comunicări de Geografie*, vol XI Ed. Universităţii din Bucureşti, ISSN 14535483

Andra A. (2009). *Bazinul hidrografic Topolog. Studiu geomorphologic*. Rezumatul tezei de doctorat, ISBN 978-973-0-06260-1

Badea L. (1983). Defileul Coziei şi valea subcarpatică a Oltului (suprafeţe de nivelare şi terase), *St. Cerc. geol., geofiz., geogr., Geog*rafie, XXX

Botezatu R. (1987). *Bazele Interpretării Geologice a Informaţiilor Geofizice*. Edit. Tehnică, Bucureşti

Chhang H., An Z., Qiang X., Song Y. & Fu C. (2006). The causes of fluvial terraces inland and its implication. *Conference: IEEE International Geoscience & Remote Sensing Symposium*, IGARSS 2006, July 31 - August 4, 2006, Denver, Colorado, USA, Proceedings, DOI: 10.1109/IGARSS.2006.396

Dragoş Gh. (1959). Recherches geologiques concernant la region Topolog et Olt, *C.R. com. Geol.* XXXVII – XXXIX, Bucureşti

Grigore M. (1989). *Defileuri, chei si vai de tip canion.* Edit. Stiintifica, Bucuresti

Ielenicz M. & Tirla L. (2012). The Carpathian river system in Romania – genesis and evolution, *Revue Roumaine de Geographie/Rom. Journ. Geogr.*, *56 (1):* 21–31

Merritts Dorothy J., Vincent K. & Wohl Ellen E. (1994). Long river profiles, tectonism, and eustasy: A guide to interpreting fluvial terraces. *Journal of Geophysical Research*, *99(B7)*: 14,031-14,050

Mihăilă N. (1971). Stratigrafia depozitelor pliocene şi cuaternare dintre Valea Oltului şi Valea Vîlsanului (sectorul Rîmnicu Vîlcea – Curtea de Argeş – Vîlsăneşti). *Studii tehnice şi economice*, Seria 3, Stratigrafie, nr. 7, IG., Bucureşti

Morris M. et al. (1997). Detecting Lateral Resistivity Inhomogeneities with the Schlumberger Array-Geophysical Prospecting 45. *EAGE Netherlands*, 435-448

Murgeanu G. (1953). Cercetări geologice asupra regiunii dintre Rîurile Topolog şi Olt. *D.S. ale şedinţelor*, vol XXXVII (1949 – 1950) Comitetul Geologic, Bucureşti

Mutihac V., Stratulat M. I. & Fechet Magdalena R. (2004). *Geologia României*. Ed. Did. şi Ped., R.A., Bucureşti

Olszak J. (2011). Evolution of fluvial terraces in response to climate change and tectonic uplift during the Pleistocene: Evidence from Kamienica and Ochotnica River valleys (Polish Outer Carpathians). *Geomorphology. 129(1-2)*: 71-78. doi: 10.1016/j.geomorph.2011.01.014

Popescu N. (1972). Valea Oltului între Turnu Roşu şi Cozia. *Observaţii geomorfologice*, B.S.S.G., vol. II (LXXII), Bucureşti

Popescu N. (1984). La pediplaine carpatique dans les Monts Făgăraş, *Analele Universităţii Bucureşti*, Geografie, An XXXIII

Posea Gr. (1997). *Suprafeţe şi nivele de eroziune, Rev. de geomorfologie*. editată de Asoc. Geornorfologilor din Rornânia, Bucureşti

Posea Gr. & Armaş I. (1999). Suprafeţe de nivelare în Carpaţi şi Alpi. O incursiune comparative. *Com. de Geogr.* , vol. III, Ed. Univ. din Bucureşti

Sîrcu I. (1958). Contribuţii cu privire la problema gipfelflurului şi a suprafeţelor de peneplenă din Munţii Făgăraşului. *Analele Ştiinţifice ale Univ. "Al. I. Cuza" din Iaşi, seria nouă*, secţ. II, Ştiinţele naturii, I – IV, fasc. 1

Visan G. (1998). *Muscelele Topologului, studiu fizico – geografic*. Edit. Universitatii Bucuresti.

Viveen W., Schoorl J. M., Veldkamp A., Van Balen R.T. & Vidal-Romani Jr. (2013). Fluvial terraces of the northwest Iberian lower Miño River. J*ournal of Maps*, 9(4):513–522 http://dx.doi.org/10.1080/17445647.2013.821096

*** (1968). *Harta geologică, 34. Piteşti, 1:200 000*, Institulul de Geologie şi Geofizică, Bucureşti

*** (1968). *Harta geologică, 27. Sibiu, 1:200 000*, Institulul de Geologie şi Geofizică, Bucureşti

*** (1977). *Harta geologică, 109 a, Negoiu, 1:50 000,* Institutul de Geologie şi Geofizică, Bucureşti

*** (1977). *Harta geologică, 126 b, Călimăneşti, 1: 50 000*, Institutul de Geologie şi Geofizică, Bucureşti

*** (1982). *Harta geologică, 108 d, Titeşti, 1: 50 000*, Institutul de Geologie şi Geofizică, Bucureşti

*** (1985). *Harta geologică, 109 c, Cumpăna, 1: 50 000*, Institutul de Geologie şi Geofizică, Bucureşti

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A complex approach in the interdisciplinary field of karst geomorphology. The case study of Anina karst area (Banat Mountains, Romania)

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Abstract

Karst regions are characterized by discontinuity and even by the lack of surface water drainage due to the fissured and porous rocks, but the rivers are often flowing in the underground. Our study area is represented by the Anina karst area, a karst region that is situated in the largest and most compact carbonate area in Romania, the Reșița - Moldova Nouă Synclinorium. This study aims to analyse a mature karst area using a complex approach in karst geomorphology. To achieve this assessment, we intended (i) to get an overall description of the morphology of the area using digital data and GIS methods; (ii) to obtain detailed data regarding cost evolution using geophysics, hydrogeology and speleology, and (iii) to correlate all the data to evaluate the karst terrain from the geomorphology perspective.
Our research is still in progress, and yet we have results that are leading to a complex approach in karst topography research from a geomorphological perspective, using different fields of study as geology, speleology, spontaneous potential as geophysical method and computer science (GIS). Based on our field measurements we were able to correlate those features that are extremely important in karst solution processes, as water circulation, underground conduits, slope, soil properties, water properties in order to have a better understanding regarding the actual landscape in the Anina karst area and also in order to develop hypotheses regarding the possible evolution of karst landforms in the studied territory.
Interdisciplinarity in karst topography studies is very important. Only by involving scientists, and techniques belonging to different scientific domains, we may understand in detail the karst topography. This complex approach is useful for stakeholders and local authorities in their feasibility studies and strategies for local development due to the fact that our study enriches the knowledge regarding karst environment "behaviour" in Anina region.

Keywords: *karst, geomorphology, complex approach, interdiscplinarity, Anina Mountains*

Rezumat. Abordarea complexă în domeniul interdisciplinar al geomorfologiei carstice. Studiul de caz al zonei carstice Anina (Munții Banatului, România)

Regiunile carstice sunt caracterizate de către discontinuitatea și chiar lipsa apelor de suprafață ca urmare a rocilor poroase și fisurate, dar râurile cel mai adesea au curgerea în subteran. Zona de studiu este reprezentată de zona carstică Anina, o regiune carstică situată în cea mai întinsă și compactă suprafață de roci carbonatice din România, Sinclinoriul Reșița - Moldova Nouă. Scopul studiului este de a analiza un areal carstic matur folosind o abordare complexă în ramura geomorfologiei carstice. Pentru atingerea acestei evaluări am intenționat (i) să obținem o imagine de ansamblu a morfologiei arealului studiat folosind date digitale și aplicând metode SIG; (ii) să obținem date de detaliu privind evoluția carstică folosind metode geofizice, hidrogeologia și speologia, și (iii) să corelăm toate aceste date pentru a evalua arealul carstic din perspectivă geomorfologică.
Chiar dacă cercetarea de față este în derulare, am obținut rezultate ce ne conduc spre o abordare complexă în cercetarea reliefului carstic din perspectivă geomorfologică, folosind diferite domenii de studiu precum geologia, speologia, potențialul spontan ca metodă geofizică și tehnica computațională (SIG). Pe baza măsurătorilor din teren am reușit corelarea factorilor importanți în procesele de disoluție carstică, precum circulația apei, canale carstice, proprietățile solului și ale apei, panta, toate aceste pentru a avea o mai bună înțelegere a carstului din Câmpul Minier Anina și pentru a putea ridica ipoteze privind posibila evoluție ulterioară a teritoriului studiat.
Interdisciplinaritatea în studiile regiunilor carstice este foarte importantă. Doar implicând cercetători și tehnici aparținând diferitelor domenii științifice, suntem capabili să înțelegem în detaliu relieful carstic. Această abordare complexă este utilă părților interesate și autorităților locale în studiile de fezabilitate și strategiile pentru dezvoltarea locală datorită faptului că acest studiu îmbogățește cunoștințele privind "comportamentul" mediului carstic în zona Anina.

Cuvinte-cheie: *carst, geomorfologie, abordare complexă, indersciplinaritate, Munții Aninei*

Introduction

Karst regions are characterized by discontinuity and even by the lack of surface water drainage due to the fissured and porous rocks, but the rivers are often flowing in the underground (Ford & Williams, 2007, 2011). In Romania, almost 2% of its surface, it's occupied by limestone (Sencu, 1978), meaning almost 4,500 km^2 (Orghidan et al., 1972). Karst geomorphology includes both surface and underground landforms research, landforms that develop on soluble rocks by solution and associated processes. Typical karst landforms develop best on pure, dense and thick limestones and marbles, and in consequence, it is very important to obtain various data regarding these two submediums. We consider that karst geomorphology is an interdisciplinary scientific field because the research in a karst area from a geomorphological perspective involves different studies, belonging to many scientific fields: geology, hydrogeology, biogeography, pedology, geophysics, speleology, computer science.

This interdisciplinary approach is widely used to study karst areas in Spain (Gutiérrez et al., 2011; Anchuela et al., 2013), Croatia (Telbisz et al., 2009), Saudi Arabia (Youssef et al., 2012) and Italy (Ercoli et al., 2012).

This study aims to analyse a mature karst area using a complex approach in the interdisciplinary field of karst geomorphology. To achieve this assessment, we intended (i) to get an overall description of the morphology of the area using digital data and GIS methods; (ii) to obtain detailed data regarding cost evolution using geophysics, hydrogeology and speleology, and (iii) to correlate all the data to evaluate the karst terrain from geomorphological perspective.

Theoretical background

A concern regarding interdisciplinarity is "how" different perspectives, belonging to different sources are situated, selected and after that used in any field of science (Payne, 1999). Another paper regarding interdisciplinarity in geography belongs to Baerwald (2010). In this paper the author tries to point out the relationship of geography with other disciplines and also the perspectives of geography as an interdisciplinary domain. Baerwald (2010) considers that geography is a "big tent" having three major areas that encourage communication and interaction, two factors extremely important in interdisciplinarity. These three major areas focus on spatial analysis, human–environment interaction, and place-based and regional analyses.

Geomorphology is the area of study leading to an understanding of landforms and appreciation for landforms and landscapes, including those on continents and islands, those beneath oceans, lakes, rivers, glaciers and other water bodies, as well as those on the terrestrial planets and moons of our Solar System (Bauer, 2004). Considered to be a composite science (Osterkamp, 2008), geomorphology is claimed by the geographers and by geologists.

The modern-day geomorphologist has a deep appreciation for the importance of slowly acting processes in concert with large-magnitude, low frequency events in leaving imprints on the landscape, for the utility of detailed process, mechanical studies as well as historical reconstructions of landform assemblages in unravelling the complexities of the present-day surface. Besides these, the geomorphologist deals with the interconnectivity between the various subspecializations of geomorphology and allied Earth and engineering sciences, and for the complementarities among twenty-first century technological capacities (Bauer, 2004).

Being connected to the ever-growing influence of the socioeconomic domain on the natural environment and, implicitly, on the relief and its evolution, geomorphology is simultaneously developing in diverse directions: on one hand, it is becoming a more rigorous geophysical science — a significant part of a larger earth science discipline; on the other hand, it is becoming more concerned with human social and economic values, with environmental change, conservation ethics, with the human impact on the environment, and with issues of social justice and equity (Church, 2010).

Karst geomorphology is represented by the study of both surface and underground landforms that are developed on soluble rocks as the consequence of dissolution and associate processes (De Waele et al., 2009).

Below are defined the main scientific domains that are used in the interdisciplinary field of karst geomorphology and there are also mentioned several references in order to emphasize the importance of each of those fields in karst terrains research.

Geology is the scientific study of the origin, structure, composition, and history of the Earth, together with the processes which have led to its present state (Whittow, 1984).

Geophysics is the science concerned with all aspects of the physical properties and processes of the Earth and planetary bodies and their interpretation, including, for example seismology, gravity, magnetism, heat flow, geochronology (Allaby, 2008).

Application of geophysical methods – GPR, DC electrical tomography, self potential – enable the knowledge of the structure of karstificable masses, to identify karst cavities and morphology of karst landforms and, of course, water circulation in karst structures. The proof of these research directions is those many papers that present investigations in karst topography that are using geophysics techniques: Chamberlain et al. (2000); Zhou et al. (2000; 2002); Gibson et al (2004); El-Qady et al. (2005); Rozycki et al. (2006); Jouniaux et al. (2009); Cardarelli et al. (2010); Anchuela et al. (2008; 2009; 2010; 2013); Moore et al. (2011); Coskun (2012); Mihevc & Stepišnik (2012) and Łyskowski et al. (2014). Karst geophysical approaches In Romanian are sporadic: Mafteiu (1991) and Mitrofan et al. (2008), studies that are using resistivity methods in the Padiș Plateau and respectively in the Cerna Valley.

Hydrogeology is the scientific study of the occurrence and flow of groundwater and its effects on earth materials (Allaby, 2008). It is closely related to karst geomorphology due to its information regarding the water circulation in karst massifs, giving important data about the evolution of the endokarst. This field of study is the link between the exokarst geomorphologycal investigations and the underground investigations in karst topography. There are many papers dealing with hydrogeology in karst terrain around the world: Bakalowicz (2005); Goldscheider et al. (2008); Williams (2008); Jeannin et al. (2012); and also in Romania, Orășeanu & Iurkiewicz (2010); Povară & Ponta (2010).

Pedology - science that has as object for its study the soils as natural units, from the perspective of their genesis, morphological characters, physical, chemical and biological properties, their classification and distribution, and general principles of use, amelioration and control their fertility (Conea et al., 1977).

Soil is the layer that separates the exokarst from the endokarst. Its presence or absence is decisive in the development of karst landforms and in karst environment pollution. There is a strong relationship between the formation of landforms, soils and vegetation on karst terrains. There are different approaches that are studying soil related with karst environment: karst aquifer investigations (Tooth & Fairchild, 2003); cave drips studies (Baldini et al., 2006; Fairchild et al., 2006); infiltration processes (Arbel et al., 2010); human influence on karst soils (Canora et al., 2005); soil formation and distribution in Yucatan, Mexico (Bautista et al., 2011); role of soil cover in groundwater recharge (Jeannin et al., 2013), the relation between vegetation formation and soil properties (Efe, 2014).

Speleology is the scientific study of the origin of caves and cave life (Whittow, 1984).

In the scientific literature, there are a large number of papers where speleology is used to present some important aspects for different karst areas, as for e.g. Kambesis (2007); Goldscheider et al. (2008); Klimchouk (2009); Debevec et al. (2012); Ballesteros et al. (2015).

Land Use/Land Cover (LU/LC) - Land use is represented by the socioeconomic inputs to land. It describes an activity with an input, a process, and also the results of this human activity. Land cover is defined as the vegetation cover on the Earth's surface. It includes also man-made features, but also bare rock, bare soil and inland water surfaces (Herold et al., 2007).

Geographical Information Science (GIS) is the system based on using electronic techniques for calculation, for acquisition, to store, analyse and display geographic data. It is an information system that is able to organize the information based on spatial criteria (geographical criteria) (Donisă, Donisă, 1998).

Remote Sensing (RS) - a system that is based on remote capturing, recording and analysis of electromagnetic or sound signals that are sent by objects and processes as emissions or reflections (Donisă, Donisă, 1998).

GIS and RS as methods in karst studies were used in different papers. In Romania, Torok-Oance et al. (2009) used DEM for the identification of the planation surfaces in Mehedinți Mountains and Torok-Oance & Ardelean (2012) used Object-Oriented Image Analysis (OBIA) for detection of barren karst areas in Mehedinti Mountains. Around the world, there are several approaches that are using GIS and RS as tools in karst terrains investigations: Orndorff et al. (2000); Hung et al. (2002); Ohms & Reece (2002); Tagil & Jenness (2008), Telbisz et al. (2009), Pardo-Igúzquiza et al. (2013), Zylshal & Haryono (2013).

In order to get a brief image regarding the domains that we mentioned above as fields that we used in our complex approach in the interdisciplinary field of karst geomorphology, we propose a schematic representation of those scientific domains and the connections/correlations that could be made between them (Fig. 1).

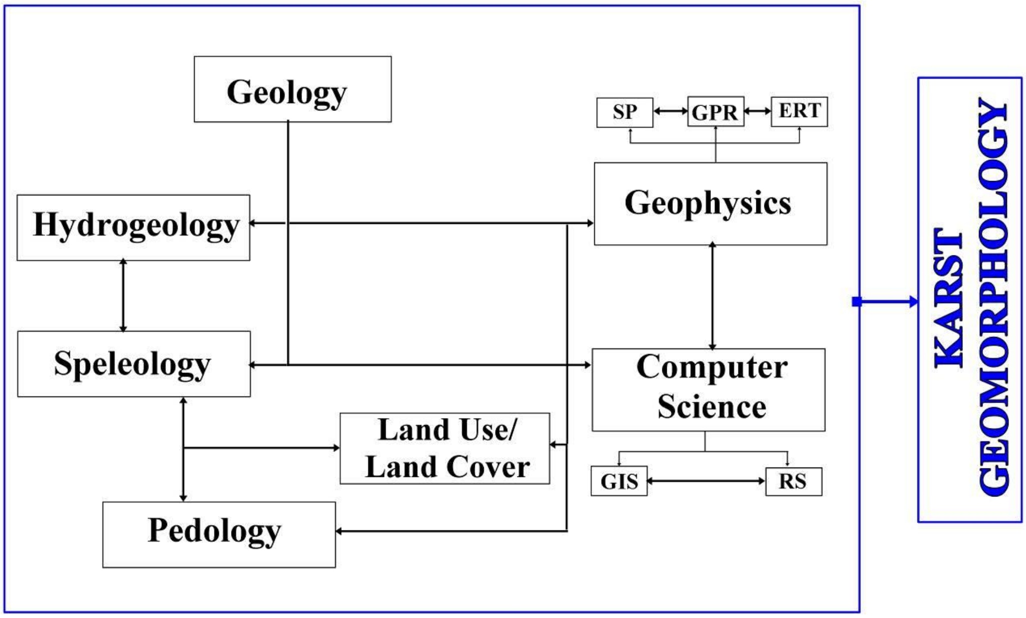

Fig. 1: Scientific domains that we used in our complex approach in the interdisciplinary field of karst geomorphology

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Case study. Methodology and results

This section of our paper explains briefly our field measurements and parts of our results in the study area which is represented by Anina karst area, a karst region that is situated in the largest and most compact carbonate area in Romania, the Reșița - Moldova Nouă Synclinorium. Anina karst area was defined by Sencu (1977) as the area that surrounded Anina town and it may be exploited by mining activities. Using the 1:25000 topographic maps and tacking into account the main geomorphological landscape characteristics, we established the geomorphological limits for this region (Fig. 2).

The lithology of the study area is formed by many types of limestone (Anina Valley's limestone, Brădet limestone, Marila limestone, Gumpina limestone, Miniș limestone) and different types of marl. We should also mention the presence of clays and noncarbonated materials that occupy smaller areas, such as granite, gravel and sandstones (Bucur, 1997).

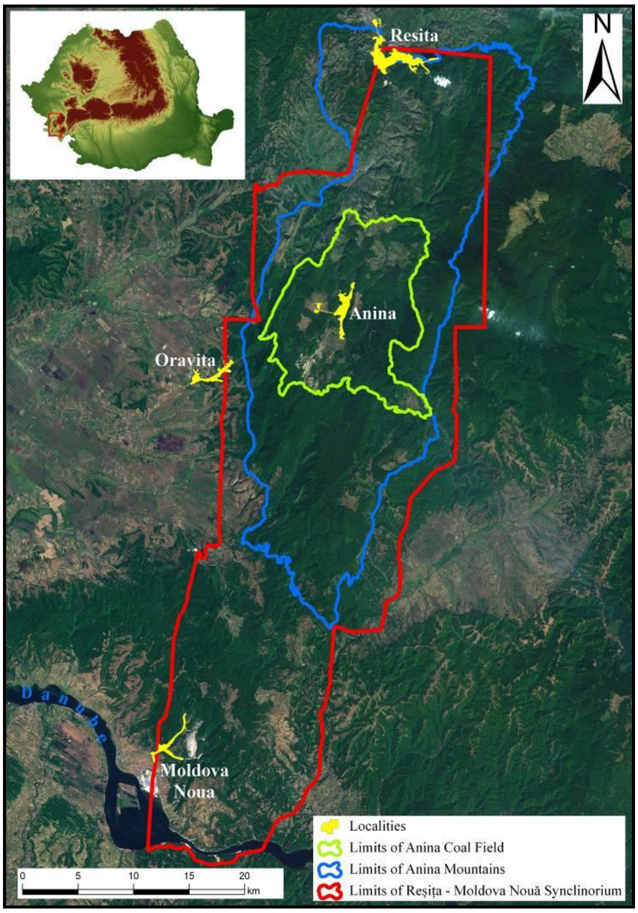

Fig. 2: The location of Anina karst area (Source of background satellite image: http://goto.arcgisonline.com/maps/World_Imagery)

Embracing an interdisciplinary perspective, we carried out several measurements in our study area. First of all, we used GIS techniques and methods to obtain an overall perspective regarding the study area analysing morphometric parameters of the study area. Hypsometry is a very important parameter, indicating that the altitude is similar on the suspended karst plateaus and the importance of faults direction in morphology (Fig. 3 - left). The slope is also extremely important in the dissolution processes due to the water and snow retention on low slopes and correlating with sinkholes, we emphasized the contribution of slope in karst terrain evolution (Fig. 3 - right).

Another approach of our study is one of the geophysical methods, naming here spontaneous potential for a preliminary approach in our area (Artugyan & Urdea, 2014). This method involves using a digital voltmeter and two non-polarising electrodes (Fig. 4 - left). We developed measurements in many sinkholes (Fig. 4 - right) and we obtained results as grids (Fig. 5 - left) and as profiles (Fig. 5 - right). The grid results were obtained in ArcMap 10 using Kriging interpolation method, using 5 meters between measurement points, as we used in the field. The profiles were obtained in Microsoft Excel, based on the field measurement distance between points, of 3 meters.

Moreover, we developed karst water analysis. We gathered data on calcium, magnesium, water pH and hardness, and also thermal conductivity (Fig. 6 - left). For soil cover we studied soil pH and soil moisture (Fig. 6 - right). Soil moisture is an important element in Spontaneous Potential values and we intended to join SP data with this parameter for a better understanding of water drainage using SP.

Another field that we have used belongs to the speleology domain. Thus, we have visited 8 caves: Buhui Cave - the largest cave with more than 6 km development and which is draining the homonymous creek, the longest underground stream in Banat Mountains with more than 3 km, Cuptoare Cave (135 meters length), Mărghitaș Cave (115 meters length), Cârneală Cave, The Cave from Caraș Spring, The Cave with Water from Gârliște Gorges, The Vertical Shaft under Black Peak, Salamanders' Cave. Buhui Cave is the largest active cave in Banat and Cuptoare Cave was in the past a gallery of Buhui Cave. In Cuptoare Cave and Mărghitaș Cave we repeated our visits to observe the level of water (for those active caves) and to observe that the drip water is different based on the season when we were there. Cârneală Cave is retaining snow for many months of the year, having a negative development and acting as snow/ice trap. The Vertical Shaft under Black Peak is quite a new discovery in the study area, having more than 200 meters' depth with further exploring potential. All these caves are indicating the level of karstification.

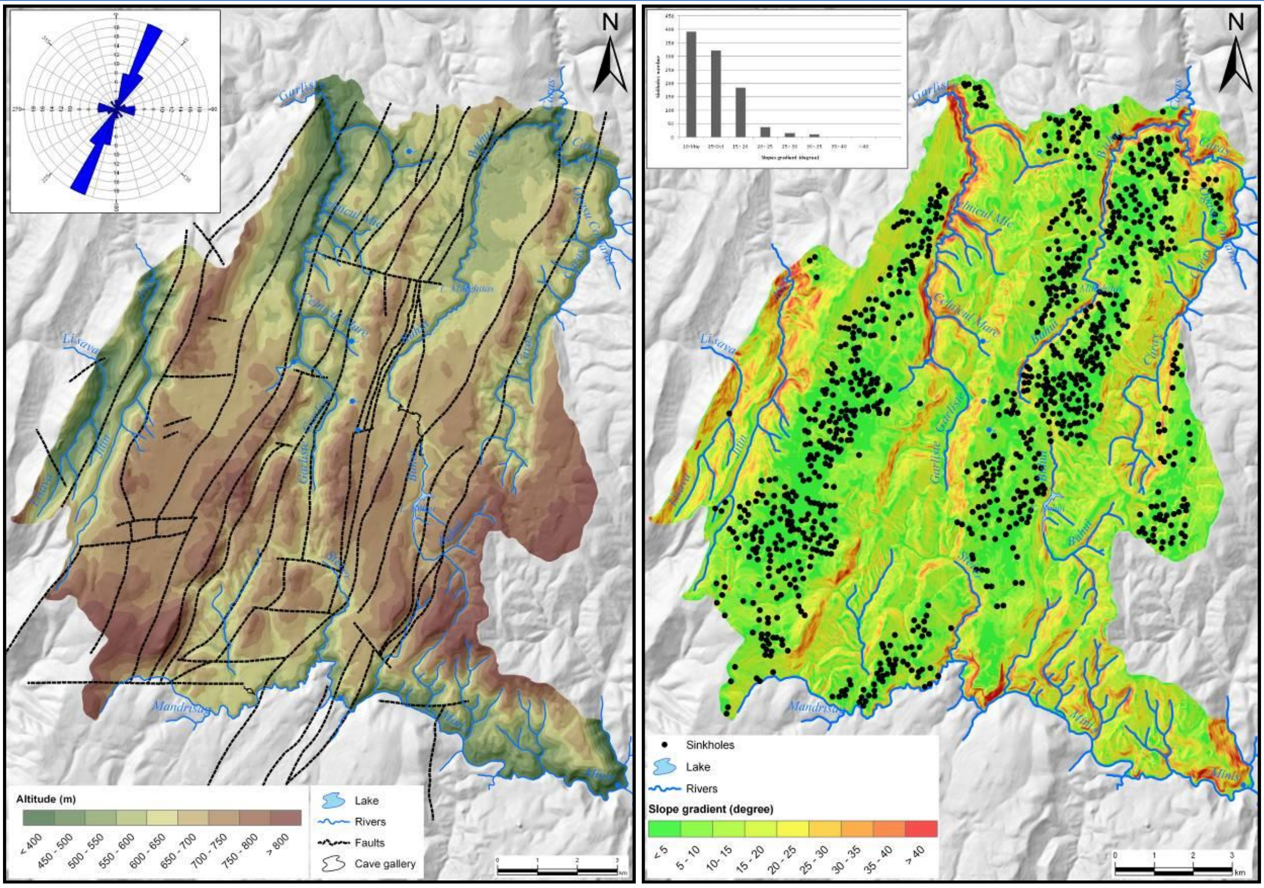

Fig. 3: The morphology and the importance of faults directions in morphology; the main faults directions (upper left corner) (left); slopes and sinkholes in slope classes (upper left corner) (right) in Anina karst area

Fig. 4: The SP measurements - the digital voltmeter (left) and one of our sinkholes study cases (right)

Based on the morphometric analysis, we were able to point out the importance of morphometric parameters for the other fields of studies (speleology or geophysics for example). The slope is indicating those areas with water stagnation and slow snow melting process as a consequence of low values of slope parameter. In those areas sinkholes are well developed, with a high density, surface water is missing, indicating the presence of the underground flowing water system. Drainage density parameter points out those areas without surface drainage, highlighting karstic suspended plateaus. The morphometric approach indicates those areas with favourable conditions for underground conduit development where we should focus our geophysical investigations and speleological research. Then, based on the geophysics we were able to observe the structure of the underground and to get a model based on SP measurements on the drainage direction into the sinkholes on the surface water. Using this geophysical method, we were able to identify the karst conduits orientation based on surface water drainage direction, that in most of the cases matches with fault orientation. Using speleology, we observed the orientation of geologic features, of fractures and the water circulation directions based on bedrock fissures.

Based on our field measurements we were able to correlate those features that are extremely important in karst solution processes, as water circulation, underground conduits, slope, soil properties, water properties in order to have a better understanding regarding the actual landscape in the Anina coast area and also in order to develop hypothesis regarding the possible evolution of karst landforms in the studied territory.

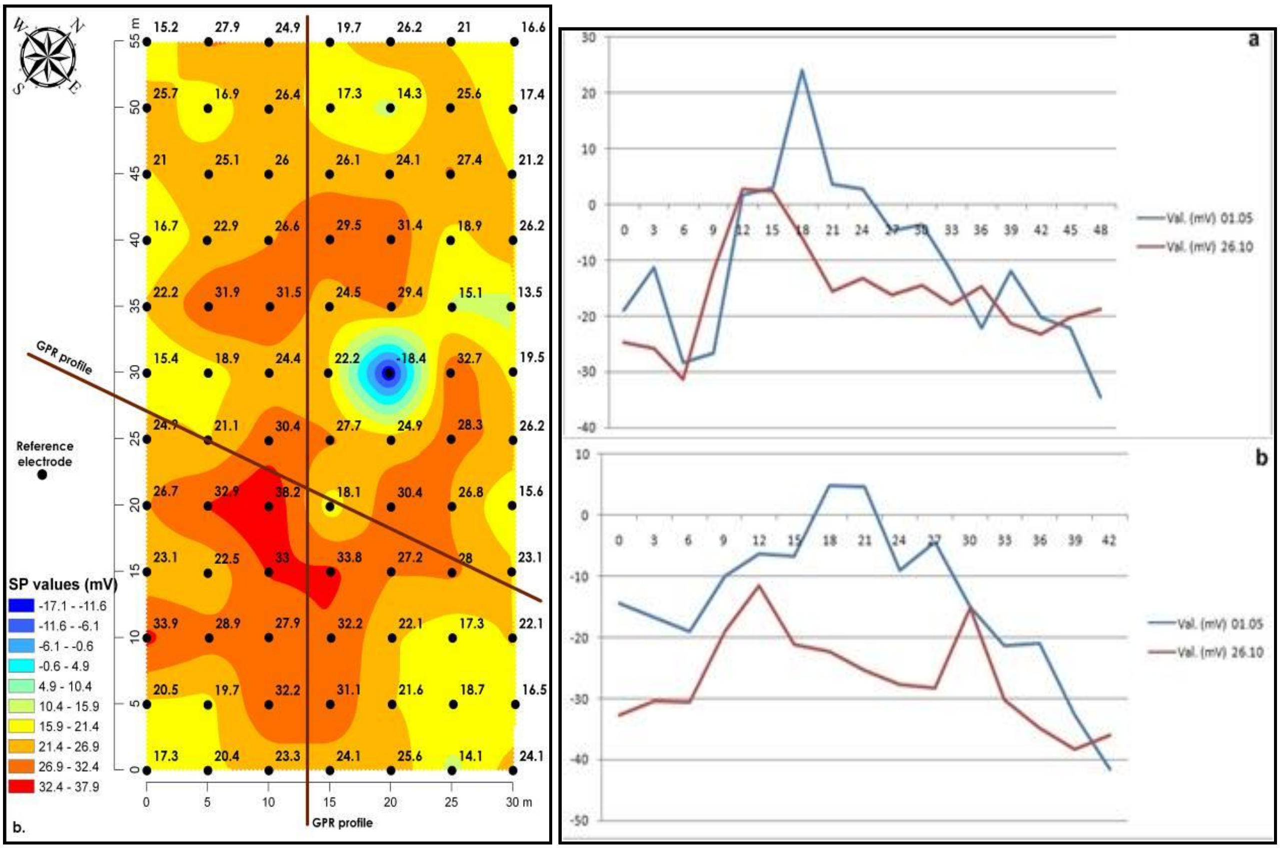

Fig. 5: The results based on SP measurements - a grid (left) and 2 profiles (right) (Artugyan & Urdea, 2014)

Fig. 6: The water chemistry analysis downstream Caraș Spring (left) and soil properties (pH and moisture) studies in a sinkhole in the Anina's neighbouring New Town (Orașul Nou) (right)

Disscusions

First of all, for the karst geomorphology, we need to know the geology because we should speak about limestone, regarded as a rock with specific mineralogy and, on the other hand, the masses of rock with some certain structure and tectonics. Then, to get the morphometric characteristics we should use computational techniques associated with GIS and geomorphometry. Because karst terrain presents both surface and underground, for the underground studies, we should use speleology to study caves and their landforms, and also SP as a geophysical method in drainage water investigations. Recognizing the essential role of groundwater in karst landscape genesis, hydrogeological approach is required to know the karst water circulation and their chemical composition. For karst geomorphology, it is very important to have information regarding the soil cover and vegetation cover, in order to understand better the duration of surface water reaching the underground.

Our research is still in progress, and yet we have results that are leading to a complex approach in karst topography research from a geomorphological perspective, using different fields of study as geology, speleology, spontaneous potential as geophysical method and computer science (GIS).

Such a complex approach, involving several scientific fields and methods, is quite a new one in the karst geomorphology. For Romanian karst terrains, this kind of research is the first one. Around the world, there are several studies having a complex approach: De Waele et al. (2009); Ercoli et al (2012); Anchuela et al. (2013). These studies were the scientific references of our research and the results have similar aspects, but there are also differences given by the geological and geomorphological characteristics of the study areas.

As De Waele et al. (2011) said, only having a better knowledge of karst geomorphology and karst hydrogeology we are able to live "together" with karst environment in order to have a sustainable development of karst resources, and not just to live in karst terrains.

Conclusions

Using many fields of study in the Anina karst area, we were able to exemplify that the karst geomorphology may be considered as an interdisciplinary field of study. If we would use only field observations and morphometric analysis, it would be difficult to have a real perspective regarding karst morphology in our study area. But combining with geophysics, water chemistry, soil properties (as moisture and pH) and speleology, we obtained different data that give us a larger perspective regarding karst topography in the Anina karst area. Our results indicate the role played by the structural features in the terrain morphology, show up the importance of slope in dissolution processes and the role played by the sinkholes in disorganising the surface hydrography. Moreover, based on our approach we were able to correlate soil pH and moisture with SP results, SP measurements that is correlated with rock stratigraphy and orientation. Also, we could identify several underground conduits that are draining the surface water into the underground.

Interdisciplinarity in karst topography studies is very important. Only by involving scientists or techniques belonging to different scientific domains, we may understand in detail the karst topography.

In our future work we intend to complete our data and to enlarge the number of our sites in the study area because a large number of data is very important for a complete perspective regarding karst geomorphology.

In the near future, we intend to use also hydrogeology and other geophysics methods as GPR and DC electrical tomography, and also to continue with the acquisition for spontaneous potential data and speleological data.

This complex approach is useful for stakeholders and local authorities in their feasibility studies and strategies for local development due to the fact that our study enriches the knowledge regarding karst terrain "behaviour" in the Anina region.

References

Allaby, M., (editor), (2008). Oxford dictionary of Earth sciences, Oxford University Press, Oxford, 654 p

Anchuela, Ó. P., Casas-Sainz, A. M., Soriano, M. A., & Pocoví-Juan, A., (2008). Mapping subsurface karst features with GPR: results and limitations, *Environmental Geology*, 58(2), p. 391-399. doi: 10.1007/s00254-008-1603-7

Anchuela, Ó. P., Soriano, A. P. J. M. A., Casas-Sainz, A. M., (2009). Characterization of karst hazards from the perspective of the doline triangle using GPR — Examples from Central Ebro Basin (Spain), *Engineering Geology*, 108(3-4), p. 225-236, doi: 10.1016/j.enggeo.2009.06.022

Anchuela, Ó. P., Casas-Sainz, A. M., Soriano, M. A., Pocoví-Juan, A., (2010). A geophysical survey routine for the detection of doline areas in the surroundings of Zaragoza (NE Spain), *Engineering Geology*, 114(3-4), p. 382-396, doi: 10.1016/j.enggeo.2010.05.015

Anchuela, Ó. P., Juan, A. P., Casas-Sainz, A. M., Ansón-López, D., Gil-Garbi, D. H., (2013). Actual extension of sinkholes: Considerations about geophysical, geomorphological, and field inspection techniques in urban planning projects in the Ebro basin (NE Spain), *Geomorphology,* 189, p. 135-149, doi: 10.1016/j.geomorph.2013.01.024

Artugyan, L., Urdea, P. (2014). Groundwater drainage monitoring and karst terrain analysis using Spontaneous Potential (SP) in Anina Mining Area (Banat Mountains, Romania). Preliminary study. Paper presented at: International Conference Karst without Boundaries, Trebinje/Dubrovnik, 11-15 June 2014

Arbel, Y., Greenbaum, N., Lange, J., Inbar, M., (2010). Infiltration processes and fl ow rates in developed karst vadose zone using tracers in cave drips, *Earth Surface Processes and Landforms*, 35, p. 1682–1693

Baerwald, T. J., (2010). Prospects for Geography as an Interdisciplinary Discipline, *Annals of the Association of American Geographers*, 100, 3, p. 493-501

Bakalowicz, M. (2005). Karst groundwater: a challenge for new resources. *Hydrogeology Journal*, 13(1), p. 148-160. doi: 10.1007/s10040-004-0402-9

Baldini, J. U. L., McDermott, F., Fairchild, I. J., (2006). Spatial variability in cave drip water hydrochemistry: Implications for stalagmite paleoclimate records, *Chemical Geology*, 235, p. 390–404

Ballesteros, D., Jiménez-Sánchez, M., Giralt, S., García-Sansegundo, J., Meléndez-Asensio, M., (2015). A multi-method approach for speleogenetic research on alpine karst caves. Torca La Texa shaft, Picos de Europa (Spain), *Geomorphology*, 247, p. 35–54

Bauer, B. O. (2004). Geomorphology, in Goudie A.S. (editor), *Encyclopedia of Geomorphology*, Routledge Ltd, London, p. 428-435

Bautista, F., Palacio-Aponte, G., Quintana, P., Zinck, J. A., (2011). Spatial distribution and development of soils in tropical karst areas from the Peninsula of Yucatan, Mexico, *Geomorphology*, 135, p. 308-321

Bucur, I. I., (1997). Formaţiunile mezozoice din zona Reşiţa-Moldova Nouă (Munţii Aninei şi estul Munţilor Locvei), Edit. Presa Universitară Clujeană, Cluj-Napoca, 214 p

Cardarelli, E., Cercato, M., Cerreto, A., Di Filippo, G., (2010). Electrical resistivity and seismic refraction tomography to detect buried cavities, *Geophysical Prospecting*, 58, p. 685–695

Canora, F., Sciortino, A., Spilotro, G., and Di Santo, A. (2005). Effects of Anthropogenic Modification of Karst Soil Texture on the Water Balance of "Alta Murgia" (Apulia, Italy). *Sinkholes and the Engineering and Environmental Impacts of Karst*, p. 423-431, doi: 10.1061/40796(177)45

Chamberlain, A. T., Sellers, W., Proctor, C., Coard, R., (2000). Cave Detection in Limestone using Ground Penetrating Radar, *Journal of Archaeological Science*, 27, p. 957–964, doi:10.1006/jasc.1999.0525

Conea, A., Vintilă, I., Canarache, A. (1977). *Dicţionar de ştiinţa solului,* Edit. Ştiinţifică şi Enciclopedică, Bucureşti, 671 p

Coskun, N., (2012). The effectiveness of electrical resistivity imaging in sinkhole investigations, *International Journal of Physical Sciences*, Vol.7(15), p. 2398-2405

Church, M., (2010). The trajectory of geomorphology, *Progress in Physical Geography*, 34, 3, p. 265-286

Debevec, B., Knez, M., Kranjc, A., Pahor, M., Prelovšek, M., Slabe, T., (2012). Preliminary study for the adaptation of the "Heaven's Cave" for tourist purposes (Phong Nha-Ke Bang National Park, Vietnam), *Acta Carsologica*, 41/1, p. 115–127

De Waele, J., Plan, L., Audra, P. (2009). Recent developments in surface and subsurface karst geomorphology: An introduction, *Geomorphology*, 106, 1–8

Donisă, V., Donisă, I., (1998). *Dicţionar explicativ de Teledetecţie şi Sisteme Informaţionale Geografice,* Edit. Junimea, Iaşi, 434 p

Efe, R., (2014). Ecological Properties of Vegetation Formations on Karst Terrains in the Central Taurus Mountains (Southern Turkey), *Procedia - Social and Behavioral Sciences*, 120, p. 673–679

El-Qady, G., Hafez, M., Abdalla, M. A., Ushijima, K., (2005). Imaging Subsurface Cavities using Geoelectric Tomography and Ground-Penetrating Radar, *Journal of Cave and Karst Studies*, v. 67, no. 3, p. 174–181

Ercoli, M., Pauselli, C., Forte, E., Di Matteo, L., Mazzocca, M., Frigeri, A., Federico, C. (2012). A multidisciplinary geological and geophysical approach to define structural and hydrogeological implications of the Molinaccio spring (Spello, Italy), *Journal of Applied Geophysics*, 77, p. 72–82

Fairchild, I. J., Tuckwell, G. W., Baker, A., Tooth, A. F., (2006). Modelling of dripwater hydrology and hydrogeochemistry in a weakly karstified aquifer (Bath, UK): Implications for climate change studies, *Journal of Hydrology*, 321, p. 213–231

Ford, D., Williams, P., (2007). *Karst Hydrogeology and Geomorphology*, John Wiley and Sons Ltd., Chichester, 578 p

Ford, D., Williams, P., (2011). Geomorphology Underground: The Study of Karst and Karst Processes, in: Gregory K., J. & Goudie A., S. (Eds.), *The SAGE Handbook of Geomorphology*, SAGE Publications Ltd

Gibson, P.J., Lyle, P., George, D.M., (2004). Application of resistivity and magnetometry geophysical techniques for near-surface investigations in karstic terranes in Ireland, *Journal of Cave and Karst Studies*, v. 66, no. 2, p. 35-38

Goldscheider, N., Meiman, J., Pronk, M., Smart, C., (2008). Tracer tests in karst hydrogeology and speleology, *International Journal of Speleology*, 37 (1), p. 27-40. Bologna (Italy)

Gutiérrez, F., Galve, J. P., Lucha, P., Castañeda, Carmen, Bonachea, J., Guerrero, J., (2011). Integrating geomorphological mapping, trenching, InSAR and GPR for the identification and characterization of sinkholes: A review and application in the mantled evaporite karst of the Ebro Valley (NE Spain), *Geomorphology*, 134, p. 144–156

Herold, M., Latham, J.S., Di Gregorio, A., Schmullius, C.C., (2007). Evolving standards in land cover characterization, *Journal of Land Use Science*, 1:2, 157 - 168, DOI:10.1080/17474230601079316

Hung, L. Q., Dinh, N. Q., Batelaan, O., Tam, V. T., Lagrou, D., (2002). Remote sensing and GIS-based analysis of cave development in the Suoimuoi Catchment (Son La - NW Vietnam), *Journal of Cave and Karst Studies*, 64(1): p. 23-33

Jeannin, P. Y., Eichenberger, U., Sinreich, M., Vouillamoz, J., Malard, A., Weber, E. (2012). KARSYS: a pragmatic approach to karst hydrogeological system conceptualisation. Assessment of groundwater reserves and resources in Switzerland, *Environmental Earth Sciences*, 69(3), p. 999-1013, doi: 10.1007/s12665-012-1983-6

Jeannin, P. Y., Häuselmann, P., Lütscher, M., (2013). Role of soil cover and epikarst on karst groundwater recharge: an experimental approach conducted on the Milandre underground laboratory (Jura Mountains, Switzerland), *International Symposium on Hierarchical Flow Systems in Karst Regions*, Budapes, Hungary, p. 86-86

Jouniaux, L., Maineult, A., Naudet, V., Pessel, M., & Sailhac, P., (2009). Review of self-potential methods in hydrogeophysics, *Comptes Rendus Geoscience*, 341(10-11), 928-936. doi: 10.1016/j.crte.2009.08.008

Kambesis, Patricia (2007). The importance of cave exploration to scientific research, *Journal of Cave and Karst Studies*, 69 (1), p. 46-58

Klimchouk, A., (2009). Morphogenesis of hypogenic caves, *Geomorphology*, 106, Issues 1–2, p. 100–117

Lange, L.A., (1999). Geophysical Studies at Kartchner Caverns State Park, Arizona. Journal of Cave and Karst Studies, 61, 2, p. 68-72

Łyskowski, M., Mazurek, E., Ziętek, J. (2014). Ground Penerating Radar investigation of limestone karst at the Odstrzelona Cave in Kowala, Świętokrzyskie Mountains, Poland. *Journal of Cave and Karst Studies*, v.76, no.3, p.184–190. DOI: 10.4311/2014EX0001

Mafteiu, M., (1991). Contributions to the investigation of the karst of Padiș area (Bihor Mountains, Romania) by means of resistivity measurements. Theoretical Applied Karstology, 4, p. 65-76

Mihevc, A., Stepišnik, U. (2012). Electrical resistivity imaging of cave Divaska jama, Slovenia. *Journal of Cave and Karst Studies*, v. 74, no. 3, p. 235–242. DOI: 10.4311/2010ES0138R1

Mitrofan, H., Povară, I., Mafteiu, M., (2008). Geoelectrical investigations by means of resistivity methods in karst areas in Romania. *Environmental Geology*, 55, p. 405-413, DOI: 10.1007/s00254-007-0986-1

Moore, J.R., Boleve A., Sanders, J.W., Glaser S.D., (2011). Self-potential investigation of moraine dam seepage, *Journal of Applied Geophysics*, 74, p. 277-286

Orndorff, R.C., Weary, D.J., Lagueux, K.M., (2000). Geographic Information Systems Analysis of Geologic Controls on the Distribution of Dolines in the Ozarks of South-Central Missouri, USA, *Acta Carsologica*, 29 (2), p. 161-175

Orghidan, T. (1972). *The fiftieth anniversary of the first speleological institute of the World*, Aapg Bulletin/International Journal of Speleology, Vol/ 4, Issue 1, p. 1-7

Osterkamp, W. R. (2008). *Annotated definitions of selected geomorphic terms and related terms of hydrology, sedimentology, soil science and ecology*, Open File Report 2008–1217, U.S. Geological Survey, Reston, Virginia, 49 p

Pardo-Igúzquiza, E., Durán, J. J. & Dowd, P. A., (2013). Automatic detection and delineation of karst terrain depressions and its application in geomorphological mapping and morphometric analysis, *Acta Carsologica*, 42/1, p. 17–24

Payne, S. L., (1999). Interdisciplinarity: Potentials and Challenges, *System Practice and Action Research*, 12, 2, p. 173-182

Povară, I., Ponta, Gh., (2010). Geology and hydrogeology of the Jiul de Vest–Cernișoara Basins, Romania, *Carbonates Evaporites*, 25: p. 117–126, DOI 10.1007/s13146-010-0017-2

Rozycki, A., Fonticiella Ruiz, J. M., Cuadra, A., (2006). Detection and evaluation of horizontal fractures in earth dams using the self-potential method, *Engineering Geology*, 82, p. 145-153

Sencu, V., (1977). Carstul din Câmpul Minier Anina, *St. Cerc. de Geologie, Geofizică, Geografie*, XXIV, 2, 199-212

Sencu, V., (1978). *Munţii Aninei*, Edit. Sport-Turism, Bucureşti, 86 p

Tagil, S. & Jenness, J., (2008). GIS-based Automated Landform Classification and Topographic, Landcover and Geologic Attributes of Landforms around the Yazoren Polje, Turkey. *Journal of Applied Sciences* 8(6): p. 910-921

Telbisz, T., Dragušica, H. & Nagy, B., (2009). Doline Morphometric Analysis and Karst Morphology of Biokovo Mt (Croatia) Based on Field Observations and Digital Terrain Analysis, *Hrvatski Geografski Glasnik*, 71/2, p. 5 – 22

Tooth, A. F., Fairchild, I. J., (2003). Soil and karst aquifer hydrological controls on the geochemical evolution of speleothem-forming drip waters, Crag Cave, southwest Ireland, *Journal of Hydrology*, 273, 51–68

Torok-Oance, M., Ardelean, Florina & Onaca, Al., (2009). The Semiautomated Identification of the Planation Surfaces on the Basis of the Digital Terrain Model. Case Study: The Mehedinţi Mountains (Southern Carpathians), *Forum Geografic. Studii şi cercetări de geografie şi protecţia mediului*, Year 8, No. 8, p. 5-13

Torok-Oance, M. & Ardelean, Florina, (2012). Object-Oriented Image Analysis for Detection of the Barren Karst Areas. A Case Study: The Central Sector of the Mehedinţi Mountains (Southern Carpathians), *Carpathian Journal of Earth and Environmental Sciences*, Vol. 7, No. 2, p. 248-254

Whittow, J., (1984). *Dictionary of Physical geography,* Penguin Books, London, 591 p.

Williams, P. W., (2008). The role of the epikarst in karst and cave hydrology: a review, *Interantional Journal of Speleology*, 37(1), p. 1-10

Youssef, A. M., El-Kaliouby, H. M., Zabramawi, Y. A., (2012). Integration of remote sensing and electrical resistivity methods in sinkhole investigation in Saudi Arabia. *Journal of Applied Geophysics* 87, p. 28–39

Zhou, W., Beck, B. F., Stephenson, J. B., (2000). Reliability of dipole-dipole electrical resistivity tomography for defining depth to bedrock in covered karst terranes, *Environmental Geology*, 39 (7), p. 760-766

Zhou, W., Beck, B. F., Adams, A. L., (2002). Effective electrode array in mapping karst hazards in electrical resistivity tomography. *Environmental Geology*, 42: p. 922–928

Zylshal, P. D. & Haryono, E., (2013). An Object Based Image Analysis Approach to Semi-Automated Karst Morphology Extraction. *Asian Conference on Remote Sensing, Bali*, Volume: 34, p. 411-418.

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Exceptional floods in small basins in North-Western Romania and the induced effects – Bârsău River, Maramureş county

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Abstract

The study aims to analyse floods from May 1970, June 1974 and May 2015, which occured in the Bârsău catchment area, one of the right tributaries of the Someș River. The junction between these two rivers is downstream of Satulung locality in Maramureș County. Bârsău catchment area is located between the Someș and Lăpuș catchment areas and has a surface of 152 km^2. The floods of the Bârsău River are fast and have a very short propagation time. They are caused both by rainfalls and snow melting. This is the case of the flood from May 1970, which had a duration of two days, whereas the floods from June 1974 and May 2015 occured just because of heavy rainfalls. From the three analyzed floods, the May 2015 flood, with a pluvial origin, reached the maximum level of 220 cm (DL+20 cm) at Buciumi gauging station and its effects strongly affected local people. Thus, the damages in the villages located inside the basin were recorded first, then quantified. After that, there were made the integrating maps of the flood prone areas as well as the hydrological and associated risks in order to identify areas with different degrees of vulnerability.

Keywords: *flash-flood, maximum discharge, maximum level, Bârsău, flood effects*

Rezumat. Inundații excepționale în bazinele mici din nord-vestul României și efecte induse – râul Bârsău, județul Maramureș

Studiul își propune să analizeze inundațiile din mai 1970, iunie 1974 și mai 2005 care au avut loc în bazinul hidrografc al râului Bârsău, unul dintre afluenții de dreapta ai râului Someș. Confluența celor două râuri se află aval de localitatea Satulung din județul Maramureș. Bazinul hidrografic Bârsău este localizat între bazinele Someșului și Lăpușului, având o suprafață de 152 km^2. Inundațiile produse de râul Bârsău sunt rapide și prezintă un timp scurt de propagare. Totodată, sunt cauzate atât de precipitații, cât și de topirea zăpezilor. În acest fel s-au produs inundațiile din mai 1970, cu au avut un timp total de două zile, spre deosebre de iundațiile din iunie 1974 și mai 2015 care s-au produs doar pe fondul precipitațiilor abundente. La nivelul celor trei studii de caz, inundațiile din mai 2015, cu origine pluvială, au atins nivelul maxim de 220 cm (CP+20 cm) la stația hidrometrică Buciumi,iar efectele au influențat puternic populația locală. Astfel, pagubele din satele localizate în interiorul bazinului au fost mai întâi înregistrate și apoi cuantificate. Ulterior, s-au realizat hărți de integrare a zonelor inundabile, a riscurilor hidrologice și asociate cu scopul de a identifica arealele cu diferite grade de vulnerabilitate.

Cuvinte-cheie: *viitură, debit maxim, nivel maximum, Bârsău, efecte ale inundațiilor*

Introduction

Flash-floods in literature

Floods study, especially that of flash-floods, regarding the effects induced by the phenomenon, was a priority for many scientists since Ancient times because of the natural disaster`s amplitude and the immense tangible or intangible economic and social damages.

A flood is a sudden and significant increase and diminution of the level and discharge values of a river, that also represent one of the most dramatical relation between man and environment, emphasized by the natural phenomenon amplitude and also by man`s difficulties to control it (Ward, 1978).

Floods are caused by both natural and anthropogenic factors, most fluvial floods being produced directly or indirectly by atmospheric events such as intense rainfall, sudden melting of snow due to a heat wave in the cold period of the year. If the rainfall is overlapping a snow layer and a frozen soil, the consequences can be catastrophic.

The damages caused by floods include a wide range of harmful effects on people's health, and their goods, public infrastructure, cultural heritage, ecological system, industrial production system and competitive power of local economy (Messner & Meyer, 2006). Absolute protection is impossible to achieve and also unsustainable, due to high costs and the inherent uncertainties. Therefore, the management of the flood-related risk is more appropriate (Schanze, 2006; Schanze et al., 2006).

In many regions of the world, floods are some of the most destructive natural hazards, often resulting in a large number of deaths and material losses. It is found that approximately 40% of deaths due to floods in Europe from 1950 to 2006 are related to the phenomenon of flash-flood (Barredo, 2009; Lumbroso & Gaume, 2012). Floods of this type are caused by the falling precipitation in liquid form in a very short time, with a very high intensity on a small area.

As Gaume et al. (2009), Marchi et al. (2010), Ruiz-Villanueva et al. (2012) say, at the European level there can be observed a spatio-temporal difference regarding the distribution of flash-floods. Thus, in the Mediterranean area (Italy, France, Catalonia), an increase of its strength is obvious during the autumn, while in continental regions (Romania, Slovakia, Germany, Austria) flash-floods generally occur during the summer.

In Romania, the largest disasters due to floods occurred in 1926, 1970, 1975, 1991, 2005 and 2010. Considering the number of deaths in 1926 (1000 deaths) it can be said that floods represent the second disaster in the recent Romanian history after the earthquake of 1977, when 1641 deaths were registered. Moreover, the recent floods in 2005, along with the 1977 earthquake, represent the most significant natural disasters in the history of Romania also because of the material damages recorded, which have been estimated at 2 billion USD for each event.

In the last decade, the frequency of floods has grown, these generating damages of 5 billion USD, which means an annual average loss of 483 mil USD. Almost half of the amount has been generated by the floods of 2005, the number of victims from this period being 208 (Senzaconi et al., 2010).

Study area and general information relating to analyzed floods

The Bârsău River (Fig. 1) has a length of 34 km and it is a right tributary of the Someș river. It springs at an altitude of 550 m in the vicinity of Vărai village (Valea Chioarului commune) and flows into the Someş collector at an altitude of 152 m on the territory of Satulung commune in Maramureş County.

The water catchment area, located between the Someș and Lăpuș water courses, overlaps almost entirely the Chioar Hills (Posea, 1980; Panda, 1980). The drained surface is about 152 km^2, and the average altitude is 317 m (Water Cadastre Atlas from Romania, 1992).

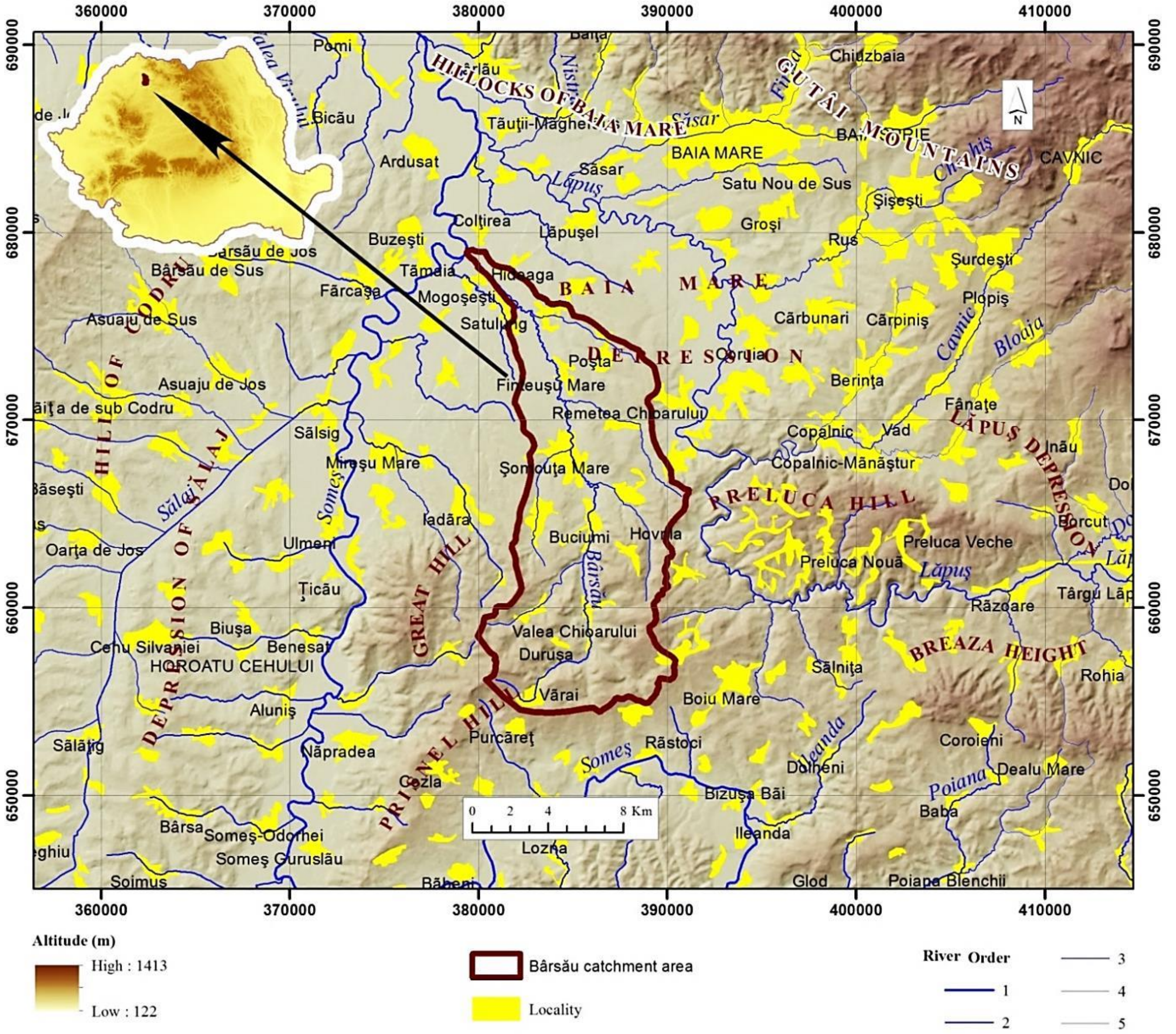

Fig. 1: The Bârsău River basin location in relation to the relief units

The Bârsău River has five main tributaries: two left tributaries - Curtuiuş-7 km, Căicana-8 km and three right tributaries – Ciolt - 8 km, Berchezoaia - 10 km and Poșta - 7 km, the last one being the main collector of Chioar Hills.

The frequency and magnitude of floods on the Bârsău River are caused not only by natural factors, but also by anthropogenic factors. The most frequent floods are caused by meteorological factors such as: both torrential and long-lasting rains, as well as snow melting overlapped with significant quantities of rainfalls.

In the Bârsău catchment area, the water flow monitoring and the observations related to the hydrological regime variations of water drainage were made just until the end of 2003 at Satulung hydrometric station. It was removed due to that being located downstream of this locality, the station was not able to issue warnings for the Şomcuta Mare town. In the year 2003, it was achieved a new station on the Bârsău River, upstream of the town, in Buciumi village. The hydrometric station was given into service from January 1, 2004, and since 2007 it has been equipped with automatic monitoring and transmitting equipment.

The threshold defence levels of the Buciumi gauging station are: AL = 80 cm, FL = 130 cm and DL = 200 cm. An important remark is that Buciumi hydrometric station has an extraordinary transmission (not daily), transmitting data only when water levels overpass the attention level.

At Satulung gauging station, two major floods were noted: the first in May 1970, when it reached a maximum level of 449 cm (FL+149 cm) and the second in June, the 2nd, 1974, when it reached a maximum level of 430 cm (FL+130 cm). The flood from 1974 was more destructive than the one from May 1970, although the level was 19 cm lower; the river's water flow was higher due to the alteration of hydraulic parameters of the river bed in the gauging station sector (WMS Archive, 1974).

After moving the station in Buciumi village, upstream from Şomcuta Mare town, there have been recorded two major floods, the first on March 25th, 2005, when it reached a maximum level of 156 cm (FL+26 cm) and a flow rate of 28.4 m^3/s. The second flood occurred in May 27th, 2015 when it reached and exceeded the danger level, the maximum level of the flood being 220 cm. It corresponds to a reconstituted water flow of 37.5 m^3/s, being the second water discharge value recorded.

The hydrologists from WMS Maramureş have reconstituted the water flow for the flood that occurred in June 2nd, 1974, for Buciumi section, resulting in a water discharge of 80.6 m^3/s (Synthesis Report May 2015, WMS Maramureș). This is the historical maximum flow drained in Buciumi section.

Database and Methods

The database used in this analysis consists both in hydrological and meteorological data, taken from the Water Management System`s archive, Maramureș.

For the creation of the cartographic material, topographic maps at a scale of 1:25,000 and licensed GIS software from the two institutions involved in this study, namely: Babeş-Bolyai University, Cluj-Napoca, Faculty of Geography and "Romanian Waters" National Administration, Bucharest were used.

The study of the occurrence conditions and the characteristic elements of the flood was based on the data and the conclusions drawn up by the specialist departments of Someș-Tisza Regional Water Branch and ”Romanian Waters” National Administration.

The evolution data of the water level and flow of the Bârsău River were processed with CAVIS, whereas the cartographic representations were obtained using the ArcMap 10.x software.

The methods used in the research, processing and analysis were: the observation method, graphic-analytical method, deductive method, statistical method and the cartographic method, with analogue and digital application.

Catchment area`s exposure and position

The floods that occur within the Bârsău basin are frequently generated by abundant rainfalls, often heavy rains or sudden snow melting. Usually, after overrunning the attention level (AL), the maximum level is reached in a very short time and within 2-3 hours, the river level is decreasing below attention level.

Slope exposure towards the general circulation of air masses

Its location in the path of moist air masses with a predominantly Western advection, located at the footsteps of the Gutâi Mountains ascension causes significant amounts of rainfalls for the Bârsău basin (Fig. 1). The multiannual values are high, more than 800 mm in the North-Eastern part of the basin (The Baia Mare Depression and the vicinity of Gutâi Mountains) and low (slightly over 700 mm) specific for the Eastern and South-Eastern extremity, where atmospheric fronts are reactivated by the crystalline massif of Dealul Mare -Țicău.

The influence of the catchment area`s shape

The shape of the hydrographical basin is an analytical expression with conventional character (Vladimirescu, 1984), which highlights the character of circular or oblong basin and it is determined as the ratio between the area of the basin and the length of the watershed. As it is closer to circularity, the accumulation of flood on the slope in the center spot will be faster and it will propagate a larger water volume in the river bed (Fig. 2).

Assessment of the basin`s shape can be done both in quantitative and qualitative terms. A quantitative assessment of the shape of the basin shall be made on the basis of formulas in which the shape of the basin is compared with a reference geometric shape.

For the quantitative evaluation, several authors have proposed a number of indicators, of which we remember those mentioned by Sorocovschi and Șerban, 2012:

- *form factor* (R_f): this is the ratio between the surface and the square maximum length of the basin (Horton, 1932);
- *the circularity ratio* (R_c) is the result of the division between the surface of the basin and the surface of the circle with the length equal to the perimeter of the basin (Miller, 1953);
- *elongation ratio* (R_l) is the result of the division between the circle with the diameter equal to the surface of the basin and the maximum length of the basin (Schumm, 1956);

Rădoane et al., 2006; Zamfir & Simulescu, 2011 and Nițoaia et. al., 2016, use the coefficient of circularity to determine the shape of the basin, calculated according to the formula:

$$C = \frac{Lc}{2\sqrt{\pi F}}$$

where: C – circularity coefficient,
Lc – watershed length (perimeter - km)
F – total area of the basin (km^2)

The value of the coefficient of circularity, C, is dimensionless, C ≥ 1, but the closer it is to unity, 1, the shape of the basin is closer to circularity.

For the studied basin, the surface was determined using ArcMap 10.x software generating two new columns in the attribute table of the basin, where the area and perimeter were calculated. These two parameters were used subsequently for the determination of circularity coefficient. After a quantitative assessment over the shape of the basin was made, the coefficient graphical represention was achieved. Thus, Bârsău basin (Fig. 2) with a coefficient of 2.41, has an elongated shape, although in its upper compartment the widening is obvious.

Floods features

May 1970 flood

In Maramures County, the flood was formed as a result of significant quantities of rainfalls in a short time (at Baia Mare there were recorded 121.2 mm in 13.05.1970) and the sudden snow melting (WMS archive, 1970).

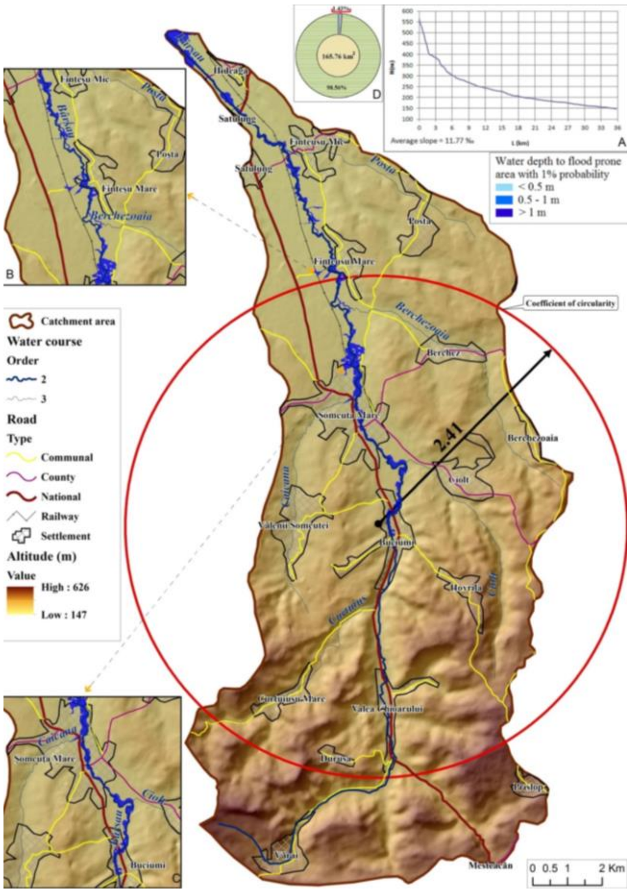

Fig. 2: Coefficient of circularity map overlapped on flood prone area at 1% probability of liquid flow. A, Longitudinal profile; B, Settlements exposed to floods; C. The Town most exposed to floods

In a period of 48 hours (11-13 May, 1970), in the Eastern and Northern Transylvania and in Maramureş, including the Bârsău basin, the recorded rainfalls were more than 50 mm, and in some areas, even over 100 mm (Table 1).

Table 1: Rainfalls recorded in 12-15 May 1970 period within Bârsău catchment area

Meteorological/ Gauging Station	Altitude (m)	Day/Precipitation (mm)				
		12			12	
Şomcuta Mare	200	7.3	120.8	128.1	6.5	4.2
Ardusat	160	4.8	75.2	80.0	5.0	8.0
Baia Mare	198	7.2	121.2	128.4	6.2	5.9
Seini	145	16.5	140	156.5	28.0	16.0
Ulmeni	165	8.0	59.6	67.8	3.5	0.0
Jibou	198	31.6	31.3	62.9	3.8	0.1

Although Figure 3 graphically presents the distribution of the rainfalls recorded in May 12-14, 1970 period throughout the country. These rainfalls fell across a soaked and frozen soil (in the mountain areas). Moreover, at higher altitudes a consistent snow cover was present, thicker than 110 cm, accumulated in the previous months. The major quantitative rainfall added water quickly restored by the layer of snow and a low evaporation rate, under

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some cold temperatures. The drainage coefficient had high values (0.7), the water flow of the rivers reaching record values. It was a flash-flood which produced an inundation with disastrous effects on the riparian settlements of the Bârsău and its collector, Someș. On Bârsău river, flood started on May 13th at 01:00 AM, when water spilled out from the minor river bed at the Valea Chioarului village and finished in May, 14th at 6:00 PM, when the water retreated. At Valea Chioarului village, the flood peak was recorded on May 13th at 05:00 PM, and on May 14th at 05:00 PM, the waters have receded. The damages recorded in this settlement are smaller (it is located in the upper basin), except for the large surfaces of agricultural terrains flooded after the overflow.

Fig. 3: Rainfalls from 12 to 14 May 1970

In Șomcuta Mare settlement, the Bârsău river spilled out on May 13th, 1:30 AM, and the flood peak was recorded on May 13th at 03:30 PM. The damages were very important and were caused by the Bârsău river overflow flooding and its tributaries, and also by the runoff on slopes (the settlement is situated at the exit of the water courses from the upper sector of the basin, in a"water gathering piazza" - Fig. 2). Șomcuta Mare, Buciumi, Fințeușul Mare settlements were partially flooded, whereas in Satulung commune, Fințeușul Mic and Satulung villages were affected.

In the Satulung locality, Someș collector waters receded only in May 18th, 1970 at 11:00 PM in the conditions of a consistent intake from the upstream. The flood of the Bârsău River in May 1970 had a single peak (maximum discharge value), the highest level reached at the Satulung gauging station was 449 cm (FL+149 cm), achieved on May 13th, 1970 at 06:00 PM.

June 1974 floods

In June, on the Bârsău river there have been five flash-floods, the amplitudes of which reached outstanding values of the water flow and levels. Their defining character trait was the succession and the increase of the maximum level up to flooding level (FL), which made it impossible to rehabilitate the anthropic and natural environment for a long period of time (about a month).

The first and most important throb occurred on the 2nd of June 1974 and was caused by exceptional rainfall quantities recorded in the area. At Șomcuta Mare, in June the 2nd, 1974 between 02:00-08:00 AM, 137 mm were recorded, although the precipitation rate per 24 hours with 1% insurance is approximately 80 mm/m^2/24 hours. The flood that took place was more destructive than the one in the 1970s, although the maximum level recorded was 430 cm (FL+130 cm), 19 cm lower than the level recorded in May 1970.

The second flood occurred in June 7 when the level came close to flooding level, 299 cm (FL-1 cm). Between the 11th-15th of June, *the third flood occured*, which reached a maximum of 400 cm (FL+100 cm). *The fourth flood*, June 25th, had a maximum level of 320 cm (FL+20 cm). The last flood occurred in June 30th and had a maximum level of 330 cm (FL+30 cm). Although on the Someș collector the flood`s magnitude was smaller than the one in March 1970, on a neighbouring water course, Sălaj Valley, (Fig. 1) the levels and flow values were overcome.

May 2015 flood

It is the first important flood produced after the gauging station`s replacement from Satulung to Buciumi, upstream from the Șomcuta Mare town.

During the night of May 26-27, 2015 in the Southwestern part of Maramureș County, important heavy rainfall quantities were recorded. Most of the rain fell between 03:00 and 05:00 AM, when some areas reached 60 l/m^2, but these values were exceeded in the watershed area between the Someș and Bârsău, respectively Bârsău and Iadăra basins (Fig. 4). Valea Chioarului and Șomcuta Mare localities related within the Bârsău basin were also affected. Table 2 presents the amount of rainfalls reported on May 27th, 2015 and the precipitation thresholds.

Table 2: The 24 hours amount of rainfall measured in May 27th, 2015, 6.00 AM (according to "Romanian Waters" National Administration)

No.	Gauging station	River	Precipitation	Threshold (mm)	Gauging station
1	Sălsig	V.Sălajului	76.4	60	03-05
2	Cicîrlău	Someş	55.9	51	03-05
3	Ulmeni	Someş	55.7	38.7	03-05
4	Lăpuşel	Lăpuş	30.7	28.6	03-05
5	Buciumi	Bârsău	24.5	-	-
6	Rastoci	Someş	71.0	-	-

When analyzing the map (Fig. 4), it is obvious that the clouds with maximum rainfall intensity followed the Someș Corridor, both to the East and

North, likely diverted by Prisnel and Dealul Mare crystalline peaks. Thereby, these clouds` route led to the cover of Bârsău upper sector, with massive lightning in the highest area, where heavy drainage is formed. The maximum flow recorded at the Buciumi gauging station was 55 m^3/s, produced on May 27, at 09:00 AM GMT, even if the flood started from a basic flow of 0.058 m^3/s!

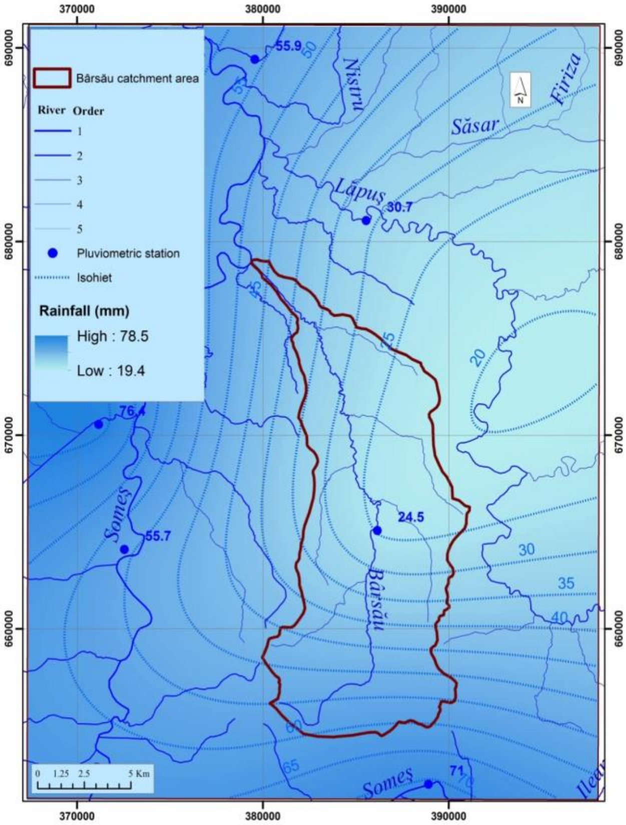

Fig. 4: Spatial repartition of 24 hours amount of rainfall measured

The total duration of the flood was 29 hours, from which the increasing time was 14 h (Fig. 5). The total volume of the flood was 1.82 million m^3, with a base volume of 1.64 mil m^3, with a 12 mm runoff layer, and a form coefficient of 0.31. The water level at a maximum flow of 55 m^3/s has reached 220 cm, overrunning by 20 cm the *danger level* (DL).

The effects of the floods

May 1970 flood`s effects

During the flood of May 1970, Valea Chioarului, Șomcuta Mare (Șomcuta Mare, Finteușul and Buciumi) and Satulung (Satulung and Finteușul) communes were affected by the overflow of Bârsău and its tributaries. The damage from May 1970 flood totalled 4028 thousand RON, the most affected locality being Șomcuta Mare (about 75%), 25% being recorded in the Satulung village, flooded by both the Someș and Bârsău rivers. At the Valea Chioarului locality, the damages were approximately 0.57% of total (Fig. 6), without any casualties.

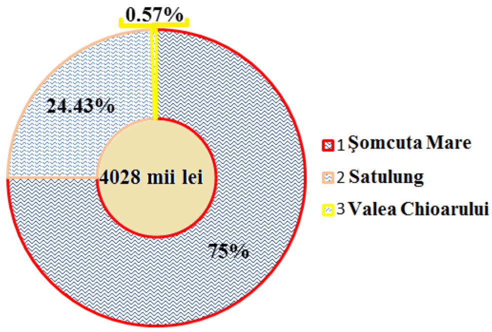

Fig. 5: Damages recorded in Valea Chioarului, Șomcuta Mare and Satulung localities during the May 1970 flood

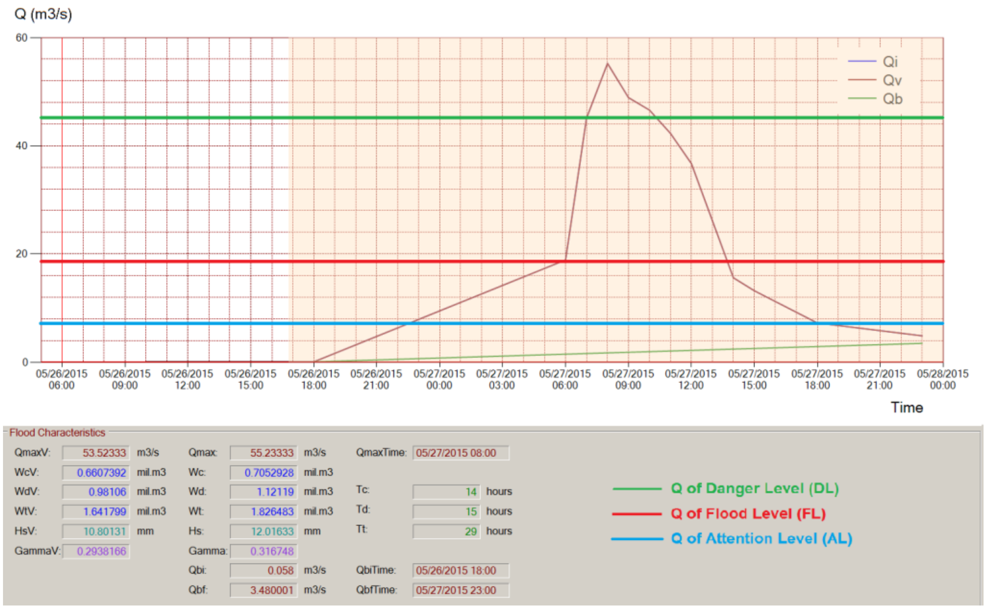

Fig. 6: Flood hydrograph to Buciumi hydrometric station, Bârsău River, realised with CAVIS software (Corbuș, 2006)

The recorded damages in Valea Chioarului refer to 0.57 km^2 of flooded agricultural terrain.

In Șomcuta Mare, the following categories of damages were recorded: 2 houses destroyed, 5 houses damaged, 1.5 km of paved road destroyed, 2 km of paved road damaged, 6 km of causeway damaged, 3 bridges destroyed, 2 bridges damaged, 10 footbridges destroyed, 5 footbridges damaged and 0.5 sqkm of agricultural terrain were flooded.

In Satulung locality the following categories of damages were recorded: 27 houses destroyed and 12 houses damaged, 13 other constructions destroyed, 7 other construction damaged, 2 km of causeway damaged, 3 bridges destroyed, 2 bridges damaged, 18 footbridges damaged, 9.23 km^2 of agricultural terrain, 2 dead animals.

June 1974 flood`s effects

As a result of this hydrological risk phenomenon, no human victims were recorded, only material damages. Thus, in the Valea Chioarului village the following damages were recorded: 2 houses flooded, 1 house destroyed, 1 other building destroyed, 1 bridge destroyed, 5 footbridges destroyed, 0.25 km2 of agricultural terrain flooded.

In Șomcuta Mare locality the following damages were recorded: 24 houses flooded, 7 houses destroyed, 12 houses damaged, 15 other constructions flooded, 15 other construction damaged, 1.5 km of paved road damaged, 14 km of causeway damaged, 5 bridges destroyed, 2 bridges damaged, 20 footbridges destroyed, 4.5 km^2 of agricultural terrain flooded, 0.02 km^2 of landslides, 4 economic agents flooded, 4 economic agents damaged and 5 dead animals.

In the Satulung locality the following damages were chronicled: 9 houses flooded, 9 houses damaged, 6 other building flooded, 2 other building destroyed, 2 other construction damaged, 1.1 km of causeway damaged, 3 bridges destroyed, 3 bridges damaged, 7 footbridges destroyed, 10 footbridges damaged, 4.8 km^2 of agricultural terrain flooded, 2.05 km^2 agricultural terrain destroyed by landslides, 0.5 km electrical lines destroyed an also 0.5 km of phone lines has been destroyed. For the June 1974 flood, there are no recordings on the value assessment of damages, only physical references.

May 2015 flood`s effects

May 2015 flood affected Șomcuta Mare commune (Șomcuta Mare, Buciumi, Finteușu and Vălenii Șomcutei) and Valea Chioarului (Valea Chioarului, Curtuiușu Mare, Durușa, Mesteacăn, Vărai and Fericea) in the Bârsău catchment area. Within the Someș basin and other adjacent tributaries, Ulmeni, Mireșu Mare, Fărcașa, Ardusat, Cicîrlău and Asuajul de Sus localities were affected, while in the Lăpuș basin Sisesti and Remetea Chioarului villages were affected. Due to the slope`s runoff and the overflow of Bârsău tributaries, many localities were affected (Șomcuta Mare, Buciumi, Finteușu Mare, Curtuiușu Mare and Valea Chioarului, as well as the localities of Vălenii Șomcutei, Durușa, Mesteacăn, Fericea, Vărai). Satulung locality was not affected by the flood that occurred in May, during the Bârsău water overflow, because its riverbed was regulated and the hydraulic section has not been surpassed.

Comparing the value of the damages recorded in Bârsău basin with those in the middle sectors of Someș and Lăpuș basins, it is obvious that more than 50% of the damage (about 62%) occurred in the limits of latter. The slope`s runoff had an important share compared to river overflow of these two rivers (Fig. 7, right).

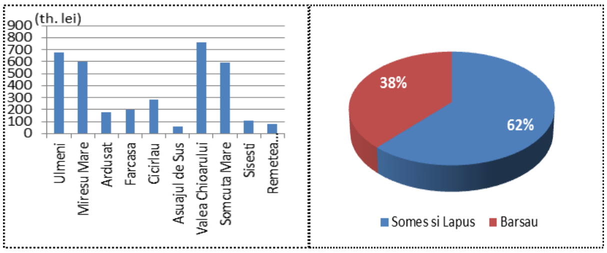

Fig. 7: Damages recorded within the Someș upper sector comparing to the neighbouring basins

The Among the villages affected by the Bârsău river, Valea Chioarului was the most affected (Fig. 5, left and right) and, close to this one, the Șomcuta Mare locality. Taking into account that Fericea river is part of Valea Chioarului commune, in the middle sector of Someș, but not Bârsău basin, it can be concluded that approximately 70% of the damages belong to the middle sectors of the Someș and Lăpuș catchment areas, and Șomcuta Mare is the most affected locality.

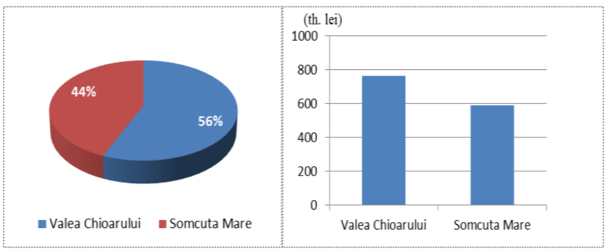

Fig. 8: Damages recorded in Valea Chioarului and Șomcuta Mare localities during the flood from May, 2015

In these two localities: houses, households, communal roads, streets, bridges, arable terrain, pastures and meadows, as well as fountains were affected. In the Valea Chioarului village, the maximum effects were reflected on some wooden bridges and over a concrete bridge while in Șomcuta Mare over the market, on two footbridges, on the locality water supply wells, on the sewerage network, and 67 animals died by drowning.

In Figure 9 the infrastructure damages recorded in those two localities are compared. Note that, excepting the households and communal roads, where the greatest damage was at Valea Chioarului, at the other indicators, Șomcuta Mare recorded bigger damages.

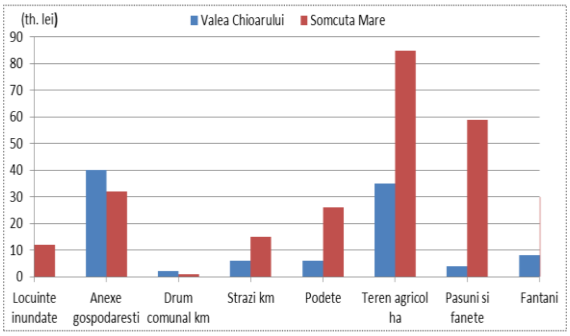

Fig. 9: Damage categories recorded during the flood from May, 2015

There were two wooden bridges destroyed, a concrete bridge was affected, the communal road has been gnawed and at Valea Chioarului side erosion took place. Creating flood prone areas related to water courses in Romania has been initiated by *Romanian Waters* National Administration, under 2007/60/EC Directive on the flood risk assessment and management - Hazard and flood risk maps. Capitalizing some information derived from this composite, an integrative map of the hydrological and associated risk related to flow with 1% probability in the Bârsău basin was created (Fig. 10).

Spatialized information allows the identification of some vulnerable areas located almost exclusively in the middle and lower sector of the Bârsău catchment area. Actually, every locality situated on the main course is exposed to high and medium risk. On the other hand, in the lower sector, low and insignificant risk is present.

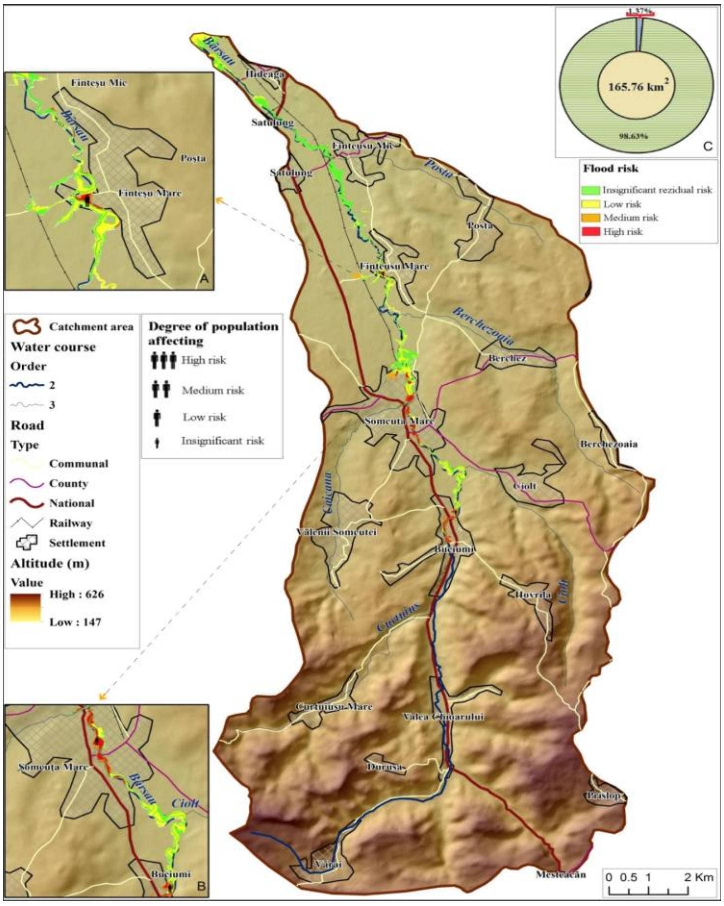

Fig. 10: Hydrological and associated risks related to maximum flow with 1% probability in Bârsău catchment area

Conclusions

The May 1970 flood was an exceptional flood, caused by rainfalls and also by the melting of snow, and floods that occurred in June 1974 and 2015 were pluvial floods, generated by heavy rainfalls during a short period of time. Șomcuta Mare is the most affected locality by the floods that occur in Bârsău catchment area, located in the junction area of Bârsău and its four tributaries: Curtuiuș, Căicana, Ciolt and Berchezoaia, torrential regime courses. Floods of the Bârsău river are usually accompanied by floods in neighboring small hydrological basins (Iadăra, Cicârlău and Sălaj), tributaries of the Someș river or on Lăpuș smaller tributaries.

The maximum reconstituted flow of Buciumi station is 80.6 m^3/s and it was achieved in June 2nd, 1974, and in May 2015, a maximum of 220 cm level was recorded (CP+20 cm), which corresponds to a maximum discharge of 60.3 m^3/s, the second historic flow value. After the flood that occurred in May 2015, the Bârsău riverbed was highly clogged, decreasing the transport capacity of the riverbed. Flooding is possible beneath the defense threshold levels because of the Bârsău river's overflow. It is necessary, on a length of about 8 km between Valea Chioarului and Satulung localities, to make desilting and recalibration works.

References

Barredo, J.I. (2009). Normalised flood losses in Europe: 1970–2006. *Nat. Hazards Earth Syst. Sci*., *9*, 97–104

Corbuş, C. (2006). *CAVIS Programme*. INHGA, Bucureşti (in Romanian)

Gaume, E., Bain, Valerie, Bernardara, P., Newinger, O., Barbuc, M., Bateman, A., Blaškovicová, Lotta, Blöschl, G., Borga, M., Dumitrescu, Al., Daliakopoulos, I., Garcia, J., Irimescu, Anişoara, Kohnova, Silvia, Koutroulis, A., Marchi, L., Mătreaţă Simona, Medina, V., Preciso, E., Sempere-Torres, D., Stancalie, Gh., Szolgay, J., Tsanis, I., Velasco, D. & Viglione, A. (2009). A compilation of data on European flash floods. *Journal of Hydrology*, *367*, 70–78. doi:10.1016/j.jhydrol.2008.12.028

Horton, R.E. (1932), Drainage basin characteristics. Trans. Amer. *Geophys*. *Un.* 350-361

Lumbroso, D. & Gaume, E. (2012). Reducing the uncertainty in indirect estimates of extreme flash flood discharges. *Journal of Hydrology*, *414–415*, 16–30. doi:10.1016/j.jhydrol.2011.08.048.

Marchi, L., Borga, M., Preciso, E. & Gaume, E. (2010). Characterisation of selected extreme flash floods in Europe and implications for flood risk management. *Journal of Hydrology*, *394,* 118–133. doi: 10.1016/j.jhydrol.2010.07.017

Messner, F. & Meyer, V. (2006). Flood Damage, Vulnerability and Risk Perception – Challenges for Flood Damage Research. In: *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures*, Series IV: *Earth and Environmental Sciences* – Vol. 67, Schanze J., Zeman E., Marsalek J. Edit., Springer, The Netherlands, 149 - 169.

Miller, V.C. (1953). *A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area*. Virginia and Tennessee, Project NR 389042, Tech. Rept. 3, Columbia University, Department of Geology, ONR, Geography Branch, New York

Mustăţea, A. (2005). *Exceptional floods on Romanian territory - Genesis and effects.* Editura SC OnestaCom Prod 94 SRL, București (in Romanian)

Niţoaia, A., Şerban, Gh., Tudose, T., Nacu, S. & Rândașu-Beuran, S. (2016). The influence of atmospheric circulation, shape and pozition of the hydrographical basin on the amplitude and effects of the August 2005 flood in Ozana and Cracău basins*. Riscuri şi Catastrofe*, No. XV, *18* (1), 57-67

Posea, Gr., Moldovan C. & Posea A. (1980). *Maramureș County*. Editura Academiei Republicii Socialiste România, Bucureşti (in Romanian)

Rădoane, N., Rădoane, M., Olariu, P. & Dumitru, D., (2006). Small catchment areas, fundamental units of interpretation of the dynamics of landscape. *Analele Universităţii „Ştefan cel Mare" Suceava* (in Romanian)

Ruiz-Villanueva, V., Bodoque, J.M., Díez-Herrero, A., Eguibar, M.A. & Pardo-Igúzquiza, E. (2012). Reconstruction of a flash flood with large wood transport and its influence on hazard patterns in an ungauged mountain basin. *Hydrological Processes*, 27(24), 3424–3437. doi: 10.1002/hyp.9433

Schanze, J. (2006). Flood risk management – a basic framework. In: *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures*, Series IV: Earth and Environmental Sciences – Vol. 67, Schanze J., Zeman E., Marsalek J., Editors, Springer, The Netherlands, 1-21

Schumm, S.A. (1956). The evolution of drainage systems and slopes in bad lands at Perth, Amboi, New Jersey. Geol. Soc. Ame. Bull. 67 (5), pp. 597-646.

Senzaconi F., Samaras I., Arghiuş V., Petrescu-Mag R. M., Costan, C. & Ozunu, A. (2010). *Critical Analysis of Flood Risk Management Strategies in the Context of Flood and Flash Flood Disaster Events in Romania*, IDRiM Conference, 1-4 September, Vienna

Sorocovschi, V. & Șerban, G. (2012). *Elements of Climatology and Hydrology. Second part: Hydrology*. Editura Casa Cărții de Știință, Cluj-Napoca (in Romanian).

Ujvari I. & Aniţan I. (1972). *Genesis, volume and runoff coefficients of the May 1970 catastrophic floods, on North-Western rivers of Romania*, Symposium „Causes and effects of the high waters from May-June, 1970", IMH, Bucureşti (in Romanian)

Vladimirescu, I. (1984). *Technical Hydrology bases*. Editura Tehnică, Bucureşti (in Romanian)

Ward, R. C. (1978). *Floods: A Geographical Perspective, Macmillan*, London, 244 pp

Zamfir, A. & Simulescu, D. (2011). Automatic delineation of a watershed using a DEM. Case study – The Oltet watershed. *Analele Universităţii „Ştefan cel Mare" Suceava*, Seria Geografie, *20*(1), 83-92. http://dx.doi.org/10.4316/GEOREVIEW.2011.20.1.25

Schanze, J., Zeman, E. & Marsalek, J., (eds.) (2006). *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures*. Schanze, J., Zeman, E., Marsalek, J., Volume 67 of the series NATO Science Series, doi: 10.1007/978-1-4020-4598-1

*** (1970-1974). WMS Archives, Maramureș

*** (1992). Water Cadastre Atlas from Romania, Ministry of Environment, Forestry and Waters & Aquaproiect, Bucharest

*** (2015). Damages Synthesis Report– the flood from May 2015, WMS, Maramureş (in Romanian)

*** (2007). Directive 2007/60/EC on the assessment and management of flooding risk - Hazard and flood risk maps, The "Romanian Waters" National Administration http://gis2.rowater.ro:8989/flood

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Spatial and temporal dynamics of human pressure within the Preajba catchment area, Romania

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Abstract

This study refers to the spatio-temporal dynamics of human pressure in Preajba basin, located in the southeastern part of Craiova municipality. The statistic and cartographic analysis is based on the determination of a variety of environmental indices: index of human pressure by demographic dynamics, index of human stress through agricultural land use, naturality index, artificialization index and environmental change index. Choosing a grid of 1.5 sqkm for calculating and comparing the artificialization index of the landscape allows a concise analysis on the environmental transformation in the above-mentioned area. Complementary, temporal dynamics of the environmental indices values is highlighted by the choice of some benchmark years, i.e. 1992, 2002, 2012, 2014 to which data and recent cartographic materials from 2009 and 2014 are added. Results, materialized in the obtained values present the state of the environment and the human pressure implications on the Preajba lacustrine ecosystem (maximum values obtained at period level): physiological or agrarian density - 52 inhabitants/ha in 1992 (Craiova); human pressure index through arable – 1.4 ha/inhabitants in 1992 and 2002 (Malu Mare); naturality index of the landscape – 9.43 in 1992 (Malu Mare); environmental change index – 3.69 in 2012 (Coşoveni). Field campaigns conducted in 2015 and 2016 confirm the research results and visually support human pressure on the environment. The proposed measures, in order to stabilize and maintain the good environmental quality in the Preajba basin targets the lacustrine ecosystem by involving local authorities in order to protect the avi-faunistic natural area status of "Preajba-Făcăi Lacustrine Complex".

Keywords: *human pressure, indices, spatial evolution, lakes, Preajba Valley*

Rezumat. Dinamica spațială și temporală a presiunii umane în bazinul hidrografic Preajba, România

Prezentul studiu face referire la dinamica spațio-temporală a presiunii umane la nivelul bazinului hidrografic Preajba localizat în sud-estul municipiului Craiova. Analiza statistică și cartografică se bazează pe determinarea unei varietăţi de indici de mediu: indicele de presiune umană prin dinamica demografică, indicele de presiune umană prin utilizarea terenurilor agricole, indicele de naturalitate, indicele de artificializare şi indicele transformării de mediu. Alegerea unui caroiaj de 1,5 kmp în vederea calculării şi comparării indicelui de artificializare a peisajului permite o analiză concisă asupra transformării mediului în arealul anterior menționat. Complementar, dinamica temporală a valorilor indicilor de mediu este evidenţiată prin alegerea unor ani etalon 1992, 2002, 2014 cărora li se adaugă date și materiale cartografice recente din 2009 și 2015. Rezultatele, materializate în valorile obţinute redau starea mediului și implicațiile presiunii umane asupra ecosistemului lacustru Preajba (valori maxime obținute la nivel de perioadă): densitatea fiziologică sau agrară - 52 loc/ha în 1992 (Craiova); indicele de presiune umană prin arabil – 1,4 ha/loc în 1992 și 2002 (Malu Mare); indicele de naturalitate al peisajului - 9,43 în 1992 (Malu Mare); indicele transformării de mediu – 3,69 în 2012 (Coșoveni). Campanii de teren realizare în anii 2015 și 2016 confirmă rezultatele cercetării susțin vizual presiunea umană asupra mediului. Măsurile propuse, în vederea stabilizării şi menţinerii calităţii bune a mediului în bazinul hidrografic Preajba vizează ecosistemul lacustru prin implicarea autorităților locale în vederea respectării statutului de arie naturală de protecție avi-faunistică, "Complexul Lacustru Preajba-Făcăi".

Cuvinte-cheie: *presiune umană, indici, evoluție spațială, lacuri, Valea Preajba*

Introduction

The landscape is a basic component of the European natural and cultural heritage, contributing to human welfare and strengthening the identities of local, regional and European communities (Pătroescu 2000 cited by Dumitraşcu, 2006). The lakes of the Preajba river valley and the surrounding area present a varied landscape typology and more than that, they are included in the "Avi-faunistic protected area - Preajba-Făcăi Lacustrine Complex", with an area of 28 ha, only 5.35% of the catchment basin.

According to the project *The educational-ecological measures and dissemination of information about protected areas on the Preajba-Făcăi Lacustrine Complex*: *Ciconia ciconia* (White stork)*; Anas platyrhynchos* (Mallard)*; Aythya ferina* (Common pochard)*; Anser anser (*Greylag goose)*; Fulica atra* (Eurasian coot); *Neomys anomalus* (Mediterranean water shrew); *Natrix tessellata* (Dice snake); *Lacerta viridis* (European green lizard); *Gobio kessleri* (Kessler's gudgeon); *Umbrat krameri* (European mudminnow) are the main species needed protection and the reason for which it had been declared a Natural Protected Area. In 2002 Cioboiu and Brezeanu remembered that the Preajba Valley Lakes can be used for pisciculture, as well as for tourist and entertainment purposes. At the moment, *most of the lakes are invaded by paludous and aquatic macrophites, which is a feature of the eutrophic ecosystems* (Goga, 2009).

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The main aim of the protected areas is biodiversity conservation and the preservation of representative samples of the natural regions in a state close to the maximum balance, as well as getting on this basis some scientific or social benefits. However, it must be achieved a compromise between the protection of biological diversity, ecosystems functions and meeting short-term and long-term resource needs of human communities and governments (MEA, 2005b cited by Primack et al., 2008; Pham et al., 2012). The present work represents a qualitative temporal analysis of the study area, necessary to enable the development of some strategic decisions that must be anticipated and understood, precursory to some processes and complex phenomena in the future. The prospective evaluation of the environment permits to avoid some dysfunctionalities, which are not visible in the present, haven't been registered in the past, but in combination with other sources may become very active in perspective (Henrichs et al., 2009).

The phrase environmental conflict defines an "incompatible interaction between at least two actors aimed at using one natural resource, in which one of the actors is affected by interaction and the other ignores this damage" (Mason and Muller, 2007). Another definition of this type of conflict is proposed by Melé (2012), which characterizes it as "a complaint regarding the pollution or the technogenic risk to which those living in the proximity of activities with environmental impact are exposed to".

Study area

Preajba-Făcăi Lacustrine Complex is located in the proximity of Craiova, in the southeastern part of the city, at a distance of about 10 kilometers. Regarding the spatial coordinates, it falls between 44º15'25'' - 44º17'00'' lat. N and 23º48'40'' - 23º54'30'' long. E. The lakes chain was built during the communist period (1976-1979) with the stated purpose of serving as a recreational area for the residents of the municipality.

The neighboring territorial administrative units of Preajba river basin (15 km², *Romanian Water Cadastre Atlas*, 1992) are: Preajba village belonging to Malu Mare commune, Făcăi neighborhood - part of Craiova municipality, Coşoveni and Cârcea local administrative units (Fig. 1). These neighboring anthropogenic areas have both direct and indirect influence over the lacustrine ecosystem, exerting a constant pressure that we attempted to quantify in the present study. Aquatic ecosystems constitute an important factor of attractiveness for secondary housing, especially due to the high quality of the environment and suitable recreational activities (Pătroescu et al., 2012).

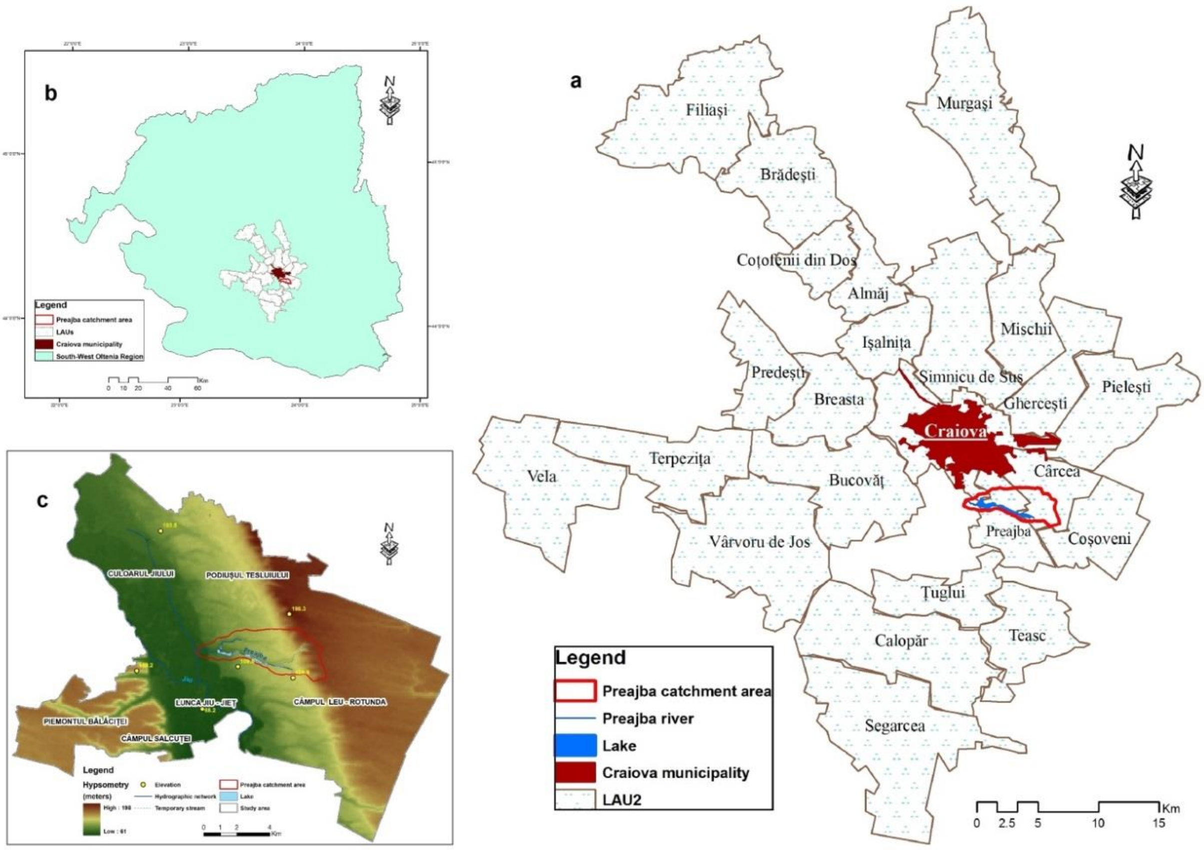


Fig. 1: Study area: a. framing in the Craiova metropolitan area; b. location within the Oltenia Region; c. hypsometric map

Preajba creek has its source near Cârcea, the difference till the point of shedding, the confluence with Craioviţa collector channel being of 121.1 m. In this natural context, to provide the gravity flow of the lakes water, surface spillways and raised dams were built in front of the water bodies. Currently this area is an *Avi-faunistic protected area - Preajba-Făcăi Lacustrine Complex*, which is administered by Diana County Association of Hunters and Anglers Diana Dolj (A.J.V.P.S. Diana Dolj).

In terms of legality, the *Craiova Metropolitan Area* association was constituted in accordance with the Law of local public administration no. 215/2001, republished, Law no. 351/2001 regarding the approval National Landscaping Plan with subsequent amendments, Law no. 350/2001 regarding landscaping and town planning with subsequent amendments and following the O.G. no. 26/2000 regarding associations and foundations.

The Craiova town's Local Council Decision no. 297/27.11.2008, allowed the association of Craiova municipality initially with five communes from the northern part of the town (Mischii, Breasta, Gherceşti, Şimnicu de Sus and Pieleşti) and later on with another 10 communes (Predeşti, Vârvoru de Jos, Işalniţa, Bucovăţ, Ţuglui, Almăj, Murgaşi, Terpeziţa, Filiaşi, Segarcea, Coţofenii din Faţă and Calopăr) and two small towns – Filiaşi and Segarcea. Just one neighbouting commune – Podari – was not included in Craiova metropolitan area, since its local administration decided not to become a member in order to avoid the annual financial contribution to the administrative association (Fig. 1).

Currently, Craiova Metropolitan Area has 149.862 ha, represents 20% of the total area of the county (741,400 ha), and counts 356,544 inhabitants, accounting for 54% of the entire population of Dolj county.

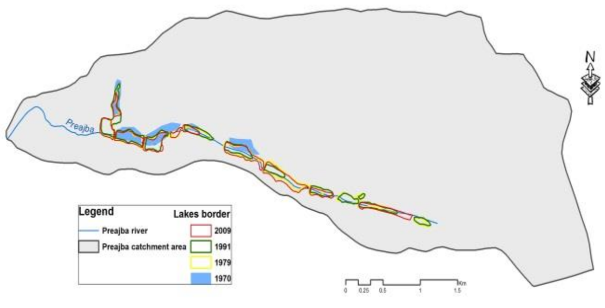
The expansion of residential areas involves the conversion of other land use mode into spaces for residential use, triggering a set of processes with accelerated dynamics in the conditions of continued growth in the number of inhabitants and promotion of some housing models focused on the individual accommodation type (Stanciu, 2009). The expansion of built areas and consequently of residential areas is included in this general trend, presenting specific elements related to causes, manifestations and effects (Iojă et al., 2011a; Vânău, 2011; Verhoef and Nijkamp, 2002). Common elements of the expansion processes of residential spaces, regardless of the level of development or geographical location, lead to environmental consequences and various manifestation forms.

The geographical position of the study area in the metropolitan area of Craiova municipality constitute an element of attractiveness, both for residents and visitors, in the context of the development of food and relaxation infrastructure on the lakes shore. In terms of expansion of constructed areas, it should be noted that it is not just individual housing, but also spaces for services, the construction of which led to artificialization.

The causes of diversification of anthropogenic pressure forms on the environment are in accordance with the economic development of Craiova municipality, which determines the need for more space, i.e. the inclusion of new territories in periburban space. Also, it can be discussed about an exodus of residents with certain financial potency to rural areas surrounding town (low cost of land and commuting to the town, to work), integrating the specific urban infrastructure to the new housing.

The spatio-temporal analysis (Fig. 2) at the level of the existing cartographic materials (*General Austrian Map of the Central Europe, Military Topographic Map, Soviet Military Topographic Map*) reveal the existence of a naturally formed lacustrine cuvette, by corroborating relief's hypsometry with soil type, of limnocrene springs with level curves (Avram & Ionuş, 2015).

The extension of artificializated surfaces is a defining feature of the 21st century, but the changes they cause in the protected areas constitute violations of the law and the endangerment of flora and fauna species and related biotope.



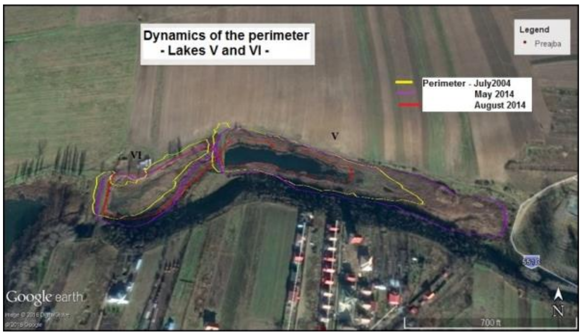


Fig. 2: Spatial and temporal dynamics of the lakes perimeter on Preajba Valley (left). Case studies: Lake V and Lake VI (right)

The habitats of community interest, which were identified in the "Natural protected area - Preajba-

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Făcăi Lacustrine Complex", are specific to wetlands: R 3150 natural eutrophic lakes, R 3160 natural dystrophic lakes and ponds, biotopes the existence of which is conditioned by forces who act on the rolling movement of water. In the riverbeds, a series of dynamic phenomena (currents, speeds variations, levels variations etc.) occur, their instability being linked to the regime of rivers and morphological elements of the riverbed. The forces acting on the mass of water flowing through riverbeds: gravity, the force of Coriolis and centrifugal force trigger these processes (Loghin, 2009).

The exoreic character of Preajba creek: springs near the Cârcea locality, the shedding into Craioviţa collector channel and then into the river Jiu, maintain the previously mentioned habitats.

This study is aimed primarily to local and regional authorities, because it reveals certain sanogenesis state of the lacustrine environment, part of the "Preajba-Făcăi" avi-faunistic protected area. Decision makers could take measures to preserve the characteristic landscape, by implementing measures closely with residents of the neighboring settlements. Thus, resolving the human pressure on the environment problem, even if a protected area or an area with high ecological valence is possible only through an authority – residents – tourist's synergy, for a sustainable development and an enhancement of the life quality within Craiova metropolitan area.

The research results will have the function of informing and diagnostic the environment within "Preajba-Făcăi avi-faunistic protected area", their quantification being possible by calculating some environmental quality indices and by studying the existing cartographic materials. It's also desired not only to identify dysfunctionalities, but also to propose solutions to gain a favorable conservation status. The lacks of accurate and fair demographic information, values about morphometry of the lakes, and also the lack of support from local authorities for this study, are restrictive elements in achieving the set goals.

Data and Methods

Human pressure on the environment is a synthetic indicator of its quality and of its transformation degree as a result of human intervention (Goudie and Viles, 2003; Goudie, 2006). It is considered that for an adult to have a high standard of living, in the temperate zone, it takes 2 hectares of land, which should be divided as follows: untouched natural area (0.8 ha), land used for agriculture (0.6 ha), forests (0.4 ha) and 0.2 ha of land for construction, industrial platforms and transport infrastructure (Dumitraşcu, 2006).

In this regard, to achieve results, various environmental quality indices were calculated, namely:

- index of human pressure by demographic dynamics (*Di=Inh./Sagra*);
- index of human pressure through arable land use (*S.t.A.=Sarab./Inh.*);
- naturality index (*Ni=Sforest/Stotal*) and the environmental change index [*Eci.=(Sforest+Shay)/Stotal*]

(Iojă, 2013; Zarea and Ionuş, 2012; Kimberly et al., 2007; Dumitraşcu, 2006; Pătroescu et al., 2000).

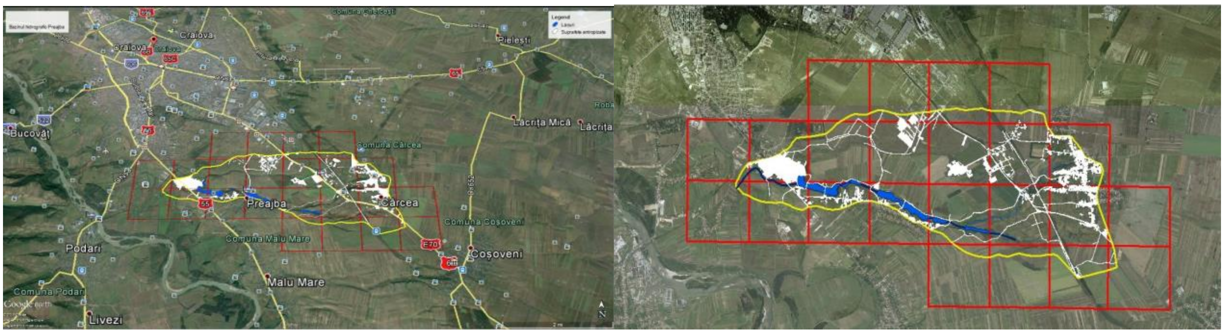
It was considered necessary to obtain not only values, but for a better understanding of the phenomena, apart from determining the values of this indices, we worked to identify a trend using the reference years 1992, 2002, 2012 and 2014.

This method has been used in literature by Călin (2010), Ionuş et al. (2011), but also by Vartolomei and Armaş (2010). Internationally, however, the issue of environmental change in morphology and physiology due to increasing human pressure has been addressed in papers belonging to Burgoyne et al. (2016). To highlight the degree of human intervention on environmental quality, we used series of synthetic indices; the quantitative value obtained being calculated based on statistical data.

The human pressure index highlights the demographic dynamics of the local administrative units analyzed, but also regarding land use, in sense of extension of built surfaces in the detriment of agricultural ones. The trend identified by calculating this previous indicator should be correlated with the residents need for food, so with the size of the arable area which is assigned for each one of these.

Agricultural land use in the areas dominated by residential is also controversial, if we consider the potential of these activities of damaging the housing quality through the use of chemicals such as pesticides or fertilizers, odours and biological risk (Holt et al., 2010; Iojă et al., 2011a; Rull et al., 2009). The dynamics of some forest surfaces for the layout of residential assemblies is another macro-territorial matter recorded in the analyzed areas, identified by calculating the naturality index. The deepening of the change ratio between natural and man-made surface was performed by analysing the environmental change index. This indicator was introduced and used for the first time by Maruszczak (1988), to assess the human impact on the Carpathian sub-landscape in Poland and then used by many Romanian authors (Armaş et al., 2003; Manea, 2003; Pătru-Stupariu, 2011; Ionuş et al., 2011; Zarea and Ionuş, 2012).

The present study includes a cartographic analysis through GIS techniques "that are becoming more commonly used in qualitative and quantitative evaluation of the environment, allowing not only the highlighting of the environmental elements dynamics, but also their spatial distribution" (Andrews et al., 2002). The cartographic representation is conditioned by the existence of some plans, maps, satellite images, aerial photos, which can be georeferenced based on them, there results, the spatial dimension of the final products. GIS techniques are used to analyze neighborhoods (Balram and Dragicevic, 2005), overlapping thematic layers (El Baroudy, 2011) and for quantifying the environmental status at spaces level. In this sense, the analysis of the artificialization index for Preajba basin was performed by using a grids system (1.5 km^2), equivalent to 1/16 of the map sheet 1:25,000, georeferenced. Subsequently, grids were imported into Google Earth PRO using the transformation of *.shp* into *.kml* (Fig. 3). Using orthophotos (2009) and Google Earth Pro (2014) vectorization and comparison of the artificial surfaces were performed.



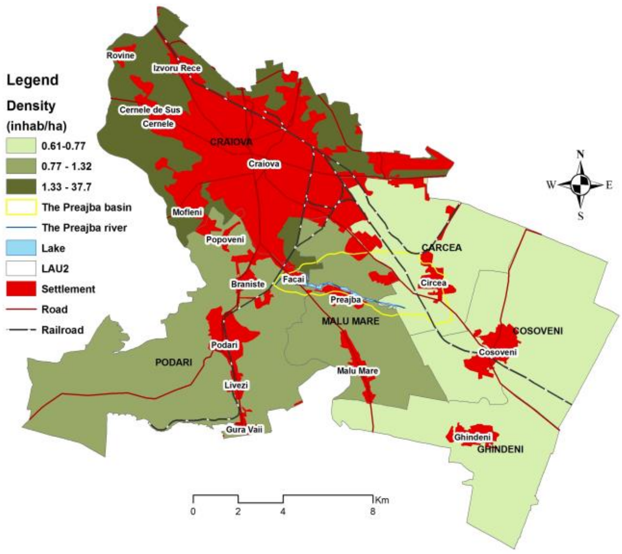
a b

Fig. 3: Spatial dynamics of human pressure in Preajba basin using grids method: a. Orthophotos - 2009; b. Google Earth PRO - 2014

Results and Disscusions

Physiological density index

The calculation of the physiological density index, as ratio between the number of inhabitants and the agricultural area reveals the existence of three classes of values: 0.61-0.77 inh./ha, 0.78-1.32 inh./ha and 1.33-37.7 inh./ha (Fig. 4).



(*Source: GIS processing; Tempo Online data*)

Fig. 4: Spatial variation of the physiological density in the study area, year 2014

The greatest human pressure through agricultural areas is felt in the northern extremity of Preajba basin, an area that overlaps a neighborhood of Craiova (Făcăi neighborhood). The expansion of human settlements usually occurs in peripheral areas with favorable environmental qualities (Primack et al., 2008), at least initially. As the territorial expansion continues, new spaces (unmodified, little modified or unbuilt) are included in the suburbs, while on the previous positions the anthropization process is practically irreversible (Antrop, 2004; Tissot et al., 2005). Thus, it is noticed the temporary nature of environmental favorability offered by the peripheral areas, but with negative implications on the natural environmental characteristics and the inhabitants' life quality (northern extremity of Preajba basin) (Fig. 5).

(Avram M., March 2016)

Fig. 5: Improper storage of household garbage in the northern extremity of Preajba basin – Magnolia residential area

The human pressure through arable

The human pressure through arable index (ha/inh.) is revealing in terms of decreasing arable

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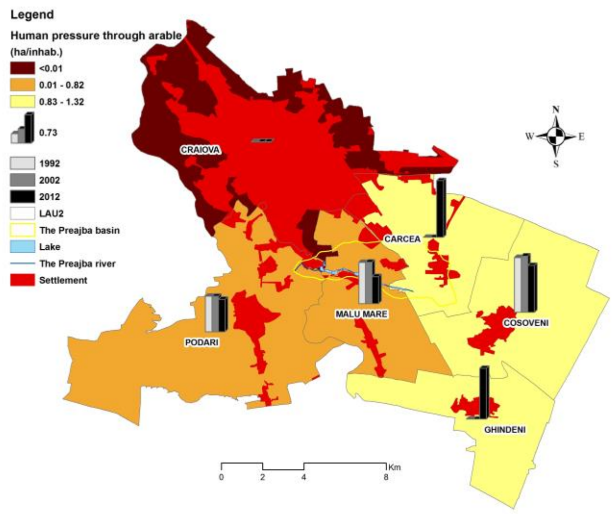
land surfaces in the detriment of areas occupied by constructions, but also in terms of growing number of residents in the settlements that overlap Preajba-Făcăi protected area. Thus, the downward dynamics of this parameter may be linked to an increased human impact on the environment. Minimum values obtained at the level of 2014 (under 0.01 ha/inh.) characterize Făcăi neighborhood, while to Coşoveni inhabitants are assigned 0.83-1.32 hectares of arable land (Fig. 6). In this context, we can say that there is an undeniable link between the regional pole of attraction that is Craiova municipality and the increase of demographic density, and residential at its periphery. But, by creating shelter for new inhabitants, the new residential areas have automatically introduced forms of aggression specific for household sources, i.e. consumption of resources and generation of environmental problems (Vânău, 2011).



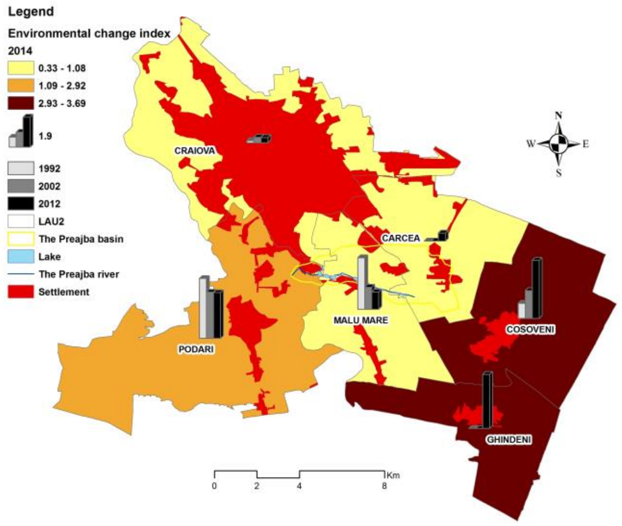
(*Source: GIS processing; Tempo Online data*)

Fig. 6: Human pressure through arable, 1992-2014 period

Environmental change index

Values of the environmental change index for 1992, 2002, 2012 and 2014 dramatically declined, which testifies for the expansion of the artificialized areas. This *de facto* state is best evidenced in Malu Mare, with values between 0.33-1.08 (Fig. 7). It should be noted that the administrative division made in 2004 prevented us from obtaining data for Cârcea and Coşoveni local administrative units which became distinct local administrative units in accordance with Law 5/2004.

The environmental change index is a parameter with major functions: to generate vital information on the current status or viability of residential spaces, on one hand, and on the role of residential spaces in structural and functional changes of other systems with which they interact, on the other hand (Pătroescu et al., 2012).



(Source: GIS processing; Tempo Online data)

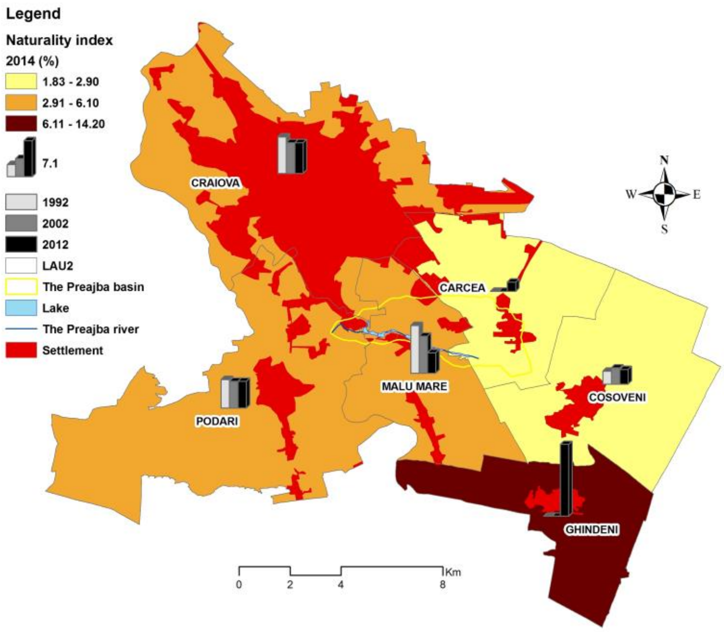
Fig. 7: Environmental change index dynamics, 1992-2014 period

Naturality index

The naturality index, the ratio between the area occupied by forests and the total area, reveals the actual situation of Preajba basin and related settlements, the decrease of forest areas. The situation highlighted by this parameter is a dramatic one, with maximum values of 6.10% of the areas on which trees and brushes are grafted (Fig. 8). This indicator should be linked on one hand with the expansion of the residential area and hence the need for bulding space (Fig. 9), and on the other hand with the expansion of arable land to meet the needs of residents for food. As a result, the increase of built surface induced major changes in land use, redistribution of the population which is a consumer of goods or generator of waste, loss of neighborhood's personality or villages and changing the structure of oxygenated surfaces (Chiesura, 2004; Daniels, 1999; Eisner et al., 1992; Hui et al., 2007).

Artificialization index

Regarding the graphical analysis, Ortophotos 2009 and Google Earth Pro 2014 cartographic documents were used. Analysis of the mentioned issue involved vectorization of anthropogenic surfaces and overlapping a 1,5 km^2 grid in diameter over Preaja basin, thus resulting 23 equal surface areas. Those two reference years were benchmarked (absolute value and percentage) by reference to a common class of values. The results show an upward dynamic of the artificialization index: 7 polygons with value of this parameter between 32.04-54.11% in 2014 and two in 2009 (Fig. 10). The anthropogenic areas (residences, household annexes, access roads etc.) increased by 22%, meaning automatically a shrinking of natural areas.



(Source: GIS processing; Tempo Online data)	*(Avram M., March 2016)*
Fig. 8: Naturality index dynamics, 1992-2014 period	**Fig. 9: New constructions of Magnolia residential area**

Artificialization index

Regarding the graphical analysis, Ortophotos 2009 and Google Earth Pro 2014 cartographic documents were used. Analysis of the mentioned issue involved vectorization of anthropogenic surfaces and overlapping a 1.5 km^2 grid in diameter over Preaja basin, thus resulting 23 equal surface areas. Those two reference years were benchmarked (absolute value and percentage) by reference to a common class of values.

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Expanding vegetation at the expense of water bodies determines chemical-physical imbalances of stagnant organisms, which entails a reduction in the number of species that constitute ichtyofauna. Also, the deforestation of the slopes is causing denudational processes, the most important being rill surface washing and landslides. These hazards constitute limiting factors in terms of tourist attractiveness of the area, along with household waste disposal on the bank and even into lakes.

Maintaining the significant or characteristic features of a landscape, justified by its heritage value derived from its natural configuration and/or human intervention, include actions aiming at a sustainable development perspective, landscape maintenance in order to target and harmonize changes induced by social, economic and environmental developments (Călin, 2010).

Thus, the values of the artificialization index (5 classes) point to the landscape equilibrium or disequilibrium, i.e. totally affected ecological balance (32.04% - 54.11%); strongly affected ecological balance (11.64% - 32.03%); moderately affected ecological balance (5.61% - 11.63%); slightly affected ecological balance (1.45% - 5.60%); relatively stable ecological balance (<1.44%).

Insularity index

The implications of this parameter, but also of the other indicators mentioned above at the level of Preajba-Făcăi Lacustrine Complex, are extremely important and reveal a steady trend in anthropic expansion and thus diminishing natural areas. Strictly at the lakes level, there can be forecasted changes in the specific biotope due to land use change in bordering terrains, but also an extension of hydrophilic vegetation in the detriment of water bodies (Fig. 11, 12).

Thus, there are noted values of over 80% vegetation for the lakes V and VI, in 2004, but also in 2014 (May and August). There is an upward trend of the vegetation for lakes III, IV, VI and X (Fig. 13), while the situation for lacustrine basins I and IX is atypical. The novelty regarding the lakes previously

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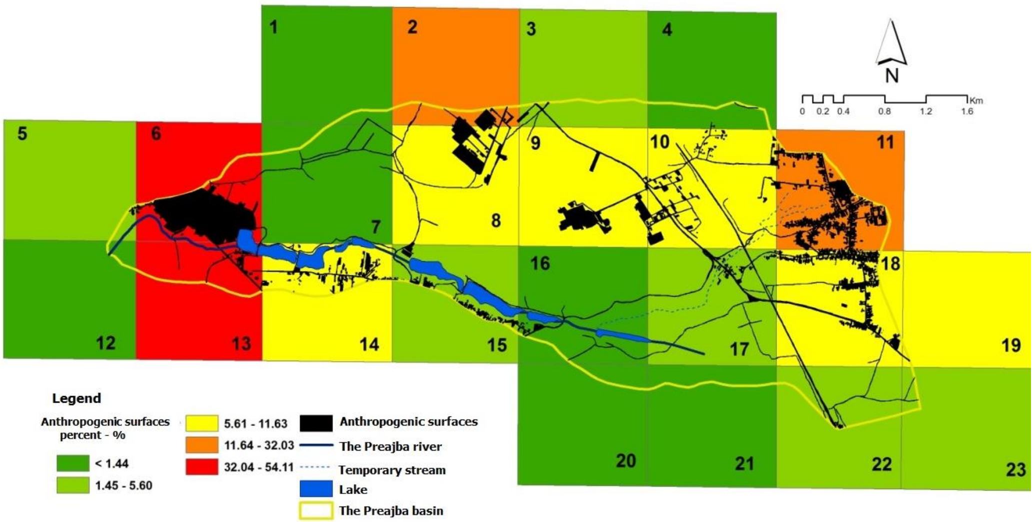
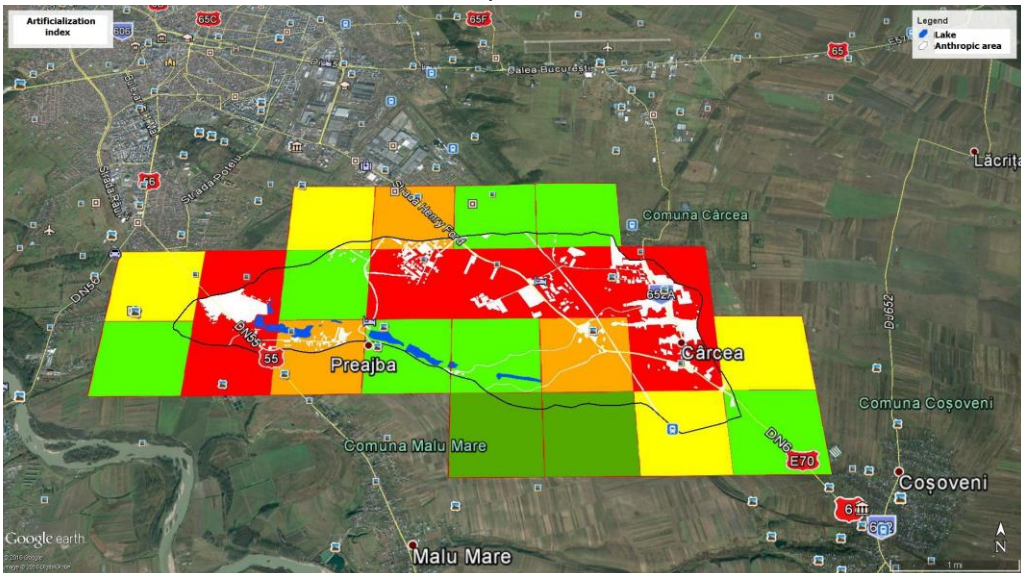
mentioned is the existence of a downward dynamics of the vegetation, which shows their regular cleaning. The first lacustrine basin of Preajba lacustrine complex is the only one arranged for fishing. The acces for people who want to fish in the first lake is permitted only after they pay a tax, so it is in the interest of administrators to prevent clogging and eutrophication of lacustrine basins (Fig. 14).



a



b

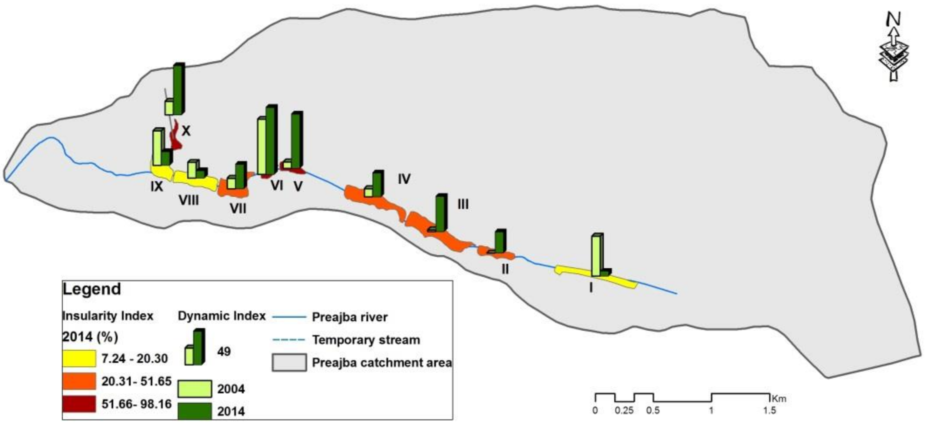
Fig. 10: Spatial dynamics of artificialization index within the Preajba basin: a. Ortophotos – 2009; b. Google Earth PRO – 2014

(Avram M., April 2016)

Fig. 11: Vegetation (*Typha*) expansion in Lake V

(Avram M., April 2016)

Fig. 12: Vegetation (*Typha*) expansion in Lake VI



(2004 and 2014 values, source Google Earth PRO)

Fig. 13: The variation of insularity index values of the lakes on Preajba Valley

Fig. 14: Spatial and temporal distribution of perimeter and vegetation - Lake V and Lake VI (mappings from 2004 - left and 2014 - right, source Google Earth PRO)

The sanogenesis condition of the lakes on Preajba Valley may correlate with the dynamics of hydro and hygrophilic vegetation. To quantify the evolution of plants in relation to the water body in the study area, we calculated the insularity index. This parameter renders the share of hydrophilic vegetation from the total surface of the lacustrine surface (Table 1).

Table 1: Temporal dynamics of the insularity index – Preajba lacustrine complex

(%)	I	II	III	IV	V	VI	VII	VIII	IX	X
2004 Iul	58.52	0	2.37	11.95	9.31	80.67	15.62	23.04	50.77	19.67
2014 Mai	7.24	47.7	35.66	34.83	90.74	70.85	29.25	71	42.59	62.89
2014 Aug	7.24	31.2	51.66	35.14	79.26	98.17	36.22	10.95	20.31	72.28

(Source: Google Earth PRO data extraction)

The environmental conflict, in general, and the one of Preajba lacustrine complex is characterized by the following dimensions: the spatial dimension or place of event; temporal dimension or time event; environmental dimension and the socio/economic one. In particular, the conflict in the study area is manifested throughout the protected area, due to the divergent interests of residents on one hand and environmental policies and legislation regarding the status of the study area, on the other hand. Regarding the outbreak moment of disagreement between the warring parties, it can be considered the year 2000, when the lakes on Preajba Valley have received the "avi-faunistic protected area" status.

The environmental dimension is not related only to the negative effects of some anthropic activities on the environment's structure and functionality, but also the accordance with the principles of environmental law, objectives of environmental policies and strategies and compliance with environmental legislation.

Conclusions

The study area corresponds to class V considering the IUCN classification, and in these protected areas it is recommended that all economic activities should be carried out with particular attention to the values for which they were granted this status (Stanciu and Florescu, 2009). In this context, in the study area economic and touristic activities should be allowed in the extent that these don't cause imbalances to the characteristic flora and fauna.

The results of this study are intended to be not only an environmental analysis, but also a useful analysis to local authorities, showing a real situation that will be positively changed by taking concrete and immediate measures. Although the expansion of built areas is a feature of the development of the society, in the studied area, this might be made respecting the avi-faunistic protected area status, namely opting for reducing environmental impact. It's heady necessary to establish strict criteria for the granting of building permits, as well as how these are realized, whereas the anthropic expansion in a 20% per 5 years progression will lead to the disappearance of the area in the next 25 years.

Human activity materialized through residential areas, agricultural activity or with applications in the tertiary domain should become striving for the harmony of human-environment co-existence.

References

Andrews, B.D., Gares, P.A. & Colby, J.D. (2002). Techniques for GIS modeling of coastal dunes. *Geomorphology*, 48, 289–308

Antrop, M. (2004). Landscape change and the urbanization process in Europe. *Landscape and Urban Planning*, 67, 9–26

Armaş, I., Damian, R., Şandric I. & Osaci-Costache G. (2003). *Vulnerabilitatea versanţilor la alunecări de teren în sectorul subcarpatic al văii Prahova*. Editura Fundaţiei România de Mâine. Bucureşti [in Romanian]

Avram, M., Ionuș, O. (2015). Spatial relations of the Preajba Valley Lakes evolution reflected on cartographic documents. *Lakes, reservoirs and ponds,* 9(2), 123-141

Balram, S. & Dragicevic, S. (2005). Attitudes toward urban green spaces: integrating questionnaire survey and collaborative GIS techniques to improve attitude measurements. *Landscape and Urban Planning*, 71, 147–162

Bailey, K. M., McCleery, R. A., Binford, M. W. & Zweig, C. (2016). Land-cover change within and around protected areas in a biodiversity hotspot. *Journal of Land Use Science*. 11(2), 154

Burgoyne, C., Kelso C. & Fethi A. (2016). Human activity and vegetation change around Mkuze Game Reserve, South Africa, *South African Geographical Journal*, 98(2), 217. doi.org/10.1080/03736245.2015.1028978

Călin, I. (2010). Statutul de protecţie al lacului Babadag şi al ariei limitrofe versus starea actuală a peisajului. *Resursele de apă din România. Lucrările primului simpozion naţional, 11-13 iunie 2010,* Târgovişte, Editura Transversal [in Romanian]

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning*, 68, 129–138

Cioboiu, O. & Brezeanu, Gh. (2002). Hidrobiological Particularities of some small Eutrophic Rezervoirs within the Hydrographical Basin of the Jiu. *Limnological Reports.* 34, 275-287

Daniels, P. (1999). When City and Country Collide. Managing Growth in the Metropolitan *Fringe*. Washington D.C.: Island Press

Dumitraşcu, M. (2006). *Modificări ale peisajului în Câmpia Olteniei*. Editura Academiei Române. București [in Romanian]

Eisner S., Gallion, A. & Eisner, S. (1992). The Urban Pattern. New York: John Willey

El Baroudy, A.A. (2011). Monitoring land degradation using remote sensing and GIS techniques in an area of the middle Nile Delta, Egypt. *Catena*. 87, 201–208

Goga, I. C. (2009). Basic data on the piscicultural communities from the hydrographic basin Preajba Valley, Oltenia. *Studies and Communication. Natural Sciences. Oltenia Museum*.25, 165-169

Goudie, A. & Viles, H.A. (2003). *The earth transformed: an introduction to human impacts on the environment*. 4th Edition. Blackwell Publishing Ltd. Oxford. UK

Goudie, A. (2006). *The human impact on the natural environment: past, present, and future*. 6th Edition. Blackwell Publishing Ltd. Oxford. UK

Henrichs, T., Zurek, M., Eickhout, B., Kok, K., Raudsepp-Hearne, C., Ribeiro, T., van Vuuren, D. & Volkery, A. (2009). Scenario development and analysis for forward-looking ecosystem assessment. *In Ecosystesms and Human Well-being – a manual for assessment practitioners*, ed. M. E. Assessment. Washington D.C.: Island Press

Holt, L.M., Laursen, A.E., McCarthy, L.H., Bostan, I.V. & Spongberg, A.L. (2010). Effects of land application of municipal biosolids on nitrogen-fixing bacteria in agricultural soil. *Biology and Fertility of Soils*. 46, 407–413

Hui, E.C.M., Chau, C.K., Pun, L.L. & Law, M.Y. (2007). Measuring the neighboring and environmental effects on residential property value: Using spatial weighting matrix. *Building and Environment*, 42, 2333–2343

Iojă, I. C., Niță M., Vânău G., Onose D., Gavrilidis A. & Hossu A. (2015). *Managementul conflictelor de mediu*. Editura Universității din București. București [in Romanian]

Iojă, I.C., Onose, D.A., Niţă, M.R., Vânău, G.O., Pătroescu, M., Gavrilidis, A.A., Saghin, I. & Zarea, R. (2011a). The Conversion of Agricultural Lands into Built Surfaces in Romania. *In 2nd International conference on Urban Sustainability. Cultural Sustainability. Green*

Development. Green Structures and Clean. 247, Cars (USCUDAR '11). Eds. V. Niola, T. Kala & C. Popescu. Praga: WSEAS

Iojă, I.C., Rozylowicz, L., Pătroescu, M., Niţă, M.R. & Vânău, G.O. (2011b). Dog walkers' vs. other park visitors' perceptions: The importance of planning sustainable urban parks in Bucharest, Romania. *Landscape and Urban Planning*. 103, 74–82

Ionuş, O., Licurici, M., Boengiu, S. & Simulescu, D. (2011). Indicators of the Human Pressure on the Environment in the Bălăciţa Piedmont. *Forum geografic*. X(2), 287-294. doi:10.5775/fg.2067-4635.2011.013.d

Iojă, C. (2013). *Metode de cercetare și evaluare a stării mediului*. Editura Etnologică. București [in Romanian]

Loghin, V. (2009). *Elemente de geomorfologie fluviatilă., Valahia University Press*. Târgovişte [in Romanian]

Kimberly, M., Mattson, P. & Angermeier, L. (2007). Integrating Human Impacts and Ecological Integrity into a Risk-Based Protocol for Conservation Planning, *Environ Manage*, 39, 125–138. doi:10.1007/s00267-005-0238-7

Manea, G. (2003). *Naturalitate și antropizare în Natural Porțile de Fier*. Editura Universității. București [in Romanian]

Maruszczak, H. (1988). The transformation of natural environment during historical time, in Starkel L. (Ed.). *Transformation of geographical environment of Poland*. Ossolineum Publisher. Warszawa. 99-135

Melé, P. (2012). Pour une géographie des conflits urbains de proximité en Amérique Latine. *Géocarrefour,* 87(1)

Pham, H.V., Kirat, T. & Torre, A. (2012). Les conflits d'usage dans les espaces ruraux et périurbains. Le cas des infrastructures franciliennes. *Économie rurale*. 332, 9-30

Pătroescu, M., Toma, S., Royzlowicz, L. & Cenac-Mehedinţi M. (2000). Ierarhizarea peisajelor rurale din Câmpia Română funcţie de vulnerabilitatea la degradare şi suportabilitate a presiunii umane. *Geographica Timisensis.* VIII-IX. [in Romanian]

Pătroescu, M., Iojă, C., Rozylowicz, L., Vânâu, G., Niţă M., Pătroescu Klotz I. & Iojă A. (2012). *Evaluarea integrată a stării mediului în spaţiile rezidenţiale*. Editura Academiei Române. Bucureşti [in Romanian]

Pătru-Stupariu, I. (2011). *Peisaj şi gestiunea durabilă a teritoriului*. Editura Universităţii. Bucureşti [in Romanian]

Primack, R., Pătroescu, M., Rozylowicz, L. & Iojă, I.C. (2008). *Fundamentele conservării diversităţii biologice*. Editura AGIR. București [in Romanian]

Rull, R. P., Gunier, R., Von Behren, J., Hertz, A., Crouse, V., Buffler, P.A. & Reynolds, P. (2009). Residential proximity to agricultural pesticide applications and childhood acute lymphoblastic leukemia. *Environmental Research*. 109, 891–899

Stanciu, M. (2009). Metode de cercetare a modelelor de consum. Bucureşti. Academia Română [in Romanian]

Stanciu, E., Florescu, F. (2009). *Ariile protejate din România. Noțiuni introductive*. Editura Green Steps Brașov [in Romanian]

Tissot, C., Le Tixerant, M., Rouan, M. & Cuq, F. (2005). Modélisation spatio-temporelle d'activités humaines à fort impact environnemental. *Cybergeo: European Journal of Geography.* 313. doi: 10.4000/cybergeo.3570

Vartolomei, F. & Armaş, I. (2010). The Intensification of Antropic Pressure Through the Expansion of the Constructed Area in the Subcarpathian Sector of the Prahova Valley/Romania (1800-2008). *Forum geografic*, IX(9), 125-132

Vânău, G.O. (2011). *Interfaţa spaţial-funcţională dintre Municipiul Bucureşti şi teritoriul suport al acestuia*. Bucureşti. Editura Universitară [in Romanian]

Verhoef, E.T. & Nijkamp, P. (2002). Externalities in urban sustainability - Environmental versus localization-type agglomeration externalities in a general spatial equilibrium model of a single-sector monocentric industrial city. *Ecological Economics*. 40, 157–179

Wilson, T.S., Sleete, B. M.*,* Davis, A. W. (2015). Potential future land use threats to California's protected areas. *Regional Environmental Change,* 15(6), 1051

Zarea, R. & Ionuş, O. (2012). Land use changes in the Bâsca Chiojdului river basin and the assessment of their environmental impact. *Forum Geografic*. XI(1), 36-44 doi:10.5775/fg.2067-4635.2012.023.i

*** (2011). The educational-ecological measures and dissemination of information about protected areas on the Preajba-Făcăi Lacustrine Complex. Measures to achieve a favourable conservation status. http://www.arealprotejat.ro/index.php [in Romanian]

*** http://www.metropolacraiova.ro/ro/date-generale/ [in Romanian]

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Evaluation of land use/land cover classification accuracy using multi-resolution remote sensing images

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Abstract

Timely and accurate land use/land cover (LULC) information is requisite for sustainable planning and management of natural resources. Remote sensing images are major information sources and they are widely used for mapping and monitoring various land features. Images from various sensors, with different spatial resolutions, are available; however, the selection of appropriate spatial resolution is an essential task to extract desired information from images. This paper presents the conclusions of the work related to LULC classification based on multi-resolution remote sensing images. Optical data collected by three different sensors (LISS IV with 5.8 m and Landsat 8-OLI with 30 m and AWiFS with 56 m spatial resolutions respectively) in 2013 are examined against the potential to correctly classify specific LULC classes. The classifications of images are performed using Maximum Likelihood Classifier (MLC). The results indicate that the overall accuracy and kappa coefficient of LISS IV with 5.8 m are higher than that of Landsat 8-OLI with 30 m and AWiFS with 56 m images. Understanding the role of spatial resolution in LULC classification accuracy will enable the appropriate interpretation of any classified images.

Keywords: *remote sensing, spatial resolution, accuracy, separability, analysis*

Rezumat. Evaluarea acurateţii clasificării modului de utilizare/acoperire a terenurilor folosind imagini de teledecţie multi-rezoluţie

Informaţii precise şi în timp util privind utilizarea/acoperirea terenului (LULC) sunt necesare pentru planificarea și gestionarea durabilă a resurselor naturale. Imaginile de teledetecție sunt surse majore de informare și sunt utilizate pe scară largă pentru cartografierea și monitorizarea diferitelor caracteristici ale terenului. Imagini de la diverși senzori, cu diferite rezoluții spațiale, sunt disponibile; cu toate acestea, selectarea rezoluției spațiale corespunzătoare este o sarcină esențială pentru a extrage informațiile dorite din imagini. Această lucrare prezintă concluziile referitoare la clasificarea LULC bazată pe imagini de teledetecție multi-rezoluţie. Datele optice colectate de trei senzori diferiți (LISS IV cu 5,8 m și Landsat 8-OLI cu 30 m și respectiv AWiFS cu 56 m rezoluție spațială), în 2013, sunt examinate în raport cu potențialul de a clasifica corect clasele specifice LULC. Clasificările imaginilor sunt realizate utilizând Clasificatorul de maximă probabilitate (MLC). Rezultatele indică faptul că precizia per total și coeficientul kappa al imaginilor LISS IV cu 5,8 m sunt mai mari decât cele ale Landsat 8-OLI cu 30 m și AWiFS cu 56 m. Înţelegerea rolului rezoluției spațiale în clasificarea precisă LULC va permite interpretarea adecvată a oricăror imagini clasificate.

Cuvinte-cheie: *teledecţie, rezoluţie spaţială, acurateţe, separabilitate, analiză*

Introduction

Earth observation data acquired from different sensors at various spatial resolutions have been used broadly in the studies of global environmental changes, management of natural resources and ecological systems. Timely and accurate LULC information is vital for several planning and management activities and also for understanding the functioning of Earth as a system (Salberg and Jenssen, 2012; Lambin et al., 2001).

During the last few decades, remote sensing technologies have made remarkable development and now a number of images from different sensors with high, medium and coarse spatial resolution are available (Clark et al., 2004). The selection of improper spatial resolution can lead to ambiguous interpretation and hence LULC classification using a single remote sensing image has some limitations such as low classification accuracy and adaptability. Therefore, with increasing number of different spatial resolution images, the selection of the appropriate one has become more complex (Chen et al., 2004). One of the basic characteristics of a remote sensing image is its spatial resolution, which extensively affects the accuracy of image classification. In the case of remotely sensed images, the classification accuracy is strongly affected by the influence of boundary pixels and the finer spatial resolution which increases the spectral-radiometric variation of LULC classes (Markham and Townshend, 1981). The linkage between classification accuracy and spatial resolution of the image strongly depends on the size and spatial patterns of LULC classes (Moody and Woodcock, 1994). The suitable spatial resolution is also a function of the type of desired information and the techniques used to extract information.

In an optical remote sensing system, the spatial resolution is defined as the smallest resolvable spatial unit on the ground recorded in an image (Woodcock and Strahler, 1987) and determines the level of observed spatial detail on the Earth's surface. The spatial resolution provides the patterns and distributions of objects (Singh et al., 2002; Frank and Tweddale, 2006). The fundamental information contained in a remote sensing image is robustly dependent on spatial resolution and it extensively affects each stage of image classification. Image classification is a widely used way to get spatially distributed LULC information (Borak and Strahler, 1999). With the launch of Landsat satellites series, several image classification techniques have been developed (Lu and Weng, 2007). The maximum likelihood classifier (MLC) is parametric in nature, representing the most widely used classification technique (Jensen, 2005; Foody et al., 1992). It assumes normal Gaussian distribution of multivariate data with pixels allocated to the most probable output LULC categories (Richards and Jia, 2003). In several studies, MLC has been used effectively for classifying LULC and other categories (Chen et al., 2004; Mishra et al., 2014a; Kumar et al., 2016; Mishra and Rai, 2016).

Therefore, the effects of spatial resolution on LULC classification accuracy have received considerable attention due to the availability of a large variety of Earth observation data. This study employs multi-resolution remote sensing images to determine how varying spatial resolution affects the accuracy of LULC classification. The classification accuracy at each spatial resolution is reported and compared.

Study area

The study area is a part of Varanasi district, Uttar Pradesh, India. Geographically, it lies between 25° 12′ 01.08″ N to 25° 20′ 43.88″ N latitudes and 82° 54′ 30.32″ E to 83° 04′ 08.64″ E longitudes and spreads over an area of 26098 ha. It is one of the oldest living cities in the world, being located on the bank of Holy River Ganga. This area is very productive and wealthy in agriculture because of its location in the Indo-Gangetic plain. The location map of the study site is shown in Figure 1.

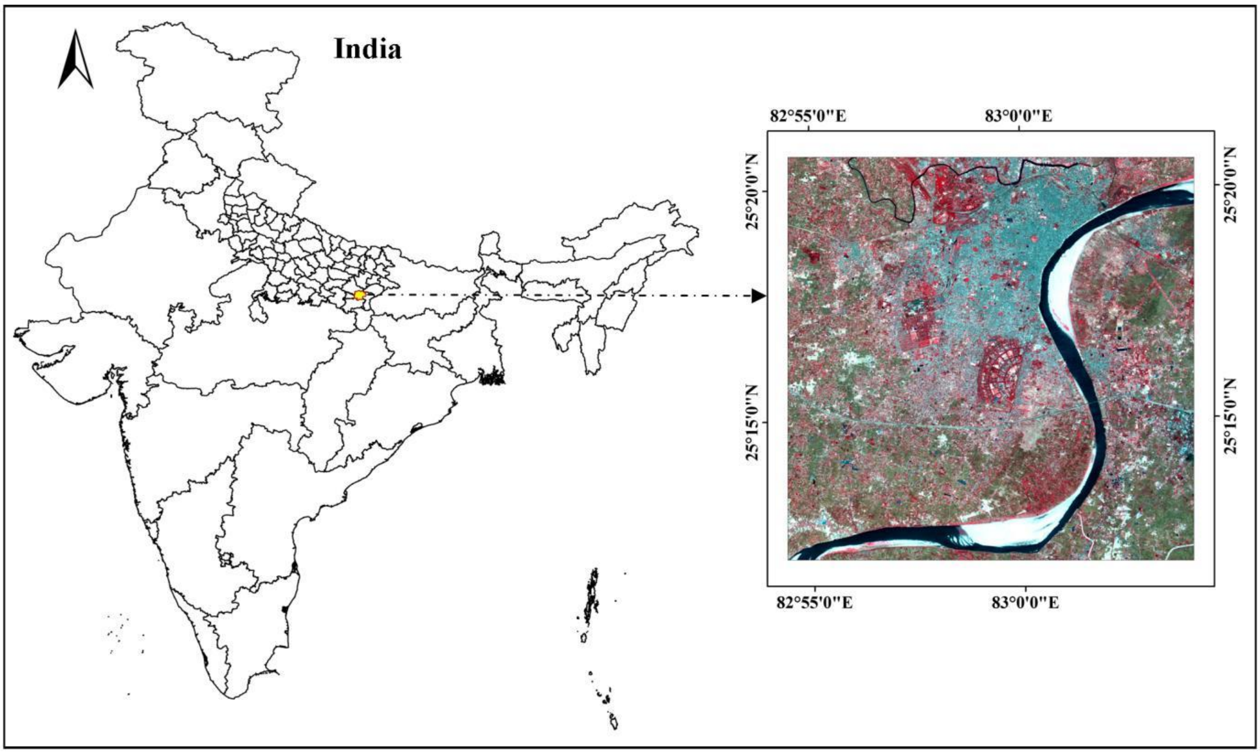

Fig. 1: Location of study area as viewed on IRS-LISS IV image

Materials and Methodology

Remote sensing images from three different sensors having a range of spatial resolutions were used in this study. To perform LULC classification, LISS IV with 5.8 m, Landsat 8-OLI with 30 m and AWiFS with 56 m spatial resolution images acquired on 6 April, 2013, 15 April, 2013 and 10 May, 2013 respectively are used. The ground truth information is also collected with the help of the Global Positioning System (GPS) and high resolution Google earth images. The characteristics of the datasets are presented in Table 1 and images are shown in Figures 2 (a), (b) and (c) respectively.

Table 1: Specifications of datasets used in this study

Satellite-Sensor	Bands	Spectral Resolution (µm)	Spatial Resolution (m)
Resourcesat-2 Linear Imaging Self Scanning (LISS IV)	B 2-Green	0.52-0.59	5.8
	B 3-Red	0.62-0.68	5.8
	B 4-NIR	0.77-0.86	5.8
Landsat-8 Operational Land Imager- Thermal Infrared Sensor (OLI-TIRS)	B 1-Coastal aerosol	0.43-0.45	30
	B 2-Blue	0.45-0.51	30
	B 3-Green	0.53-0.59	30
	B 4-Red	0.64-0.67	30
	B 5-NIR	0.85-0.88	30
	B 6-SWIR 1	1.57-1.65	30
	B 7-SWIR 2	2.11-2.29	30
	B 8-Panchromatic	0.50-0.68	15
	B 9-Cirrus	1.36-1.38	30
	B 10-TIRS 1	10.60-11.19	100
	B 11-TIRS 2	11.50-12.51	100
Resourcesat-1 Advanced Wide Field Sensor (AWiFS)	B 2- Green	0.52-0.59	56
	B 3- Red	0.62-0.68	56
	B 4- NIR	0.77-0.86	56
	B 5- SWIR	1.55-1.70	56

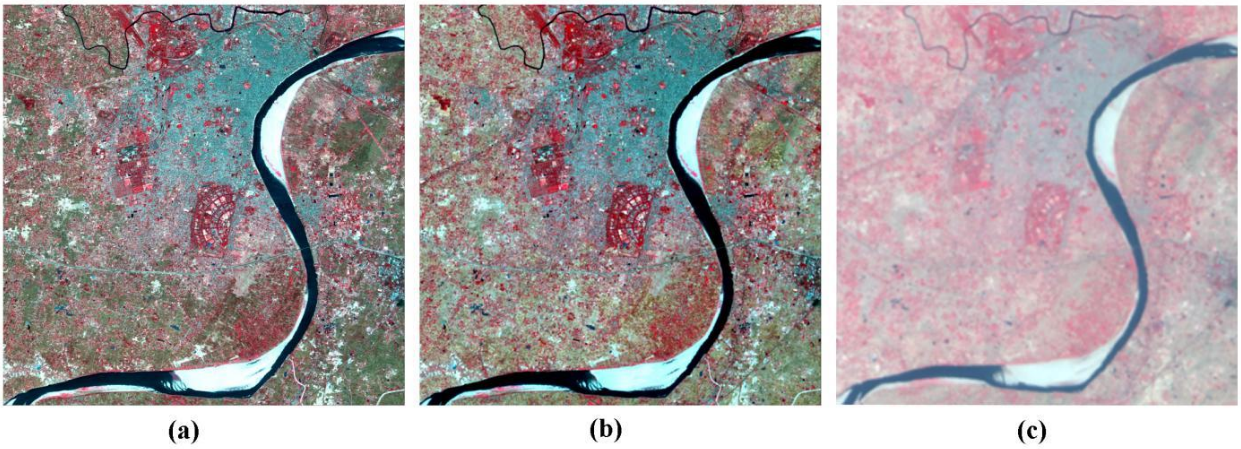

Fig. 2: Data sets in false colour composite (FCC) (a) LISS IV (b) Landsat 8-OLI (c) AWiFS

Image pre-processing

The processing and interpretation of multi-resolution images is performed by using ENVI (v5.1) image processing software. The images are first imported into ENVI and the layer stacking option available in basic tools is used to generate false colour composite (FCC) for all the images. The areas of interest (AOI) are extracted by subsetting the images. It is essential to perform geometric correction to obtain spatially distributed LULC maps. The image-to-image registration procedure is used to co-register all the datasets. During image transformation, the first-degree polynomial equation and nearest neighbour resampling method is used. The images are in the Universal Transverse Mercator (UTM) coordinate system (Zone 44, North), with World Geodetic System (WGS) 1984 datum. Only 9 bands of OLI sensor of Landsat-8 satellite are used in this study. The FCCs are preferred to create training samples for classification and analysis purpose.

Class separability analysis

A statistical measure named transformed divergence (TD) is used for inter-class separability analysis (Swain and Davis, 1978). It is a measure of statistical distance between two training samples (signatures). It may also be used to evaluate the separability between LULC classes prior to image classification. In several studies, the TD method is used to measure the separability between classes (Kumar et al., 2015; Mishra et al., 2014b). Its values vary from 0 to 2.0 and show how well the selected training samples are statistically separable from each other. Generally, a value greater than 1.9 means a good separability, while a value under 1.7 is regarded as poor separability between two classes. The equation below is used to conduct class separability analysis by using the TD method for all datasets:

$$TD_{ij} = 2000\left(1 - \exp\left(\frac{-D_{ij}}{8}\right)\right) \quad (1)$$

Here, D_{ij}= divergence between two signatures and it can be calculated by:

$$D_{ij} = \frac{1}{2}\operatorname{tr}\left((C_i - C_j)(C_i^{-1} - C_j^{-1})\right) + \frac{1}{2}\operatorname{tr}\left((C_i^{-1} - C_j^{-1})(\mu_i - \mu_j)(\mu_i - \mu_j)^T\right)$$

Where, i and j = the two signatures (classes) being compared, C_i = The covariance matrix of signature I, μ_i = The mean vector of signature I, tr = the trace function which calculates the sum of the elements on the main diagonal, T = the transpose of the matrix.

LULC classification

MLC is the most widely used supervised classification technique based on the likelihood of a pixel belonging to a specific class (Jensen, 2005). It is a parametric statistical approach that involves the normal distribution of class signatures. MLC is a pixel based technique relying on a multivariate probability density function of classes (Richards and Jia, 2003). This technique uses training samples or class signatures apprehended directly from the image to be classified. The probability of a pixel belonging to one of the classes is computed. Then, a particular class is assigned to the pixel with maximum probability. The equation used for MLC is given as:

$$D = \ln(a_c) - [0.5\ln(|Cov_c|)] - [0.5(X - M_c)]T(Cov_c^{-1})(X - M_c)] \quad (2)$$

Where, D = weighted distance, c = particular class, X = measurement vector of the candidate pixel, M_c= mean vector of the sample of class c, a_c = percent probability that any candidate pixel is a member of class c, Cov_c= covariance matrix of the pixels in the sample of class c, $|Cov_c|$ = determinant of Cov_c, Cov_c^{-1} = inverse of Cov_c, ln = natural logarithm function and T = transposition function.

Accuracy assessment of LULC classification results

The LULC classification results are evaluated to test the validity and dependability of the produced classified maps. The classification results are assessed by computing the overall accuracy (OA), user's accuracy (UA), producer's accuracy (PA), and Kappa coefficient (Kc) (Congalton and Green, 1999). It is not convenient to test each and every pixel of classified maps. So, a set of reference pixels or testing samples are collected with the help of field visits and Google earth images. The OA, PA, UA and Kc are computed using equations as (3), (4), (5) and (6) respectively as follows:

$$OA = \frac{1}{N}\sum_{i=1}^{r} n_{ii} \quad (3), \qquad PA = \frac{n_{ii}}{n_{icol}} \quad (4), \qquad UA = \frac{n_{ii}}{n_{irow}} \quad (5),$$

$$K_c = N\sum_{i=1}^{r} n_{ii} - \sum_{i=1}^{r}\frac{n_{icol}n_{irow}}{N^2} - \sum_{i=1}^{r} n_{icol}n_{irow} \quad (6)$$

Results and Disscusions

After collecting training samples of each LULC class, LISS IV, Landsat 8-OLI and AWiFS images are classified using supervised MLC. Each image is classified into seven major LULC classes like agricultural land, dense vegetation, sparse vegetation, fallow land, built up, water bodies and sand. The TD values are estimated for all LULC class pairs under the present study. The highest TD values are found for LISS IV image followed by Landsat 8-OLI and AWiFS images. The TD value greater than 1.9 indicates better separability between two LULC classes. The detailed information of separability analysis using TD method for all the datasets are given in Table 2.

The MLC based LULC maps of LISS IV, Landsat 8-OLI and AWiFS images are shown in Figures 3, 4 and 5. Accuracy assessment is the qualitative assessment of classification results based on remote sensing images. It is helpful in evaluating the classification techniques and determining the level of error that might be contributed by the image. The accuracy assessment results for MLC based classified maps of LISS IV with 5.8 m, Landsat 8-OLI with 30 m and AWiFS with 56 m spatial resolutions are shown in Table 3. The achieved OA for classified products from LISS IV, Landsat 8-OLI and AWiFS images are 83.28%, 77.93% and 74.61% respectively, with Kc of 0.805, 0.742 and 0.705 respectively. The area distribution of LULC classes for the datasets is presented in Table 4.

Table 2: Separability analysis between LULC classes using TD distance method

LULC Class pairs	TD values		
	LISS IV	Landsat 8-OLI	AWiFS
Agricultural land-Dense vegetation	1.99	1.98	1.99
Agricultural land-Open vegetation	1.94	1.75	1.60
Agricultural land-Fallow land	1.99	1.98	1.99
Agricultural land-Built up	1.99	1.99	1.99
Agricultural land-Water bodies	2.00	2.00	1.99
Agricultural land-Sand	2.00	2.00	2.00
Dense vegetation-Open vegetation	1.99	1.92	1.95
Dense vegetation-Fallow land	2.00	2.00	1.99
Dense vegetation-Built up	2.00	2.00	1.99
Dense vegetation-Water bodies	2.00	2.00	1.99
Dense vegetation-Sand	2.00	2.00	2.00
Open vegetation-Fallow land	1.99	1.99	1.89
Open vegetation-Built up	2.00	2.00	1.99
Open vegetation-Water bodies	2.00	2.00	1.99
Open vegetation-Sand	2.00	2.00	1.99
Fallow land-Built up	1.99	1.99	1.99
Fallow land-Water bodies	2.00	2.00	1.99
Fallow land-Sand	1.99	2.00	1.94
Built up-Water bodies	2.00	2.00	1.97
Built up-Sand	2.00	2.00	1.99
Water bodies-Sand	2.00	2.00	2.00

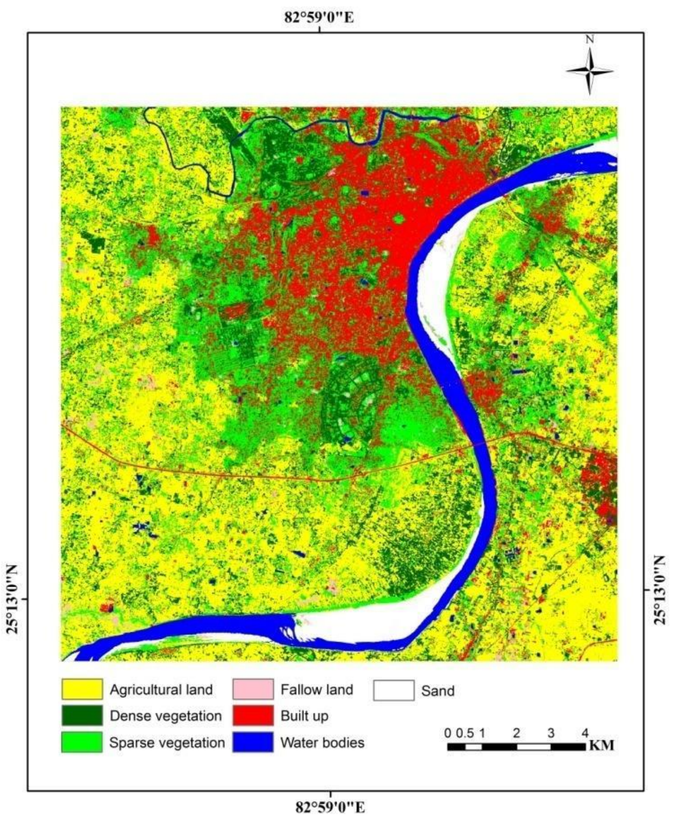

Fig. 3: MLC based LULC map of LISS IV image

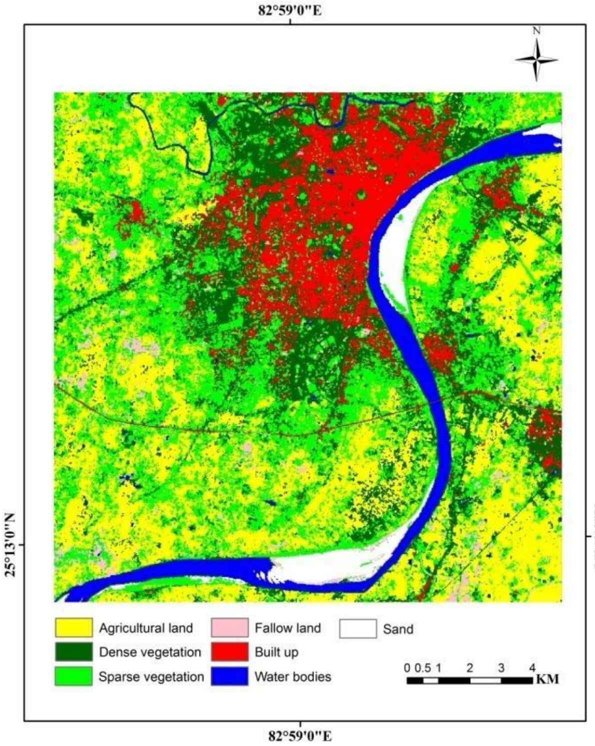

Fig.4: MLC based LULC map of Landsat 8-OLI image

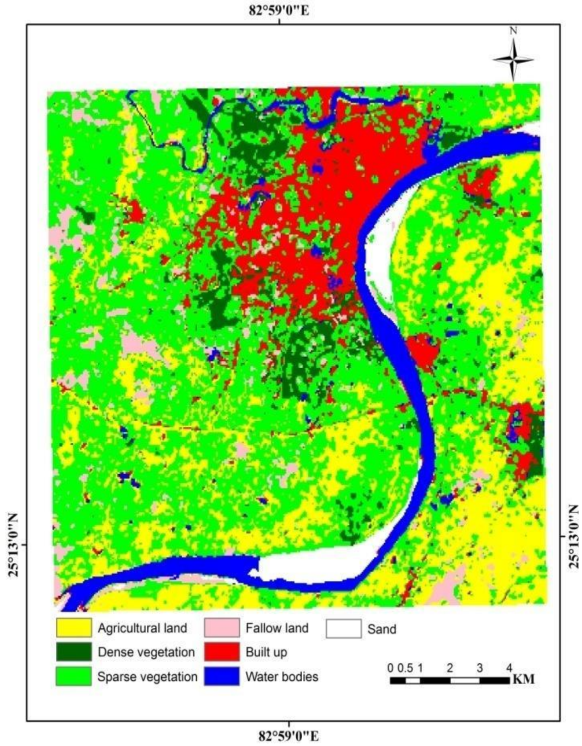

Fig. 5: MLC based LULC map of AWiFS image

Table 3: Accuracy assessment of LULC classification results

LULC classes	LISS IV		Landsat 8-OLI		AWiFS	
	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)
Agricultural land	80.86	79.34	75.76	74.69	72.78	72.56
Dense vegetation	82.80	85.98	78.78	81.40	77.58	79.64
Sparse vegetation	83.02	77.83	78.10	74.10	75.41	70.31
Fallow land	81.24	76.67	73.46	66.19	66.16	63.02
Built up	84.96	86.20	79.36	79.49	75.76	75.13
Water bodies	84.88	91.06	80.40	88.61	78.31	84.66
Sand	84.58	85.13	78.25	79.54	74.14	75.50
OA (%)	83.28		77.93		74.61	
Kc	0.805		0.742		0.705	

Table 4: Area distribution of LULC using LISS IV, Landsat 8-OLI and AWiFS images

LULC classes	LISS IV		Landsat 8-OLI		AWiFS	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Agricultural land	10390	39.81	7947	30.45	6257	23.98
Dense vegetation	4032	15.45	5035	19.29	1384	5.30
Sparse vegetation	5237	20.07	7803	29.90	11490	44.03
Fallow land	412	1.58	605	2.32	1179	4.52
Built up	3819	14.63	2857	10.95	3235	12.40
Water bodies	1312	5.03	1222	4.68	1822	6.98
Sand	896	3.43	629	2.41	731	2.80
Total Area	26098	100.00	26098	100.00	26098	100.00

The PA is a calculation of omission error while UA is a measure of commission error of an individual LULC class. The classified result derived by LISS IV image indicates that PA varied from 80.86% for agricultural land to 84.96% for built up, while, UA varied from 76.67% for fallow land to 91.06% for water bodies. The classified result derived by Landsat 8-OLI image indicates that PA varied from

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73.46% for fallow land to 80.40 % for water bodies, while, UA ranged from 66.19% for fallow land to 88.61% for water bodies. The classified result derived by using AWiFS image indicates that PA varied from 66.16% for fallow land to 78.31% for water bodies, while, UA varied from 63.02% for fallow land to 84.66% for water bodies.

Furthermore, the effects of spatial resolution are also observed on the interpretation and degree of information for classified images. Figure 6 shows the degree of interpretation of different LULC classes in various spatial resolutions, by visual comparison of LULC thematic maps at two different sites. The lower UA values of fallow land are found for Landsat 8-OLI and AWiFS images, as compared to that found for LISS IV image, which is higher. It reveals that the interpretation and identification of fallow land is easier by using the high spatial resolution image of LISS IV than the moderate and coarse spatial resolution images of Lamdsat8-OLI and AWiFS.

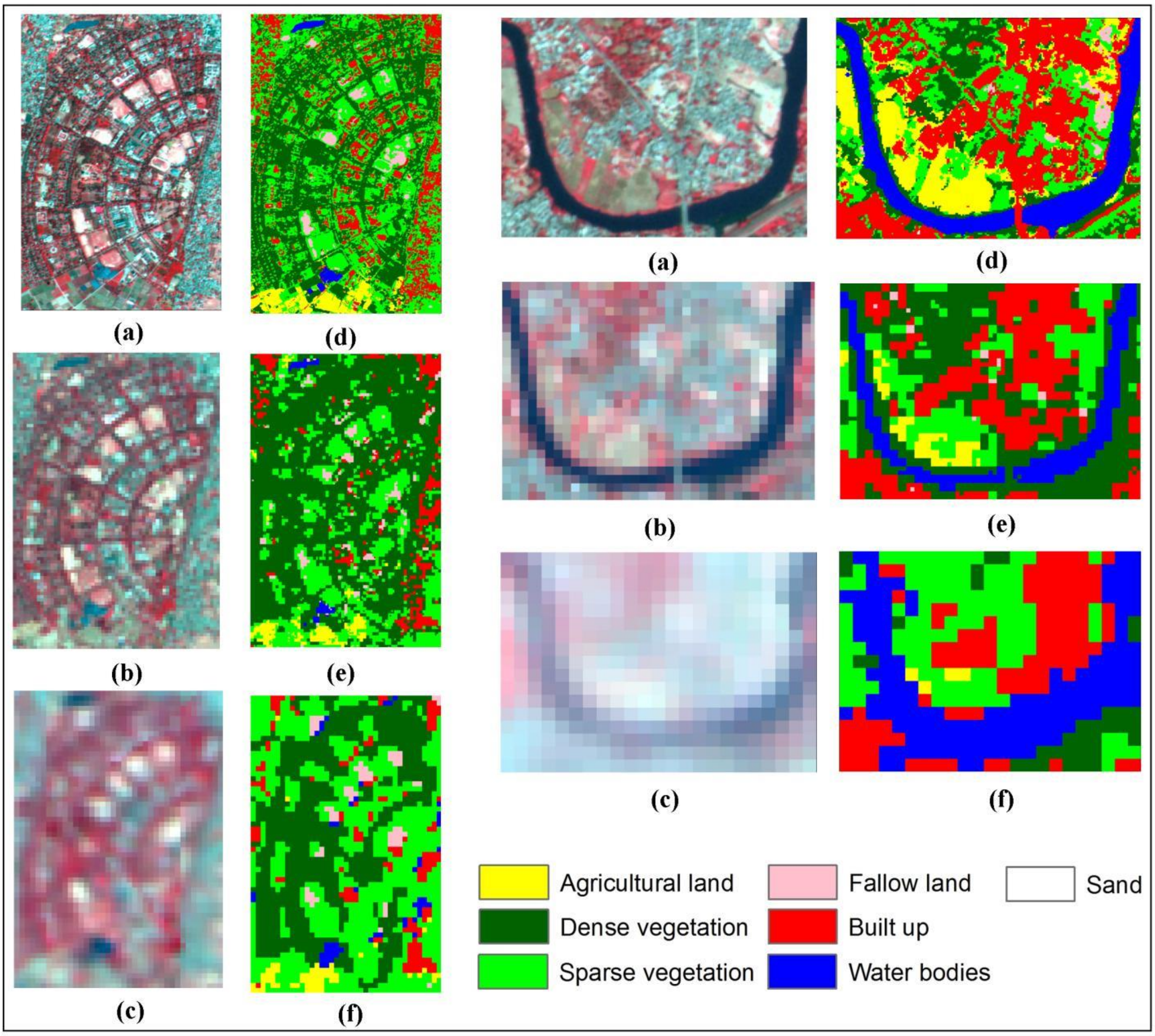

Fig. 6: Visual comparison at two selected sites: (a) LISS IV Image; (b) Landsat 8-OLI image; (c) AWiFS image and (d) MLC based classified image of LISS IV; (e) MLC based classified image of Landsat 8-OLI; (f) MLC based classified image of AWiFS

Table 4 also indicates that there is a larger difference in area calculations of agricultural land and sparse vegetation for Landsat 8-OLI and AWiFS images than that of LISS IV image. One explanation might be the misclassification between agricultural land and sparse vegetation for multi resolution satellite images. Furthermore, the LISS IV image with high spatial resolution overcomes the influence of boundary pixels and reduces the mixed pixel problems in LULC classification. It is very helpful in achieving higher OA than that of coarser spatial resolution images. The Landsat 8-OLI and AWiFS images are not found appropriate for clearly selecting the training samples, as compared to the LISS IV image. Therefore, it is observed that LISS IV image performed significantly better in comparison to Landsat 8-OLI and AWiFS images.

Conclusions

The present study evaluates the performance of MLC for LULC classification using multi-resolution remote sensing images. In addition, the effects of spatial resolution on LULC classification accuracy are examined. It is observed that with the increase in spatial resolution, OA and Kc also increased. There is a significant increase in classification accuracy from 56 m to 5.8 m, with the moderate increase for the intermediate spatial resolution of 30 m. This study illustrates the potential of finer spatial resolution image to improve the thematic accuracy of LULC classification significantly, particularly for spectrally complex classes. The finer spatial resolution image also reduces the mixed-pixel problem to a great extent and it is found to provide more detailed information on LULC structures. Therefore, it is concluded that spatial resolution plays a vital role and influences the classification accuracy and details.

References

Borak, J.S., Strahler, A.H. (1999). Feature selection and land cover classification of a MODIS-Like data set for a semiarid environment, International Journal of Remote Sensing, 20, 5, pp. 919–938.

Chen, D., Stow, D. A., Gong, P. (2004). Examining the effect of spatial resolution and texture window size on classification accuracy: an urban environment case, International Journal of Remote Sensing, 25, pp. 1–16, 2004.

Clark, D.B., Read, J.M., Clark, M.L., Cruz, A.M., Dotti, M.F., Clark, D.A. (2004). Application of 1-m and 4-m resolution satellite data to ecological studies of tropical rain forests, Ecological Applications, 14, pp. 61-74.

Congalton, R.G., Green, K. (1999). Assessing the accuracy of remotely sensed data: principles and practices. CRC/Lewis Press, Boca Raton.

Foody, G.M., Campbell, N.A., Trodd, N.M., Wood, T.F. (1992). Derivation and applications of probabilistic measures of class membership from the maximum-likelihood classification, Photogrammetric engineering and remote sensing, 58, pp. 1335–1341.

Frank, T.D., Tweddale, S.A. (2006). The effect of spatial resolution on measurement of vegetation cover in three Mojave Desert shrub communities. Journal of arid environments, 67, pp. 88-99.

Jensen, J. (2005). Introductory digital image processing: A remote sensing perspective (3rd edition). Upper Saddle River, NJ: Prentice Hall.

Kumar, P., Gupta, D.K., Mishra, V.N., Prasad, R. (2015). Comparison of support vector machine, artificial neural network and spectral angle mapper algorithms for crop classification using LISS IV data, International Journal of Remote Sensing, 36, 6, pp. 1604–1617.

Kumar, P., Prasad, R., Choudhary, A., Mishra, V.N., Gupta, D.K., Srivastava, P.K. (2016). A statistical significance of differences in classification accuracy of crop types using different classification algorithms, Geocarto International, pp. 1-19. DOI: 10.1080/10106049.2015.1132483.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C. et al. (2001). The causes of land-use and land-cover change: moving beyond the myths, Global Environmental Change, 11, 4, pp. 261–269.

Lu, D., Weng, Q. (2007). A survey of image classification methods and techniques for improving classification performance, International Journal of Remote Sensing, 28, 5, pp. 823-870.

Markham, B.L., Townshend, J.R.G. (1981). Land cover classification accuracy as a function of sensor spatial resolution, XV International Symposium on Remote Sensing of Environment, Ann Arbor.

Mishra, V.N., Rai, P.K. (2016). A remote sensing aided multi-layer perceptron-Markov chain analysis for land use and land cover change prediction in Patna district (Bihar), India, Arabian Journal of Geosciences, 9, 4, DOI: 10.1007/s12517-015-2138-3.

Mishra, V.N., Rai, P.K., Mohan, K. (2014a). Prediction of land use changes based on land change modeler (LCM) using remote sensing: a case study of Muzaffarpur (Bihar), India. Journal of the Geographical Institute Jovan Cvijic, 64, pp. 111–127.

Mishra, V.N., Kumar, P., Gupta, D.K., Prasad, R. (2014b). Classification of various land features using RISAT-1 dual polarimetric data, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-8: 833-837.

Moody, A., Woodcock, C.E. (1994). Scale-dependent errors in the estimation of land-cover proportions: Implications for global land-cover datasets, Photogrammetric engineering and remote sensing, 60, 5, pp. 585-596.

Richards, J. A., Jia, X. (2003). Remote sensing digital image analysis (4th edition). Heidelberg, Germany: Springer.

Forum geografic. Studii și cercetări de geografie și protecția mediului
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http://dx.doi.org/10.5775/fg.2016.137.i

Salberg, B., Jenssen, R. (2012). Land-cover classification of partly missing data using support vector machines. International Journal of Remote Sensing, 33, pp. 4471-4481.
Singh, R. P., Sridhar, V. N., Dadhwal, V. K., Navalgund, R. R., Singh, K. P. (2002). Comparative evaluation of Indian remote sensing multi-spectral sensors data for crop classification. Geocarto International, 17, 2, pp. 7-12.
Swain P.H., Davis, S.M. (1978). Remote Sensing: the Quantitative Approach. New York: McGraw-Hill.
Woodcock, C.E., Strahler, A.H. (1987). The factor of scale in remote sensing. Remote sensing of Environment, 21, 3, pp. 311-332.

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Modelling of Ecosystem Indicators in Geographic Information System Environment (A Case Study of the Sweet Chestnut Forest, Belasitsa Mountain, Bulgaria)

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Abstract

The aim of the present research is to show the possibilities of applying computer technology in ecosystem investigations. The object of the research is the chestnut forests located on the Northern slopes of Belasitsa mountain (Southwest Bulgaria). Three study areas are determined for detailed investigation of structural and functional parameters (indicators) of chestnut ecosystems. These areas are located in forests with different ages (45-120 years old), different forestry management and different state. Ecosystem indicators are modeled on the base of field investigation and available published data, and the assessment of the forest state is done by spatial interpolation (inverse distance weighted) in geographic information system (GIS) environment (ArcGIS). Resulting model values are verified and validated by field investigations. An output layer showing the state of the chestnut forest in the investigated region is generated on the base of the raster surfaces, result of the interpolation and application of map algebra. Also weight coefficients to the assessment values of the different indicators are used which makes the spatial analysis more correct. Created mapping model shows significant matching areas of forests in poor condition and forests in good conditions compared to the relevant determined on the base of forest management plan. The research confirms the advantages of GIS technology in processing large and varied data for assessing the impact of many factors on forest vegetation.

Keywords: *ecosystem indicators, chestnut, geographic information system, interpolation, modelling*

Rezumat. Modelarea în mediul Sistemelor Informaţionale Geografice a indicatorilor ecosistemici (Studiu de caz Pădurea Castanilor Dulci, Munţii Belasitsa, Bulgaria)

Scopul prezentei cercetări este de a arăta posibilitățile aplicării tehnicii de calcul în cadrul investigațiilor ecosistemului. Obiectul cercetării în constituie pădurile de castan situate pe versanţii nordici ai Munţilor Belasitsa (sud-vestul Bulgariei). Trei zone de studiu au fost alese pentru investigarea detaliată a parametrilor structurali și funcționali (indicatori) a ecosistemelor de castan. Aceste zone sunt situate în păduri cu vârste diferite (în vârstă de 45-120 ani), cu modalităţi diferite de gestionare a pădurilor și în diferite stări. Indicatorii ecosistemici sunt modelaţi pe baza investigațiilor de teren și a datelor publicate disponibile, iar evaluarea stării pădurilor se realizează prin interpolare spațială (distanța ponderată inversă) în sistemul informaţional geografic (ArcGIS). Valorile rezultate ale modelului sunt verificate și validate prin investigații pe teren. Un strat de ieșire care arată starea pădurii de castan din regiunea investigată este generat pe baza suprafețelor raster, ca rezultat al interpolarii și aplicării cartografierii algebrice. De asemenea, sunt utilizaţi coeficienții de greutate la valorile de evaluare ale diferiților indicatori, ceea ce face ca analiza spațială să fie mai corectă. Modelul de cartografiere creat prezintă o potrivire semnificativă a zonelor cu păduri în stare proastă și păduri în stare bună, comparativ cu cele determinate pe baza planului de gestionare a pădurilor. Cercetarea confirmă avantajele tehnologiei SIG în procesarea de date mari și variate pentru evaluarea impactului multor factori asupra vegetației forestiere.

Cuvinte-cheie: *indicatori ecosistemici, castan, sistem informaţional geografic, interpolare, modelare*

Introduction

Vegetation and particularly forest has a significant importance for forming and functioning of natural complexes and it also has an important role in economic and social spheres. Sustainable development of the forests is a guarantee of biodiversity conservation and in this relation scarcity of forest resources, their vulnerability and slow recovery require consecutive ecosystem researches and extension of the scope of the research methods. The impact of many factors on vegetation requires the use of a significant quantity of diverse information in researches, and this can cause difficulties in the collection and management of information. The problems are related to difficult accessibility to the study areas and insufficient possibilities for data collection in some cases, as well as to difficulties in receiving, processing and analysing all necessary data, and also to the lack of enough reliable data, poor compatibility between data from different sources, and week coordination between institutions responsible for different data types. These problems could be solved in considerable scope by use of GIS and remote sensing which provide very good opportunities in collection, organisation, coordination and analysis of spatial data.

The development of information technologies determines their increasingly wide use in the study of natural components, in particularly of vegetation. The need of research and management of forest resources on large areas, characterised by a variety of components, and the analysis of significant amount of spatial information set the beginning of the development of GIS technology. The first GIS is developed by Roger Tomlinson for the aim of forestry in Canada in 1962 but stronger development of the technology and extending the scope of the applications is observed since 80s of the 20th century. The question about modelling of biocomponent indicators and areal presentation of point data is discussed in many publications. Lyon et al (1987) developed cartographic model of fauna habitats on the base of digital spatial information and data of available habitat models. GIS and remote sensing are used by Ryan & Shreier (1989), Joy & Klinkenberg (1994), Coulombe & Lowell (1995), Lowell (1989), Perez et al. (2006) as methods of investigating and modelling of different vegetation types and ecological indicators. Concerning the vegetation, local conditions (climatic, soil and topographic) have to be taken into account and multifactor analysis to be applied for better results of spatial modelling of point data (Store &. Jokimaki, 2003, Franklin et al., 1997).

The application of spatial analyses in GIS environment for modelling ecosystem indicators and assessment of ecological state of forest vegetation is considered in the current article. Fifty one indicators about soil conditions, structural and functional characteristics of vegetation are evaluated. The method is applied to sweet chestnut forests. A spatial interpolation of the values of those indicators is done and a map presenting the total evaluation is created using the built GIS database.

The interest to the research of the sweet chestnut forests (*Castaneasativa* Mill.) is determined by the economic and public interest to these forests, because of the quality of wood and delicious fruits, which are used in the food and pharmaceutical industries (Amorini et al., 2000; Bratanova–Doncheva et al., 2002; Bounous, 2007; Dimitrova, 2008). The sweet chestnut forests are considered to be very appropriate for implementing the idea of creating a multifunctional forest. According to the general assessment of the experts, degradation processes occur in chestnut forest due to ecological (Perlerou, Diamandis, 2007; Vettraino et al., 2007) and social-economic reasons (Conedera et al., 2004). Because of that the habitats of *Castaneasativa* Mill. are subject of special protection and they are included in the CORINE system, code 41.9, and are in the list of the types of natural habitats which are of interest of the European community. Having regard to the Directive 92/43/EEC their protection requires determining of "specially protected areas", type 9260 – sweet chestnut forests (Bratanova-Doncheva, 2003). Due to the limited distribution of the chestnut species and their communities in Bulgaria, there is a danger of their loss in the country flora and vegetation.

The above mentioned situation requires development of researches regarding the assessment and protection of phytodiversity in the chestnut forests, as well as complex researches and assessment of the ecological state of the forests with the aim of their sustainable use.

Problems related to chestnut have been considered in different direction. The investigations are done mainly about chestnut fruits, diseases, pests, selection and introduction (Petrov, 1982; Petkov, Rosnev, 2002; Lauteri et al, 2009). Questions about assessment and protection of phytodiversity and its changes in chestnut forests also have been discussed. Phytocoenological researches of relatively well preserved chestnut communities in Belasitsa mountain, of their composition and structure, have been done (Dimitrova et al., 2003; Tzonev et al., 2011) as well as detailed investigations of the biomass and production of chestnut phytocoenosis (Dimitrova, 2008; Manetti et al., 2001). Researches clarifying functioning of chestnut ecosystems in Bulgaria started in the last years. They begin with the project "Assessment of the dynamic of structural and functional parameters of chestnut coenosis (*Castaneasativa* Mill.) – Belasitsa in the conditions of global climate change" (CASTBul), 2003" (Bratanova-Doncheva at al., 2005) and continue with the project "State and prospects of the *Castanea sativa* population in Belasitsa mountain: climate change adaptation; maintenance of biodiversity and sustainable ecosystem management. BG 0031 EEA (Zlatanov et al., 2011).

Research area. Subject of investigation

The subject of research is the chestnut formation (*Castaneeta sativae*) located on the northern slopes of Belasitsa mountain, the most south-western part of Bulgaria (Fig. 1). It takes an area of 1460 ha between 250 and 900 m altitude. The formation extends from east to west between villages Razhdak and Gabrene and the total length of the forest belt is about 30 km. The soils in the area are Cambisols and brown. The climate is Continental-Mediterranean in the food of the mountain and mountainous in the high parts. The sweet chestnut has limited distribution in Bulgaria but it forms unique ecosystems and it is very valuable tree species, therefore it is needed to protect the chestnut forests. They are also a livelihood for local population.

Three sampling areas (SA) are determined for a detailed study of structural and functional parameters of chestnut ecosystems. They are situated in forests different by age (45-120 years old), state and forest management as follow: old forests (100-120 years old) in poor state and without sylvicultural activities (SA2); and young forests (less than 45 years old), where sylvicultural activities are conducted in different intensity (SA1 and SA3). These sampling areas are of size 0.20 – 0.25ha. The parameters of the areas are given in Table 1.

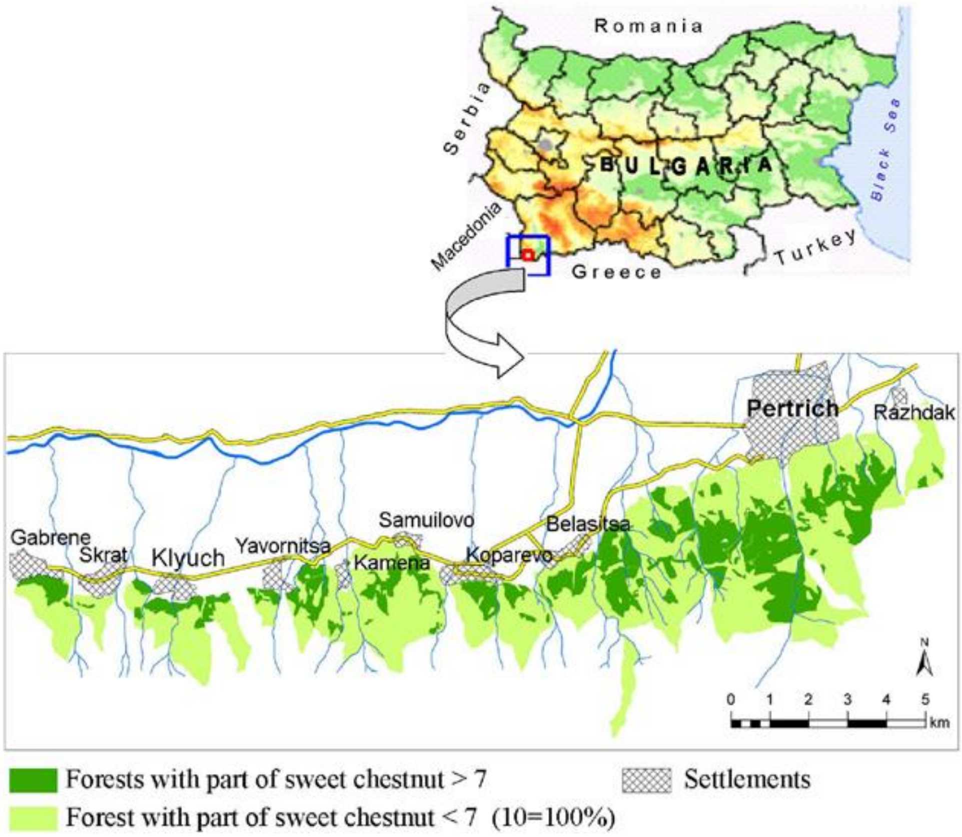

Fig. 1: Distribution of sweet chestnut formation

Table 1: Parameters of sampling areas

Parameters	SA1	SA2	SA3
Area (ha)	0.25	0.20	0.20
Altitude (m)	750	650	500
Slope (degree)	17	28	23
Exposition	North-east	East	North-west
Part of the slope	high	low	high
Soil	Dystric Cambisols	Eutric Cambisols	Hromic Luvisol, Mollic
Mechanical composition of the soil	deep, rocky, light	medium, vary rocky with heavier mechanical composition	medium deep, rocky, leached
Composition of the tree layer, site index	Chestnut 10* 2 sublayers, site index II**	Chestnut 9, beech1 3 sublayers, site index IV-V	Chestnut 10 2 sublayers, site indexs I
Origin	natural	natural	natural
Age	45 years	100 - 120years	45 years
Total canopy (1=100%)	0.7	0.8	0.5
Association	Castanetum – Mixoherbosum	Castanetum – Mixoherbosum	Castanetum – Mixoherbosum
Sylvicultural activities	Cuttings 30 years ago; sanitary fellings	no	Cuttings 30 years ago; selective felling 15 years ago

* - participation of the tree species in the tree layer (10=100%)
** - productivity class – lowest V– highest I

Sampling areas are chosen to be in association *Castanetum – Mixoherbosum*, because this association is the most widespread in the chestnut formation.

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Data and research methodology

Modelling of the ecosystem indicators for the whole investigated area is done using the data of field work in the three sampling areas and also on the base of the data taken of the Forest Management Plan of State forestry "Petrich". The initial data are entered in ArcGIS environment as graphic and attribute information. The graphical information is organised in different layers as follow:

- forest with taxation characteristics – polygon layer;
- roads, paths, watersheds and borders of settlements – line layer;
- rivers – line layer;
- plant associations – polygon layers.

The attribute information includes the data available in the forest management plan and data about main structural and functional indicators (features) of the ecosystem (Table 2).

The digital forest model of the Forest Management Plan of State forestry "Petrich" is used in the research for building the GIS database. Rivers and relief are digitised using topographic maps in scale 1:25000. Layer of plant associations is created on the base of the data taken during the field investigation.

The modelling of the indicators of forest ecosystems is done on the base of the information from the 3 sampling areas using spatial analysis and inverse distance weighted (IDW) interpolation. Building of the assessment model is done in the following sequences:

1. Determining of chestnut forest areas that are similar enough to one of the three sampling areas. On the base of the forestry parameters we accept that these areas are the same or at least similar, in their general parameters, to one of the detailed studied sampling areas.
2. Building attribute database for the three sampling areas (SA1, SA2, SA3) using the results of the field research and data of other research for these areas. Fixing the data of the sampling areas to the determined similar areas and combining them in one layer of ecosystem indicators.
3. Creating particular layers and adding the field data of the sampling areas to the geometric objects at section level as follow:

- microbiological characteristics (species, indices);
- intensity of micro- and macro-elements cycles;
- stocks of fall off and litter;
- flora parameters;
- phytomass stocks and productivity of grass, shrub and tree layers;
- content of macro- and micro- elements in phytomass and soils;
- soils (physical properties and chemical composition);
- damages caused by insects (species composition, insect level attack);
- coefficient of damage and degree of defoliation;
- soil nematodes (composition, structure).

4. Determining the centroid of each polygon in the forest sections layer. This layer is used for spatial IDW interpolation to receive the spatial distribution of forest indicators (Table 2).
5. Filling the data gaps for the areas where the field researches have not been done by calculating the model values of the above mentioned forest indicators using IDW interpolation. At this interpolation method we accept that the dependence between closely distributed points is stronger and decrease with increasing the distance. Therefore, regarding the nature of the interpolated data, this method is chosen as the most appropriate for interpolation in this case.
6. Model verification.
7. Reclassification of the calculated raster grids, in scales depending on the values of each indicator and its importance for the state of the chestnut forest.
8. Modelling of the forest state by spatial summing of the indicators in pixels of 20 m. The output layer is calculated by following map algebra $S = \alpha F1 + \beta F2 + \gamma F3 + \ldots + \sigma F51$, where F is the assessment of the corresponding indicator (Table 2), $\alpha, \beta, \ldots \sigma$ - weight coefficient showing the importance of this indicator.

The above mentioned activities for modelling the ecosystem indicators in GIS environment and the assessment of the state of the chestnut forests in the investigated forest belt in Belasitsa mountain are made according to the following structural scheme (Fig. 2):

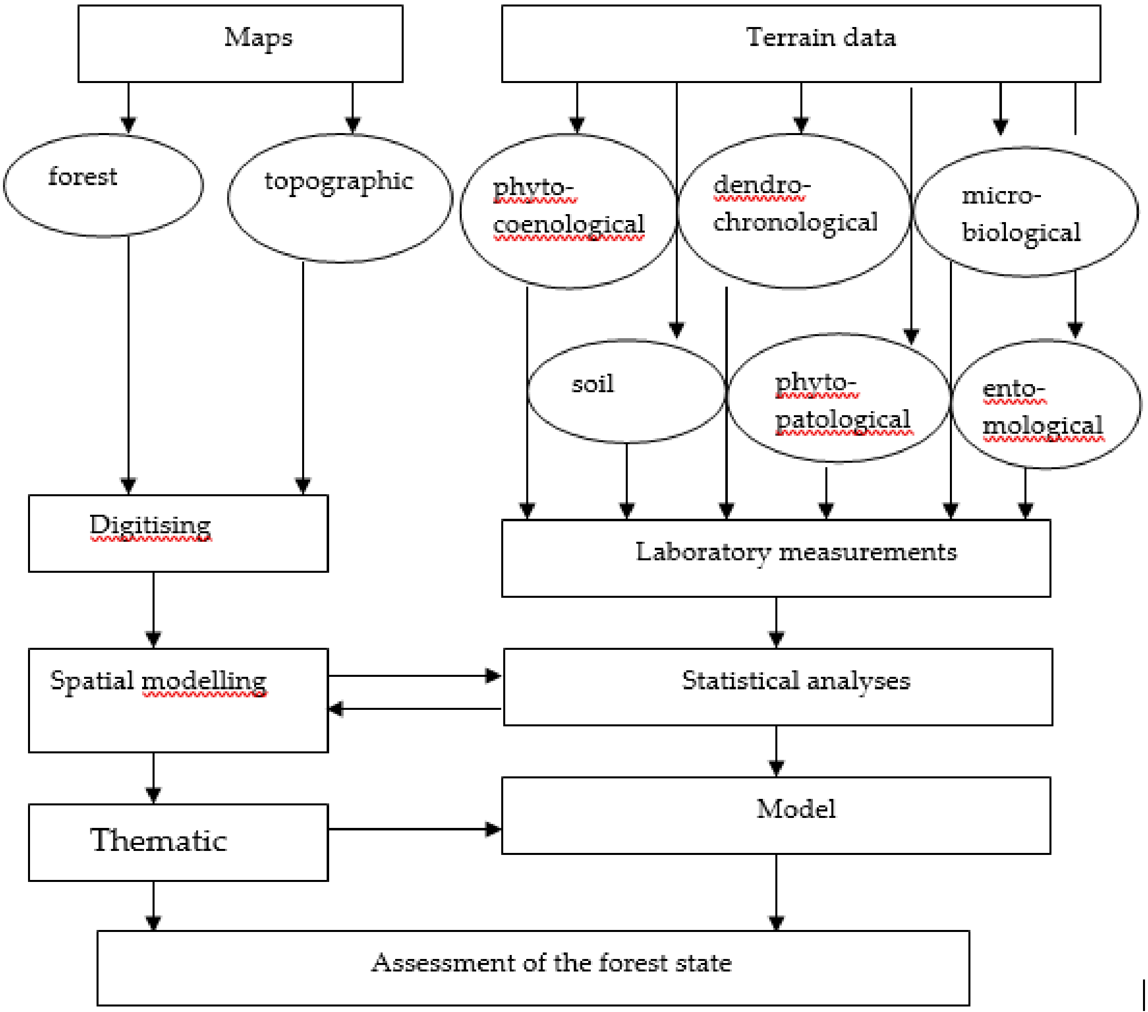

Fig. 2: Structural scheme of the data used and of the main research activities

Application of GIS technology in modelling the ecosystem indicators and results of the research

The GIS database built during the current research includes all collected available data about the chestnut ecosystems in Belasitsa mountain. The approach of neuron networks and genetic algorithms (Goldberg 1989; Varbanov et al., 2005) are used to assess the main factors (indicators) which characterise the sampling areas and simultaneously distinguish them in the best way. Fifty-one indictors which describe structural-functional state of the ecosystems are chosen (Table 2). A weight coefficient (an integer ranging between 0 and 1) is given to each indicator. This coefficient corresponds to the rate in which the indicator influences the ecosystem state. These weights enhance the impact of some of the 51 indicators (through its high value) and weaken the influence of other (through lower values near to 0) which helps to focus further research on important for ecosystem state factors and relationships (Dimitrova, 2008). The structural-functional indicators which have a greater importance for the state of the chestnut forests are determined on the base of statistical analyses and expert's evaluation. They are inputted in GIS environment and are the base for building the GIS model. Areas similar to each one of the sampling areas have been determined of all chestnut forests in Belasitsa mountain. It is accepted that these areas have the same or similar characteristics with the sampling areas (Fig. 3). Forest with participation of chestnut 7 (number of the tree species in a given area, 10 = 100%) or greater than 7, age less than 70 years, altitude between 500 and 900 m, and in poor state are accepted as similar to SA1. Forests with participation of chestnut 7 or greater than 7, age 100-200 years, altitude between 300 and 650 m, and in poor or average state are accepted as similar to SA2. And forest with participation of chestnut 7 or greater than 7, age less than 60 years and in good state, without limits in particular altitude belt are accepted as similar to SA3.

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Table 2: Structural and functional ecosystem indicators of chestnut belt in Belasitsa mountain

Indicator		SA 1		SA 2		SA 3	
		characteristic/ indicator value	assessment*	characteristic/ indicator value	assessment*	characteristic/ indicator value	assessment*
Soil type	F1	Dystric Cambisols	2	Eutric Cambisols	2	Hromic Luvisol, Mollic	2
Soil saturation coefficient, %	F2	27,401	3	40,328	3	46,248	3
Hygroscopic humidity, horizon Ah, %	F3	2,18	3	2,69	3	2,45	3
Humidity of permanent wilting, horizon Ah, %	F 4	5,64	2	5,48	2	5,96	2
pH(H2O), horizon Ah	F5	6,1	3	6,2	3	6,45	3
Phosphorus,horizon Ah, mg/100g	F6	84	3	86	3	77	3
Humus, horizon Ah, %	F7	5,27	3	5,48	3	5,92	3
Carbon, horizon Ah, %	F8	3,05	3	3,18	3	3,43	3
Total nitrogen, horizon Ah, %	F9	0,16	3	0,19	3	0,18	3
Potassium, horizon Ah, mg/100g	F10	206,1	3	206,1	3	173,5	3
Total calcium, horizon Ah, mg/kg	F11	419	3	787	3	641	3
Total magnesium, horizon Ah, mg/kg	F12	711	3	537	3	433	3
Total sodium, horizon Ah, mg/kg	F13	151	3	121	3	99	3
Total iron, horizon Ah, mg/kg	F14	8300	3	7327	3	7351	3
Total manganese, horizon Ah, mg/kg	F15	613	3	1702	3	722	3
Total cooper, horizon Ah, mg/kg	F16	17,6	3	12,5	3	14,8	3
Total zinc, horizon Ah, mg/kg	F17	40,4	3	43,5	3	30,8	3
Total lead, horizon Ah, mg/kg	F18	14,9	3	29	3	16,1	3
Total cadmium, horizon Ah, mg/kg	F19	1,33	3	1,17	3	0,83	3
Average immobilisation mineralization index	F20	7,8	2	13,300	2	13,500	2
Average denitrifying, cells in 1 g absolutely dry sample(a.d.s.)	F21	20000	2	229000	1	76000	2
Species, number.	F22	78	2	116	2	102	2
Damage coefficient of the total tree layer, %	F29	49	1	24,62	1	55,58	1
Damage coefficient of the chestnut I sublayer, %	F30	-	-	62	1	-	
Damage coefficient of the chestnut II sublayer, %	F31	-	-	71	1	-	

Damage coefficient of the chestnut III sublayer, %	F32	-	-	54	1	-	
Loranthoseuropaeus L., number/ha	F33	395	1	290	1	16	2
Castanea sativa Mill. crown defoliation, avarege mark	F34	2	1	3	1	2	1
Regeneration, tree layer *Castaneasativa* Mill., n/m^2	F35	3,8	3	1,3	3	1	1
Nematodes in litter TNN, spec/100g	F 39	7672	2	7387	2	9040	2
Nematodes in litter B/F, ratio	F 40	2,16	2	2,24	2	11,41	2
Nematodes in soil TNN, spec/100g	F 41	186	2	356	2	320	2
Nematodes in soil B/F, ratio	F42	0,36	2	2,52	2	0,34	2
Insect level attack	F43	weak - average	1	average- strong	1	weak - average	1
Insect level attack in roots	F44	weak	2	weak	2	weak	2
Insect level attack in leaves	F45	weak	2	weak	2	weak	2
Insect level attack in stems	F46	weak	2	strong	1	weak	2
Insect level attack in young sprouts	F47	weak	2	weak	2	weak	2
Insect level attack in flower	F48	weak	2	weak	2	weak	2
Insect level attack in fruits	F49	weak	2	strong	1	weak	2
Association	F23	Castanetum - Mixoherbosum	2	Castanetum - Mixoherbosum	2	Castanetum - Mixoherbosum	2
Layers, number	F24	3	3	3	3	3	3
Tree layer, number sublayers	F25	2	2	3	2	2	2
Total number, number/ha	F26	1134	2	1985	1	556	2
Bush layer (canopy,%)	F27	60	2	40	2	70	2
Herb layer (canopy, %)	F28	50	2	20	2	60	2
Total productivity of chestnut coenosis(t/ha/y)	F 50	17,83	3	5,09	1	10,86	3
Annual litter fall , t/ha, absolute dry weight, total	F36	5,5	1	4,61	1	4,03	1
Mulch stocks, t/ha	F37	6,8	1	12	1	6,3	1
Total intensity of biological turnover, rate	F38	7	3	6	2	7	3
Average radial increment, cm	F51	0,295	2	0,292	2	0,265	2

*1- negative, 2- neutral and 3- good (favorable) state

The ecological state of chestnut trees in Belasitsa mountain is modelled using interpolation of the ecosystem indicators values with applying a spatial mask – chestnut belt in Belasitsa. As a result of interpolation raster (grid) surfaces are generated for the whole chestnut belt. Figures 4, 5 and 6 show the spatial distribution of the chestnut communities productivity, litter fall and mulch stocks.

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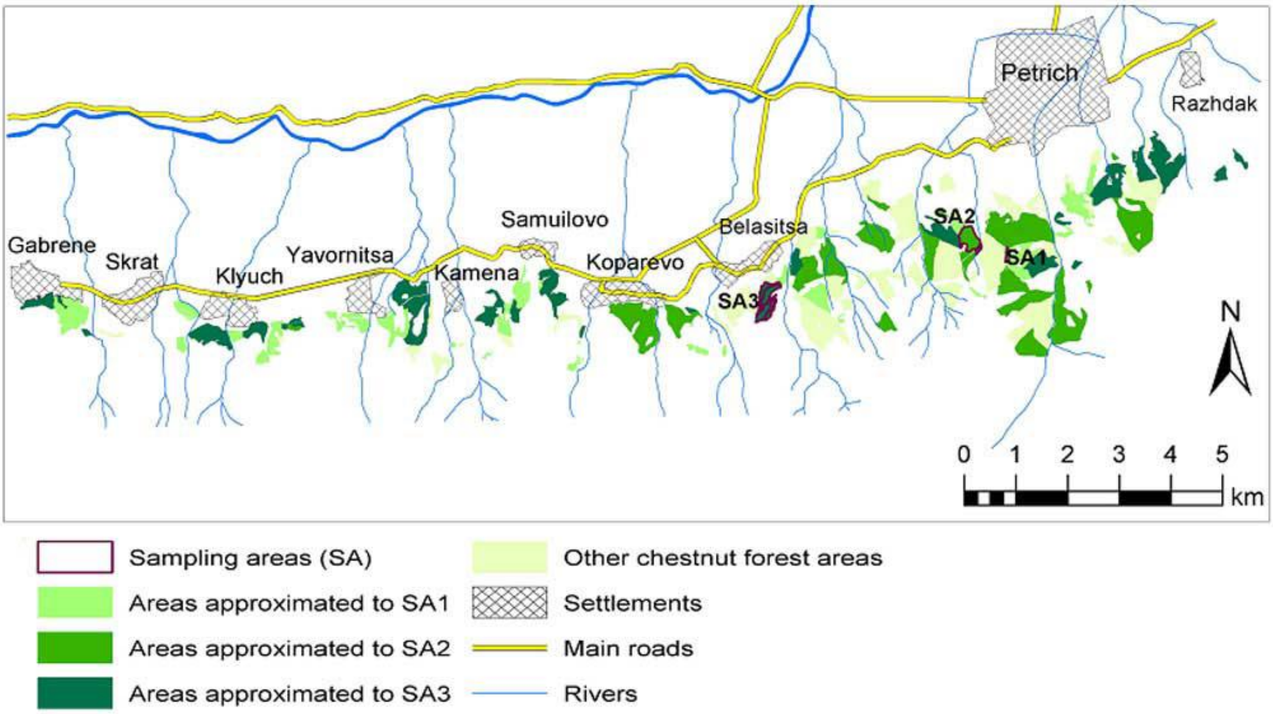

Fig. 3: Model distribution of chestnut trees in Belasitsa mountain, approximated to the indicators of SA1, SA2 and SA3 sampling areas

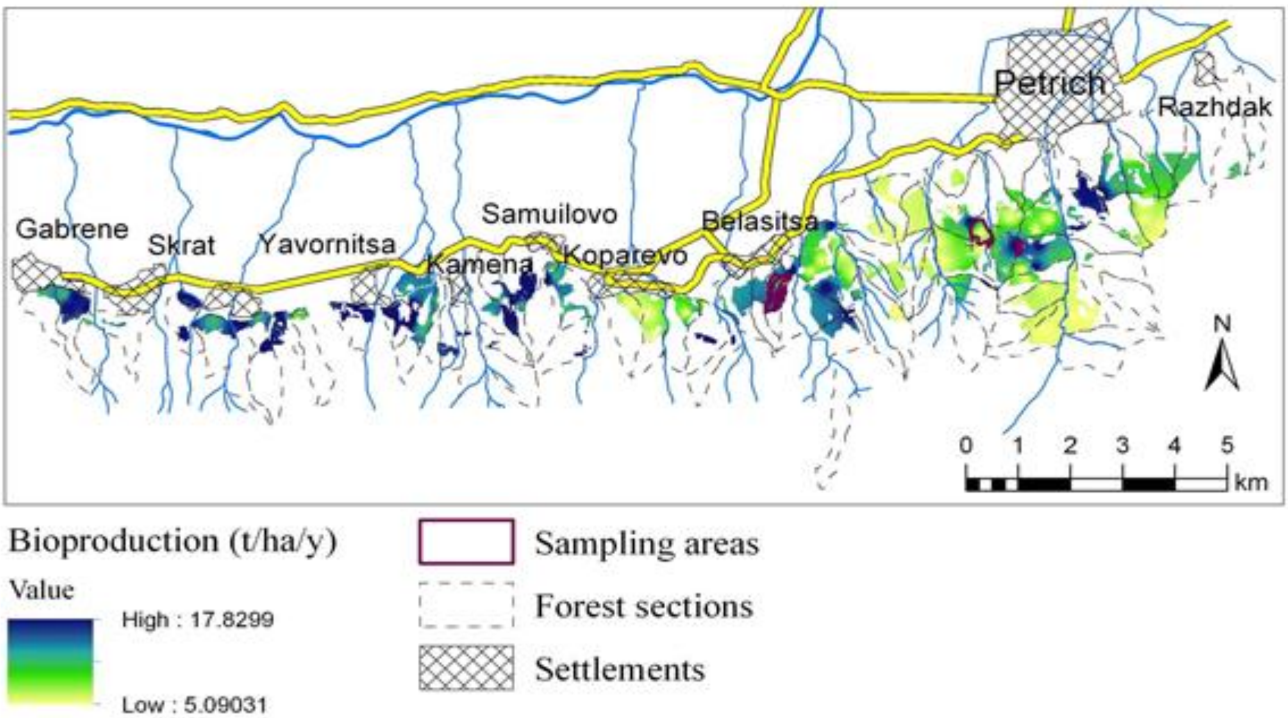

Fig. 4: Spatial distribution of chestnut bioproductivity

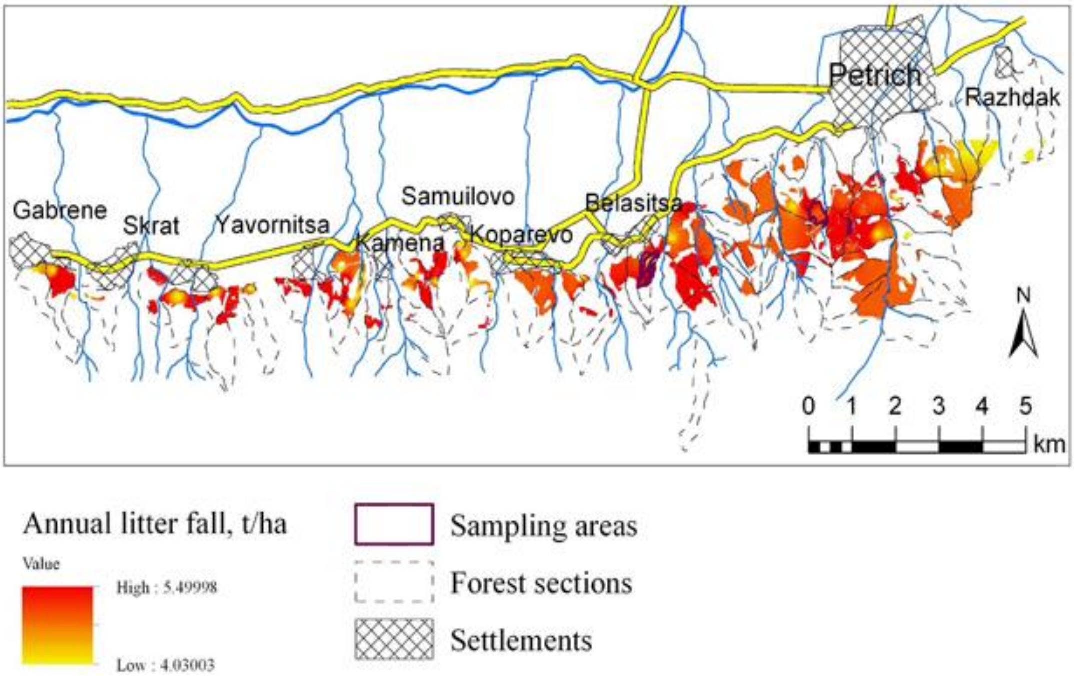

Fig. 5: Spatial distribution of litter stocks

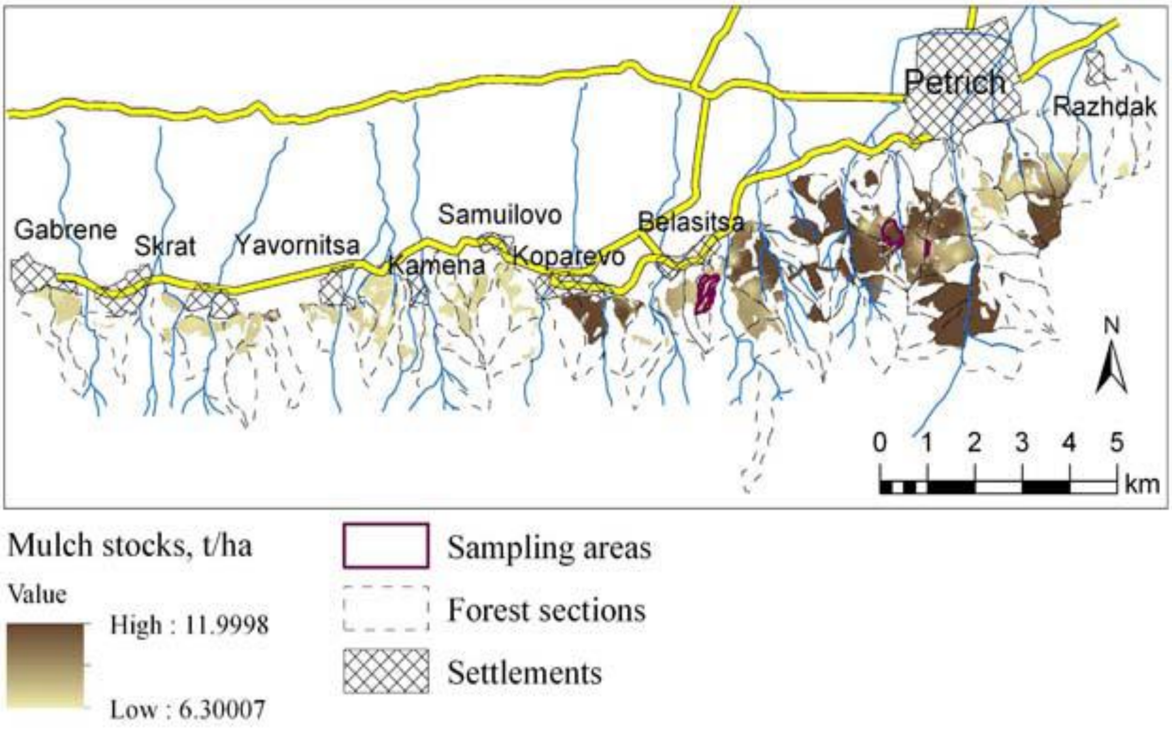

Fig. 6: Spatial distribution of chestnut mulch stocks

New field researches were carried out after the interpolation of the ecosystem indicators with the aim to check the results of the interpolation. Three forest sections were visited and the following indicators were investigated: species composition, structure, state and regeneration. The investigated indicators in two of the sections show significant similarity to the interpolated values of the model sampling areas. Having regard that the verified indicators are presented in young and old forest, we can accept that the model has a sufficient accuracy. This allows accepting the modeled values of the all indicators in the whole chestnut belt as sufficiently reliable.

On the next stage of the research the generated raster grids were reclassified in conditional marks of 1 to 3 (1 – negative, 2- neutral and 3 – favorable state) having regard the values of each indicator and its importance for the state of the chestnut forest (Table 2). The state of the chestnut forests is modeled by calculating an output layer of the assessments of the all indicators. This layer is generated using map algebra on the base of the equation (pointed above in the text, section III), where weighted values of the indicators (Table 2) are taken into account. This layer shows the state of the chestnut forests as a result of the impact and interaction of the chosen significant structural and functional indicators of chestnut ecosystems (Fig. 7). Forests in about 30% of research area are in bad state and 40% are in good state. There is a significant matching of territories of forests in poor and forests in good condition with the corresponding areas derived of the Forest Management Plan. This could be grounded by the fact that the assessment of the forest state takes into account many indicators.

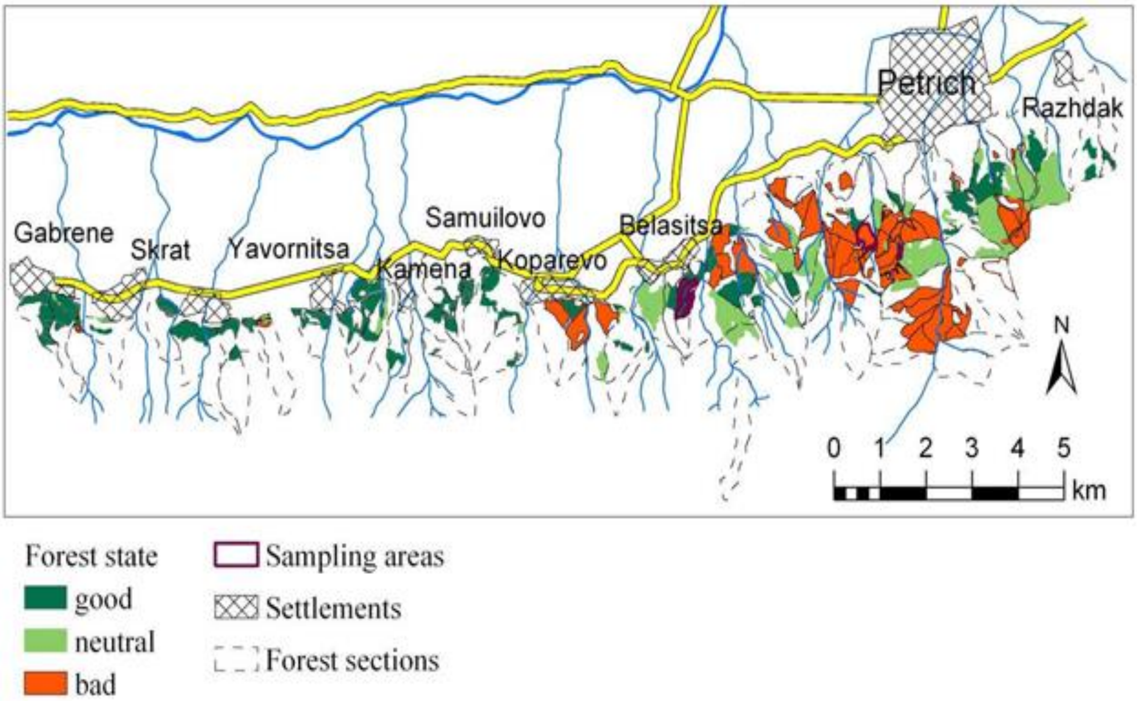

Fig. 7: Assessment of the state of the chestnut forests by ecosystem indicators

Conclusions

Having regard the researches on the ecosystem indicators and the analysis of the indicators given in Forest Management Plan we can conclude that chestnut forests in Belasitsa mountain are in poor, medium and good state in the different parts on the researched area. The area of forests where a drying-up is monitored is less extended that those with undamaged phytomass. However, in terms of other indicators, such as economic and ecosystem indicators, larger areas of chestnut forests are damaged.

The built GIS database gives possibilities for easily performing spatial analysis and surface representation of ecosystem indicators. In this case, the method of inverse distance weighted interpolation gives sufficient good results which are validated by the verification at random location on the terrain. Implementation of an integrated approach and multi-criteria analysis in ecosystem studies increases the accuracy of the spatial analysis. The spatial models which were created and the implemented approach of the research could be used in forestry for achieving sustainable development of forest ecosystems and management of forest resources.

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References

Amorini E., Bruschini, S., Manetti, M. (2000). Alternative silvicultural system in chestnut coppice: effects of silvicultural practices on stand structure and tree growth. *Ecologia Mediterranea,* 26, p. 155-163.

Bounous, G. (2007). Strategies to improve the chestnut culture in Europe: methods to replantations and valorisation of the productions. *I-st* Balkan *Regional Workshop on Sustainable Management of Sweet Chestnut Ecosystems* CAST Bul 2005 2-5.11.2005, Blagoevgrad, p. 11-25

Bratanova-Donchevcheva, Sv. (2003). Chestnut coenosis in Bulgaria – is it possible their sustainable management? In: *International conference "75 years. Forest Research Institute-BAS",* vol. I, p. 170-179. (In Bulgarian)

Bratanova-Donchevcheva Sv., Velev V., Lyubenova, M., Atanasova, M. (2002). Eco biological and phytocoenotic characteristic of *Castanea sativa* Mill. In Bulgaria, Regional meeting about management of the chestnut forests, Petrich, *Proc. "The chestnut forests—combination of ecological functions and use",* p. 17-27. (In Bulgarian)

Bratanova-Donchevcheva Sv., Lyubenova, M., Ignatova, N., Chipev, N., Popov, G., Fikova, R., Ovcharov, D., Mirchev, St., Grozeva, M., Tzvetkova, A., Ivancheva, J., Naumova, Sv., Peneva, V., (2005). Report of the project "Assessment of the dynamic of the structural and functional parameters of chestnut forests (*Castanea sativae* Mill.) in Belasitca in situation of global climate change " (CAST Bul). (In Bulgarian)

Conedera M., Krebs, P., Tinner W., Pradella M., Torriani D. (2004). The cultivation of Castanea sativa Mill. in Europe, from its origin to its diffusion on continental scale. *Veget. Hist. Archaeobot.* 13: 161-179.

Coulombe, S., Lowell, K. (1995). Ground-truth verification of relation between forest basal area and certain ecophysiorgahic factors using a geographic information system. *Landscape and Urban Planning*, 32, 127-136.

Dimitrova, V. (2008). Assessment of the structure, functional state and degradation processes in chestnut (*Castaneasativa* Mill.) ecosystems of Belasitza concerning the sustainable management. PhD thesis, University of Forestry, 158 p. (in Bulgarian)

Dimitrova V., Lyubenova, M., Bratanova-Donchevcheva, Sv., Chavdarova, M. (2003). Floristic investigations of the chestnut communities in the Belasitca mountain, *Sofia university "St. Kliment Ochridski" year book,* vol.96, livre 4, pp. XX (in Bulgarian)

Franklin, S.E., Lavigne, M. B., Deuling, M. J., Wulder, M. A. & E. R. Hunt Jr. (1997). Estimation of forest Leaf Area Index using remote sensing and GIS data for modelling net primary production. *International Journal of Remote Sensing, Volume 18, Issue 16, pp 3459-3471, DOI: 10.1080/014311697216973.*

Goldberg, D. (1989). Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison-Wesley Publishing Company Inc,* 1989.

Joy, M., Klinkenberg, M. (1994). Handling uncertainity in a spatial forest model integrated with GIS. *Proceedings of GIS'94*, Vancouver, British Colombia, pp 359-365.

Lauteri, M., Monteverdi, M., Scarascia-Mugnozza, G. (2009). Preservation of chestnut (Castanea sativa Mill.) genetic resources and adaptive potential in relation to environmental changes. In: Bounous, G., G. Becarro (eds.) *Proc. Ist Eur. congress on chestnut.* ISHS Acta Hort 866: 677–682.

Lowell, K. (1989). Differences between ecological land type mapsproduces using GIS or manual cartographic methods. *Photogrammetric Engineering and Remote Sensing*, 56, 169-173.

Lyon, J., Asce, A., Heinen, J., Mead, R. & Roller, N. (1987). Spatial data for modelling wildlife habitat. *Journal of Surveying Engineering*, 113, 88-100.

Manetti, M., Amorini, E., Becagli, C., Conedera M. & Giudici, F. (2001). Productive potential of chestnut (*Castanea sativa* Mill.) stands in Europe. *For Snow Landsc Res* 76: 471–476.

Pérez, M. F. M., Vicente, V. R. & Maseda, R. C. (2006). Using GIS to measure changes in the temporal and spatial dynamics of forestland: experiences from north-west Spain, *Forestry,* 79 (4): 409-423.doi: 10.1093/forestry/cpl027

Petkov P., Rosnev B. (2002). The state of the chestnut in Belasitca mountain ant actions for its improvement. Regional meeting about management of the chestnut forests, Petrich, Procced. *"The chestnut forests—combination of ecological functions and use",* p. 41-48. (in Bulgarian)

Petrov, M. (1982). Selection and introduction of sustainable to diseases chestnut varieties for nut production. Procced. *"Problems of chestnut in R. Bulgaria",* MGGP, Sofia., p.9-13. (in Bulgarian)

Ryan, A., Shreier, H. (1989). Modelling corn production with GIS and remote sensing techniques. *Proceedings of Canadian Conference on GIS,* Ottawa, Ontario, pp 125-133.

Store, R., Jokimäki, J. (2003). A GIS-based multi-scale approach to habitat suitability modelling, *Ecological Modelling,* Volume 169, Issue 1, pp 1-15.

Tzonev, R., Lyubenova, M., Hinkov, G., Karakiev, T. (2011). Syntaxonomy of Sweet chestnut (*Castanea sativa* Mill.) forests in Belasitsa mountain, Bulgaria. *Journal of Balkan Ecology*, 2, 171-186

Varbanov S., Chipev, N., Bratanova-Doncheva, Sv. (2005). Using of neuronic nets and genetic algorithms for assessment of the state of the chestnut forests in Belasitca. *Procced. of I national scien. Conf. Of ecology – biodiversity, ecosystems, global changes,* Petekson, Sofia, 131-139.

Vettraino A., Morel, O., Perlerou, C., Robin, C., Diamandis, S. & Vannini A. (2007). Ink Disease of European chestnut stands and orchards with special reference to the ecology and distribution of the associated Phytophtora species. In: *Procced. I-st Bal. Reg. Workshop on sustainable management of sweet chestnut ecosystems, Cast Bul 2005,* 2-5.11.2005, Blagoevgrad p. 153-169

Zlatanov, T., Velichkov, I. & Nikolov, B., eds. (2011). State and prospects of the *Castanea sativa* population in Belasitsa mountain: climate change adaptation; maintenance of biodiversity and sustainable ecosystem management. *Project BG 0031 EEA report,* FRI, Sofia

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Floristic composition and functional zones pattern of the beach-dune system along the Danube Delta coast - Romania

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Abstract

This paper presents the floristic composition of vegetation for each feature on a beach-dune system sector from the western Black Sea coast, Romania. The studied site is a relatively small fragment of the 10 km shore on the southern part of the Danube Delta Biosphere Reserve (DDBR) that may be susceptible to anthropogenic pressure in the coming years. Out of the 38 identified species, ten are threatened species according to the national Red List of endangered plant species. Compositae and Poaceae are the families with the highest number of species. The analysis of floristic spectrum shows a mixture of elements of plant communities, but Pontic and Ponto-Caspian elements are prevalent.
Physiognomically, the foredunes in the Danube delta coast have a typical morphology, with a smooth profile and do not exceed 2 m high. They are vegetated by herbaceous annual and perennial plants, but in terms of abundance the native dune builder rhizomatous grasses are rare.
The fore dunes from this Black Sea coast sector serve as vital habitat and refuge for *Convolvulus persicus* L. within the western limit of its geographical range. This endemic Ponto-Caspian element defines a particular habitat type within the Black Sea biogeographic region: "Pontic shore dunes with *Convolvulus persicus* L." Currently, the main threats of this habitat are cattle grazing and the increasing touristic activities (human trampling, horse riding and all-terrain vehicle riding).

Keywords: *Pontic shore-dunes, vegetation zones, Convolvulus persicus L., regional endemic, ecological refuge, habitat type*

Rezumat. Spectrul floristic şi modelul zonelor funţionale ale sistemului plajă-dune din zona costieră a Deltei Dunării

Lucrarea prezintă compoziția floristică a vegetației pentru fiecare subunitate de relief a unui sector a sistemului plajă-dune frontale din cadrul coastei de nord-vest a Mării Negre, România. Zona de studiu reprezintă un aliniament de 10 km de ţărm aflat în extremitatea sudică a Rezervației Biosferei Delta Dunării (RBDD) și expus riscului creșterii presiunii antropice în următorii ani. Din cele 38 de specii de plante cormofite, identificate între plaja înaltă și spatele dunelor frontale, potrivit Listei Roșii naționale, 8 sunt specii rare și amenințate. Analiza spectrului floristic scoate în evidență prezenţa unui amestec de elemente care compun comunitățile de plante, însă elementele pontice și ponto-caspice sunt dominante. Morfologia dunelor frontale de pe coasta deltaică este tipică, însă profilul lor are pante line și au înălțimi sub 2 m. Aceste dune sunt vegetate de plante anuale și plante erbacee perene, însă din punct de vedere al abundenței, gramineele cu rizomi, i.e. acele specii care sunt constructoare de dune, sunt rare.
Dunele frontale din acest sector costier al Mării Negre sunt habitat vital și refugiu ecologic pentru specia *Convolvulus persicus* L., a cărui limită vestică a arealului de raspândire este în Delta Dunării. Extinderea populaţiilor acestui endemit ponto-caspic în ultimul deceniu a contribuit la individualizarea unui tip particular de habitat în cadrul regiunii biogeografice continentale Marea Neagră (Pontică), denumit "Dune de ţărm pontice cu *Convolvulus persicus* L." Principalele amenințări ale speciei şi habitatului definit de aceasta sunt pășunatul vitelor cornute mari și turismul estival (călcatul în picioare, cursele de cai, cursele ATV).

Cuvinte-cheie: *dune de țărm pontice, zone de vegetație, Convolvulus persicus L., endemit regional, refugiu ecologic, tip de habitat*

Introduction

Due to the action of wind, waves and tides, sandy shores are some of the most dynamic landscapes on Earth (Maun, 2004). For the most part, in the beach-dune system the shore is colonized by annual plants starting with the drift line. This limit is delineated by the high water mark and it is characteristically associated with the line of marine detritus, usually a macro algal litter (Deidun, Saliba, & Schembri, 2009). The strip zone with marine organic debris forms the drift line habitat (Rodwell, 2000; Gheskiere, Vincx, Weslawski, & Degraer, 2005), which also is named the strand zone or pioneer zone (Maun, 2009). This fringe habitat is colonized by specialized plants species. Most of them are pioneer annuals that are classified as nitrophilous-halophytes (Salisbury, 1952; Doing, 1985; Pakeman & Lee, 1991) and the colonization is strongly dependent on the shelter and nutrients that can be provided by the flotsam and the jetsam that washes up on the strandline (Crawford, 2008; Chapman, 2013).

Although the development and the botanical composition of strandline communities often varies considerably from one year to another, commonly no more than three or four species are able to grow on any beach (Doing, 1985). For instance, along the temperate coasts, there are rarely quoted more than six plant species in a particular place and they mainly belong to Chenopodiaceae and Brassicaceae families (Lee & Ignaciuk, 1985). On the European coastlines, the most typical strandline species are *Cakile maritima* Scop. (Wrigth, 1927; Davy, Scott, & Cordazzo, 2006), *Salsola kali* (L.) Scop., *Atriplex littoralis* L., and *Crambe maritima* L. (Doody, 1991; Davidson et al., 1991). In addition, perennial members of Convolvulaceae (*Calystegia soldanella* L. Roem. & Schult.), and Poaceae (*Ammophila* sp., *Elymus* sp., *Leymus* sp.) are most frequent on the landward drift lines (Doody, 1991; Maun, 2009).

Besides the biological diversity value and the great ecological value of the drift line habitats (Davidson et al., 1991; Gheskiere, Vincx, Weslawski, & Degraer, 2005; Deidun, Saliba, & Schembri, 2009), all these plants help to combat the erosion of the upper beach (Doody, 2012). From the geomorphological point of view, the seaward edge of vegetation represents the border where the sand accumulation by wind and the building of the foredune start (Hesp, 2013). Along a prograding shore, plant species from the drift line and high beach are important biotic geomorphological agents because of their role in trapping the sand and building dunes. Consequently, where sand accumulates within and behind individual plants, embryo dunes are initiated landward of the high beach, which subsequently become foredunes (Hesp, 1983, 1989, 2004; Carter & Wilson, 1990; Davidson et al., 1991; Packham & Willis 1997; Davinson-Arnott, 2010; Hesp, 2013; Montreuil, Bullard, Chandler, & Millet, 2013;) with a different vegetation.

But only particular plants are specialized as "dune-building" species; as Maun, 2009; Durán & Moore, 2013 demonstrated, the plant zonation from drift line-high beach system is the primary factor that controls the maximum size of foredunes and therefore the amount of sand stored in a coastal dune system. Beside wind velocity and rates of sand transport, the morphological development of embryo dunes depends on plant density, plant distribution, height and cover. Tall, dense species such as *Ammophila arenaria* tend to produce higher hummocky dunes, whereas lower, spreading plants such as pan tropical creeping vine *Ipomoea pes-caprae* tend to produce lower less hummocky dunes (Hesp, 2004). In the absence of vegetation, dune systems can exhibit significant mobility, where all or part of the dune can migrate (Short & Hesp, 1982), commonly landward, due to onshore winds (Davis & Fitzgerald, 2004).

The seashore and coastal sand dunes are among the most endangered and threatened ecosystems worldwide because of escalating anthropogenic pressures as a result of coastal development, direct human use - mainly associated with recreational activities - high erosion rate, and global sea level rise. Despite many and unique ecological services that are provided by dune ecosystems (Heslenfeld, Jungerius, & Klijn, 2004; Brown & Mc Lachlan, 2006; Maun, 2009; Everard, Jones, & Watts, 2010; Frosini, Lardicci, & Balestri, 2012; Durán & Moore, 2013) in Europe, almost all coastal countries (European Environmental Agency 1999; Doody 2012) face losing and degradation of sand dune landscape, which are leading to a dramatic biodiversity loss, caused by the alteration and disappearance of many habitats and the rarefaction and/or local extinction of the most typical and extremely specialized native species (Buffa, Fantinato & Pizzo, 2012). On the other hand, coastal dune habitats are included in the CORINE biotope classification (Devillers, Devillers-Terschuren, & Ledant, 1991), EUNIS habitats (http://eunis.eea.europa.eu/upload/EUNIS_2004_report.pdf). At the European Union level, some of them were assessed as priority habitats or habitats of community interest in Annex I of EU Habitats Directive (CE 43/92).

In a wild dune-beach system from Europe, based on the coastal dune classification (Psuty, 2004) and according to the last Interpretation Manual of European Union Habitats (EU 28), two habitat types are expected to exist at least: "2110 Embryonic shifting dunes" and "2120 Shifting dunes along the shoreline with *Ammophila arenaria* ". But if on a sandy beach there occurs formation of annual plants with sea-rocket communities, and *Cakile maritima* is the characteristic species, then this type of vegetation should be considered under "2110 Embryonic shifting dunes habitat type as well" instead of "1210 Annual vegetation of drift lines habitat" as it was defined before EU 28.

The floristic diversity and specific plant communities from the Black Sea coast were particularly assessed by Géhu & Uslu (1989), Kavgaci (2007), in the Turkish area, Petrova & Apostolova (1995), Tzonev, Dimitrov, & Roussakova (2005), Făgăraş, Anastasiu, & Negrean (2010), Petrova (2011), in the Bulgarian area. Within the Romanian Black Sea coastline, particular studies on flora and vegetation were performed, especially within deltaic plain, by Pallis (1915), Panţu, Solacolu, & Păucă (1936), Dihoru & Negrean (1976 a, b), Popescu & Sanda (1976), Roman (1992), Sanda & Popescu (1992), Ciocârlan (1994), Hanganu et al., (2002), Strat (2005, 2007, 2009), Doroftei et al. (2011), Făgăraş (2013, 2014). Our research is the first detailed analysis of the floristic composition of the deltaic shore which gives full information about plant species distribution along of each morphological and functional feature of the beach-dune system.

However, in the last years, the shore vegetation within the Danube delta was assessed especially according to the Habitats Directive requirements (Făgăraş, 2013, 2014) as part of the first monitoring of conservative status of the habitats and species of Community interest from Romania in order to report the summarized and analysed results to the European Commission according to Article 17 of the Habitats Directive (Mihăilescu, Strat, Cristea & Honciuc, 2015). Nevertheless, for the Romanian coastline, published lists of phytodiversity in accordance with shore zonation of sandy shores features are scarce.

This paper presents the assessment of the plant diversity of the beach-dune system along the southern part of the Danube delta coast in accordance with the shore zonation of forms in order to identify dune-building plant species. Life forms spectra and floristic elements were also assessed and a distinctive habitat type for the western Black Sea coast is described. The main threats and the vulnerability of shore area and its habitats were also investigated.

Materials and Methods

Study site

The studied area is a sandy shore on the southern part of the Danube delta coast that is located between Sf. Gheorghe and Sulina mouth arms (Fig. 1). The general orientation of the deltaic shore is north and the study area is called Sărăturile shore due to it is development as part of the marine beach ridge plain that has same name (Fig. 1), and, virtually, in the the future it is expected that this current foredune ridge will become the newer added part of the Sărăturile beach ridge plain as a result of the prograding processes.

The entire coast is microtidal, with a maximal tidal range of 0.12 m at spring tide (Bondar, Roventa, & State, 1973), which means that the coast is a wave-dominated type (Short, 1996). The wave energy climate is medium (Vespremeanu-Stroe & Preoteasa, 2007), with a mean wave-height of 0.8 m, but during storm surges the water-level fluctuations can reach a maximum of 1.2-1.5 m height (Giosan et al., 1999).

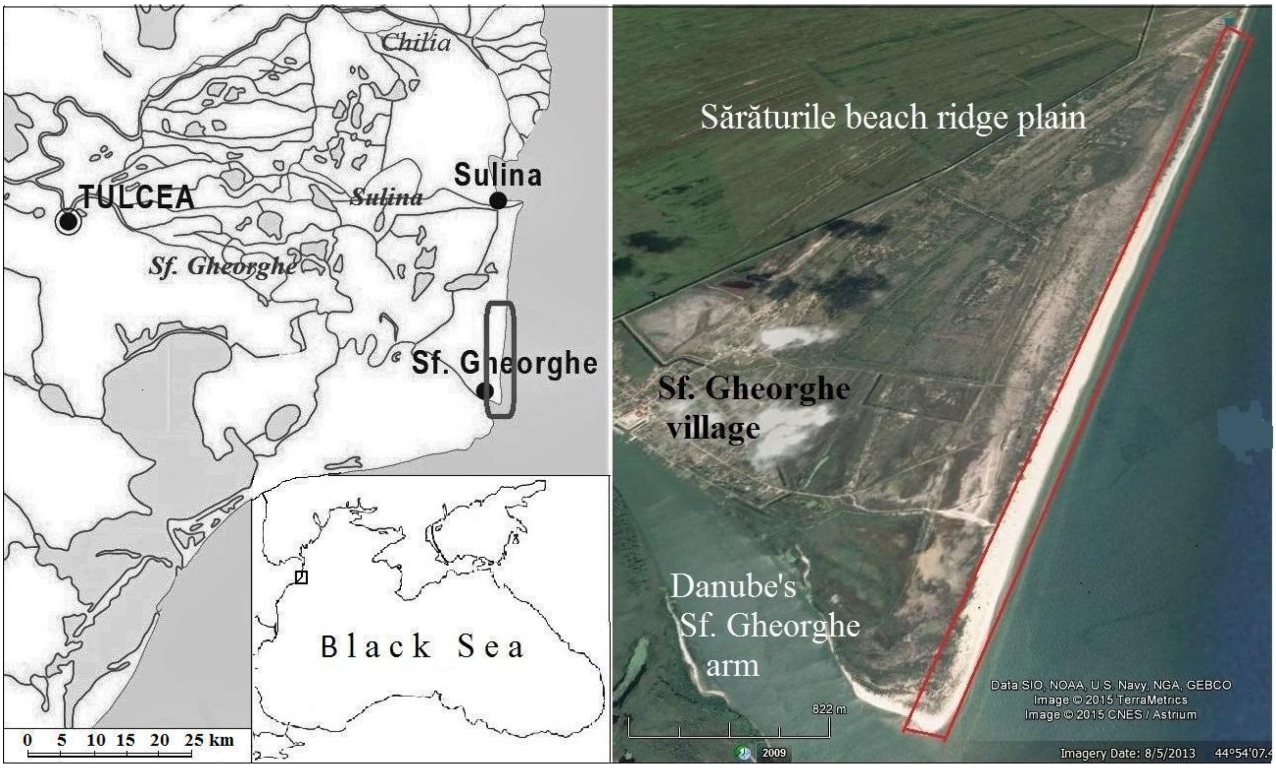

Fig. 1: Map of the study site

The climate of the area may be described as temperate continental with Pontic influences (Bogdan, 2008). The mean annual air temperature is 11.3 °C and the annual amplitude 22.3 °C. For the last 25 years, the mean annual rainfall amount is 281 mm and the potential evapotranspiration is around 730 mm per year, which means a severe water deficit but, due to the proximity of the sea, the relative humidity is high (annual mean: 87%). Based on the aridity De Martonne index value (13), the climate is semi-arid (Strat, 2010). According to the Rivas-Martinéz system (Rivas-Martinéz et al., 2004), the bioclimate of this area (Fig. 2) can be described as Mediterranean xeric continental type (Strat, 2010). The Period of Plant Activity (i.e., months with mean temperature > 3.5 °C, Rivas-Martinez et al., 2004) is nine months and the average growing season length (defined as the average number of days a year with a 24-hour average temperature of at least 5°C) has changed from 254 days for the period between 1951-2000 to 268 days in first decade of the 21st century (Strat, 2015). Prevailing winds are northerly (Strat, 2001; Vespremeanu-Stroe, Cheval, & Tătui, 2012) and they are responsible for the biggest storms that have an average speed of 9.8 m/s and durations that range between 8 and 22 hours (RCMGG, 1994).

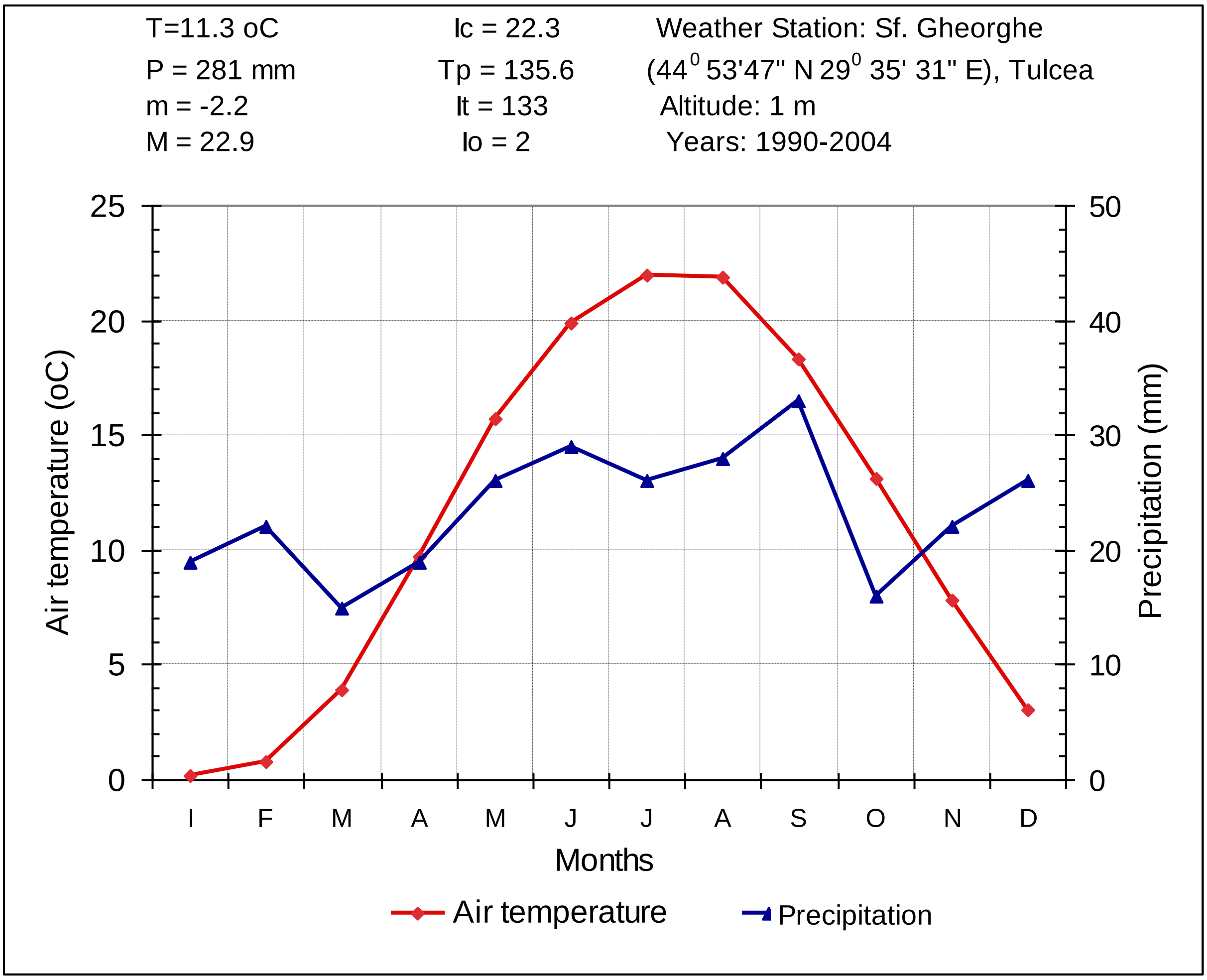

Fig. 2: Bioclimatic classification of Sărăturile beach ridge plain (South eastern Danube delta coastal stretch) for the period. Bioclimatic indices are calculated after Rivas-Martinez et al. 2004, as it follows: P = Yearly average recipitation, T= yearly average air temperature, m=Average of the minimum temperature of the coldest month, M = Average of the maximum temperature of the coldest month, Ic = Continentality index, Tp = Yearly positive temperature, Itc Io = Ombrothermic index

Geomorphologicaly, Sărăturile shore is composed by a beach-dune system that stretches 15 km northward Sf. Gheorghe arm mouth (Vespremeanu, 1987). The width of the beach decreases progressively from the southern sector (50-70 m), named Cape Buival (Fig. 3a), to the northern extremity, where it has around 20-30 m (Tătui, Vespremeanu-Stroe, & Preoteasa, 2013). On the southern extremity of shore, due to significant amounts of sediments delivered by Sf. Gheorghe mouth bar, in the last years the shore line has been advanced with 1-2 m/year (Tătui, Vespremeanu-Stroe, & Preoteasa, 2013) (Fig. 3b). The beach sediments are composed by medium-fine sands (Giosan et al., 1999) and shell debris.

The organic detritus that is washed up along the high water mark hardly makes a clearly defined strip zone. Accumulations of drift material have not macroalgal litter content since the sandy bottom of the littoral and infralittoral zone is not vegetated by macroalgae. Instead of macroalgal litter, the organic debris from the drift line is composed locally by "camca", especially in the proximity of river mouths. The word "camca" is the local term for shredded leaves, decayed rhizomes, and aerial stems of *Phragmites australis* which accumulates on the beach and that are subsequently mixed with shells debris and sand. In addition to this, there are larger fragments of rhizomes and stems of reed and pieces of "plaur" or "plav" (the local names of floating reed fen), which originate from the Danube delta. Annual drift line plant species are often rooted in these pieces of *plaur*, along with plant species that are characteristic of the floating reed fen like *Solanum dulcamara* L. and the fern species *Nephrodium thelypteris Schott.* Shell debris and pieces of dung, which are dropped by cattle that graze on foredunes, are quite frequent.

The beach is followed by a well-defined foredunes alignment, which makes a rather continuous ridge with a smooth profile, but it not exceeds 2.5 m in height (Vespremeanu-Stroe & Preoteasa, 2007).

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Hummock dunes, which are built around the erratic *Hippophae rhamnoides* L., *Eleagnus angustifolia* L., and *Tamarix ramossisima* Ledeb., and blowouts are present, too. Ecologically, these foredunes are semi-fixed yellow dunes, because they are vegetated by annual as well perennial herbaceous plant species.

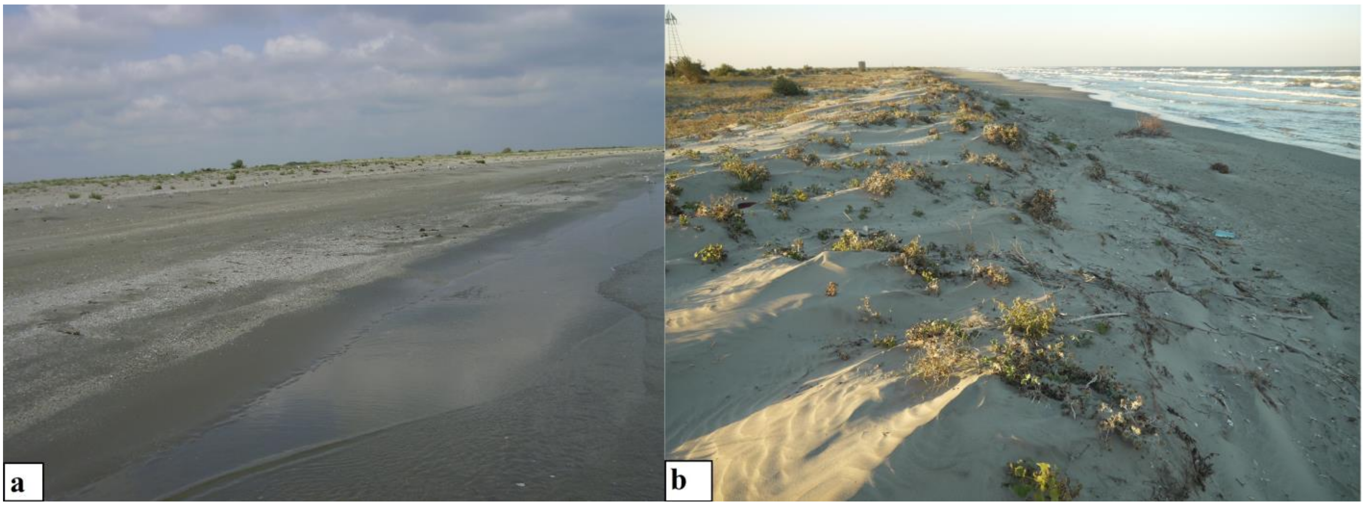

Fig. 3: The Sărăturile Shore. General view of the southern part, close to Sf. Gheorghe mouth arm (a). The new incipient foredune ridge from the southern part of Sărăturile shore (Picture taken in September 2014)

Concerning the functional areas within the Danube Delta Biosphere Reserve, the study site, together with the entire Sărăturile beach ridge, is located within a transition zone, where human activity is allowed (http://www.ddbra.ro/rezervatia/delta-dunarii/prezentare-generala/zonare-functionala-a19). At 3 kilometers' westwards from the shore there is Sf. Gheorghe village with a current population of less than eighth hundred inhabitants (INS, 2013).

Field survey and data collection

The floristic surveys were carried out on the southern Danube delta coastline located between Sf. Gheorghe and Sulina distributary mouths. Species composition of the vegetation was recorded in July 2012 and August 2014. Unpublished field observations made by the author from 2003 to 2014 were also integrated. In order to record the floristic diversity and plant communities, a transect method was employed. Twenty-five strip transects one meter wide were established perpendicular to the shore line following each morphological feature of the beach-dune system according to Vespremeanu (1987, 2004): drift line, beach berm, embryo dunes, foredunes, which morphologically and functionally have three sections (seaward dune side, top dune and lee side), and, from place to place where foredunes have gaps as a result of storm-surges breaching, washover fans. The presence or absence of vascular plant species was recorded along each transect at 2 meter intervals using 1-m^2 quadrats and following every morphological feature of the beach-dune system. Species-specific cover was recorded using the Braun-Blanquet scale (Braun-Blanquet, 1932).

Species were identified by referring to standard floras (Panțu, Solacolu, & Păucă, 1936; Popescu & Sanda, 1976; Dihoru & Negrean, 1976 a, b; Ciocârlan, 1994; Doroftei et al., 2011) and floristic keys (Ciocârlan, 2000) of the Danube Delta. The nomenclature of taxa is according to *Flora Europaea* (Tutin *et al.*, 1964-1980), the Euro+Med PlantBase (www.emplantbase.org), and the International Plant Names Index (www.ipni.org). For updated botanical names and authorities of plant species, www.theplantlist.org website has been used. Life forms and floristic elements were assessed according to Ciocârlan (1994, 2000). Endemic, rare and threatened species were classified according to Red Book of higher plants from Romania (Dihoru & Negrean, 2009).

Results

On the Sărăturile beach-dune system there were recorded 38 species of vascular plants that belong to 15 families, but not all are typical coastal plants species (Table 1). From them, a typical strandline is *Salsola kali* subsp. *ruthenica* (Iljin) Soó whilst typical coastal psammophytes are *Eryngium maritimum* L., *Leymus racemosus* (Lam.) Tzvel. subsp. *sabulosus* (Bieb.), *Convolvulus persicus* L., *Centaurea arenaria* subsp. *borysthenica* (Gruner) Dostál, *Medicago marina* L., *Polygonum maritimum* L. Compositae (9 species) and Poaceae (7 species) are the most represented families, accounting for 42 % of the identified species. Species richness ranged from 3 to 12 species per transect and 0 to 5 per quadrat. The estimated mean plant cover is around 30% but it is lower on the upper beach and seaward of foredunes and higher (around 45%) on the landward of foredunes.

Table 1: The plant list from Sărăturile beach dune system, the Danube Delta, North-Western Black Sea coast. Cont = continental; Euras = Eurasiatic; Medit = Mediterraean; Pont = Pontic; Pan = Panonnian; Balk = Balkanic; Atl. = Atlantic; Cosm. = Cosmopolitan; N. Amer. = North American. *Species that are listed on Romanian Red List

Nr. crt.	Family	Species name	Origin	Life form	Shore feature occurrence
1	Ephedraceae	*Ephedra distachya* L.*	Cont-Euras.	Chamaephyte	Landward side of the foredune
2	Amaranthaceae	*Atriplex litorallis* L.	Euras.	Therophyte	Drift line
		Corispermum nitidum Kit.	Pont. – Pan.	Therophyte	Foredune crest, Landward side of the foredune
		Salsola kali subsp. *ruthenica* (Iljin) Soó	Euras.	Therophyte	From drift line to the dune base from the landward side
3	Aristolochiaceae	*Aristolochia clematitis* L.	Medit.	Cryptophyte-Geophyte	Landward side of the foredune
4	Apiaceae	*Eryngium maritimum* L.*	Medit.	Hemycryptophyte	Berm, Foredune
5	Boraginaceae	*Tournefortia sibirica* L.*	Euras.	Cryptophyte-Geophyte	Driftline
		Onosma visianii Clem.	Pont. Pan.-Balk.	Hemytherophyte	Dune base from landward side
6	Brasicaceae	*Cakile maritima* subsp. *euxina* (Pobed.) Nyár *	Pont.	Therophyte	Seaward side of the foredune
7	Compositae	*Artemisia tschernieviana* Besser *	Pont.	Chamaephyte	Foredune crest and landward side of the fore dune
		Centaurea arenaria M.Bieb. ex Willd.	Pont.-Pan. – Balc.	Hemytherophyte	Foredune crest and landward side of the fore dune
		Centaurea pontica Prodan & Nyár.*	Endemism in Romania	Hemyterophyte	Foredune crest and landward side
		Helichrysum arenarium ssp. *Ponticum*	Pont.	Hemycryptophyte	Landward side of the foredune
		Lactuca tatarica (L.) C.A.Mey.	Cont. Euras.	Hemycryptophyte	Drift line
		Petasites spurius (Retz.) Rchb	Atl.-Pont.	Geophyte	Landward side of the foredune
		Scolymus hispanicus L.	Medit.	Hemyterophyte	Fore dune crest and landward side of the fore dune
		Tripolium pannonicum subsp. *tripolium* (L.) Greuter	Euras.	Hemycryptophyte	Drift line
		Xanthium strumarium L.	Cosm.	Therophyte	Fore dune
8	Convolvulacea	*Convolvulus persicus* L.*	Pont. –Casp.	Hemycryptophyte	High beach, Fore dune
		Cuscuta sp	Cosm.	Therophyte	Parasite on *C. persicus*, *Eryngium maritimum* and *X. strumarium* , E. *seguieriana* from Foredune crest and landward foredune
9	Elaeagnaceae	*Hippophae rhamnoides* L.	Euras.	Phanerophyte	Foredune crest, Back dune
		Elaeagnus angustifolia L	Euras.	Phanerophyte	Landward side of the fore dune
10	Euphorbiaceae	*Euphorbia peplis* L.	Euras.	Therophyte	Drift line
		Euphorbia seguieriana Neck.	Cont. Euras	Hemycryptophyte	Foredune crest, Landward side of the foredune
11	Leguminosae	*Medicago marina* L.	Medit.	Hemycryptophyte	Foredune heels
		Amorpha fruticosa L.	N. Am. (invader)	Phanerophyte	Fore dune toe
12	Plantaginaceae	*Linaria genistifolia* subsp. *Euxina* (Velen.) D.A.Sutton	Pont.	Therophyte	Base of the lee side oredune
		Plantago coronopus L.	Atl.-Medit.	Therophyte-Hemycryptophyte	Drift line, high beach
		Plantago maritima L.	Pont.-Medit	Hemycryptophyte	Driftline, seaward side of the beach
13	Poaceae	*Aeluropus littoralis* (Gouan) Parl.	Pont.-Medit.	Hemycryptophyte	Foredune crest, Landward side of the foredune
		Cynodon dactylon (L.) Pers.	Cosm.	Geophyte	Foredune crest, Landward side of the foredune
		Elymus farctus subsp. *bessarabicus* (Savul. & Rayss) Melderis	Pont.	Geophyte	Beach, Foredune toe, Foredune crest

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		Elymus elongatus subsp. *ponticus* (Podp.) Melderis*	Pont.	Geophyte	Beach, Foredune toe, Foredune crest
		Elymus athericus Elymus athericus (Link) Kerguelen	Atl.	Geophyte.	Beach, Foredune toe, Foredune crest
		Leymus sabulosus (Bieb.) Tzelev.	Euras.	Geophyte	Beach, Foredune toe, Foredune crest
		Secale sylvestre Host.	Cont.-Euras.	Therophyte	Foredune toe, Foredune crest
14	Polygonaceae	Polygonum maritimum L.	Medit.	Therophyte	Landward side of the foredune
		Polygonum arenarium Waldst. & Kit.	Pont.-Medit.	Therophyte	Landward side of the foredune
15	Tamaricaceae	*Tamarix ramosissima* Ledeb.	Cont.-Euras.	Phanerophyte	Foredune toe

Life form spectra show that the vegetation of the entire beach-dune system is dominated by hemicryptophytes (39%) and subordinately by therophytes (31%). The rest of taxa are geophytes, phanerophytes, and chamephytes. In terms of floristic elements, around 45% of taxa are Pontic, Pontic-Mediterranean and Ponto-Caspian elements, which is normal considering geographical position of the Danube Delta.

According to the Romanian Red List (Dihoru & Negrean 2009), ten taxa that occur in the study area are threatened as follows: four of them were categorized as critically endangered (*Convolvulus persicus L., Argusia sibirica* L. (Dandy), *Petasites spurius* (Retz.) Rchb.*, Euphorbia peplis L.*), two endangered (*Cakile maritima* subsp. *euxina* (Pobed.) Nyár*, Artemisia campestris* subsp. *inodora* Nyman), and four as vulnerable (*Eryngium maritimum, Polygonum maritimum L., Scolymus hispanicus L.*, C*entaurea arenaria* Bieb. subsp. *borysthenica* (Gruner) Dostál).

Based on the floristic survey of each morphological feature of the beach-dune system, the following distinct vegetation zones are characteristic of the Sărăturile shore - Danube Delta (Fig. 4): (1) the drift line or pioneer zone, consisting of dominant pioneer annual plant *Salsola kali* subsp. *ruthenica* (Iljin) Soó; (2) the berm (upper beach and embryo dunes), consisting mainly of pioneer annual plants and perennial dune-building species; (3) the foredunes, consisting of dune-building and burial-tolerant stabilizing , herbs, grasses, and shrubs. These functional zones have a perfect correspondence with the general worldwide coastal foredune zonation given by Doing (1985).

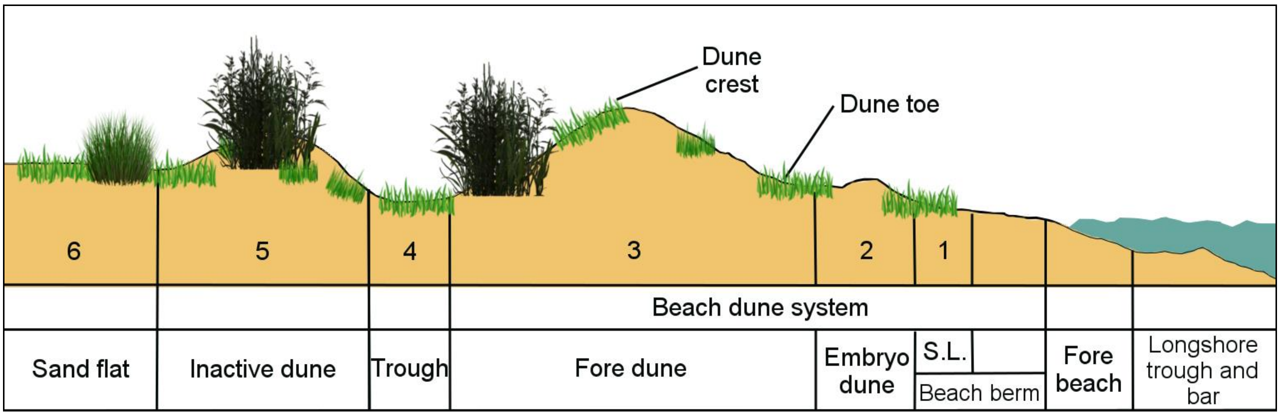

Fig. 4: Morphological features and functional ecological zone of the prograding shore Sărăturile, the Danube delta. 1. Strandline (S.L) – vegetated with halophytic annuals; 2. Ebryo dunes/white dune, developing above swash limit. They are instable, subject to wave action, vegetated with annuals and rhizomatous herbs and grasses; 3. Fore dune/ yellow dune, instable, under wind blow action, vegetated with herbaceous annuals, perenial herbs and grasses, erratic shrubs (*Hippophae rhamnoides*, *Elaeagnus angustifolia*); 4. Trough (interdune/back dune zone), more wet than dunes, vegetated with annuals and shrubs; 5. Inactive dune (back dune)/grey dune, stable, well vegetated, with herbs and shrubs. 6. Sand flat, temporary inundated, vegetated with halophillous species plants (*Salicornia herbacea, Juncus maritimus, Statice gmelini, Plantago maritima, Spergularia* sp.).

a) The drift line or pioneer zone

Across the Sărăturile shore there was not a continuous band of drift line flora species*.* During the floristic survey, the typical drift line plant species were *Salsola kali* subsp. *ruthenica* (Iljin) Soó and *Argusia sibirica (L.)* Dandy but only *Salsola* was spread on the entire shore*.* It makes ribbon-like stands which run along the water-line for hundreds of meters. On the drift line there are large plants which are associated with the wet sand that contains organic litter in contrast to the small stunted (10-15 cm) and unbranched individuals that were found on foredunes, above the limit of storm inundation. On the drift line and upper beach, *Salsola* individual plants develop ephemeral nebka and shadow dunes as they trap sand (Fig. 5a).

*Argusia sibirica (*synonym *Tournefortia sibirica)* was the only perennial plant with stabilizing growth habit that it was found on the drift line zone. It occurrs in the vicinity of the Sf. Gheorghe arm mouth where it makes the monospecific associations (Fig. 5b) named *Tournefortietum sibiricae* (Popescu & Sanda, 1975; Sanda, Ollerer, & Burescu, 2008) or is accompanied by *Salsola kali*. Branched stems of *Argusia sibirica* make clumps that develop small embryo dunes as they trap blowing sand. The occurrence of *Argusia sibirica* in this particular area was reported in the early of the twentieth century (Panțu, Solacolu, & Păucă, 1936) but, based on our ascertainments in the last decade, the area covered by its populations has dramatically decreased, most probably because of the human pressure.

E. maritimum and *Xanthium strumarium* L. occurs along the entire shore. Only on the southern extremity, close to the Sf. Gheorghe mouth discharge, *Leymus racemosus* subsp. *sabulosus* L., *Plantago coronopus* L*, Atriplex littoralis* L., *Lactuca tatarica* C.A. Mey, *Plantago maritima* L., and *Euphorbia peplis* L. were recorded, but the abundance of species was very low.

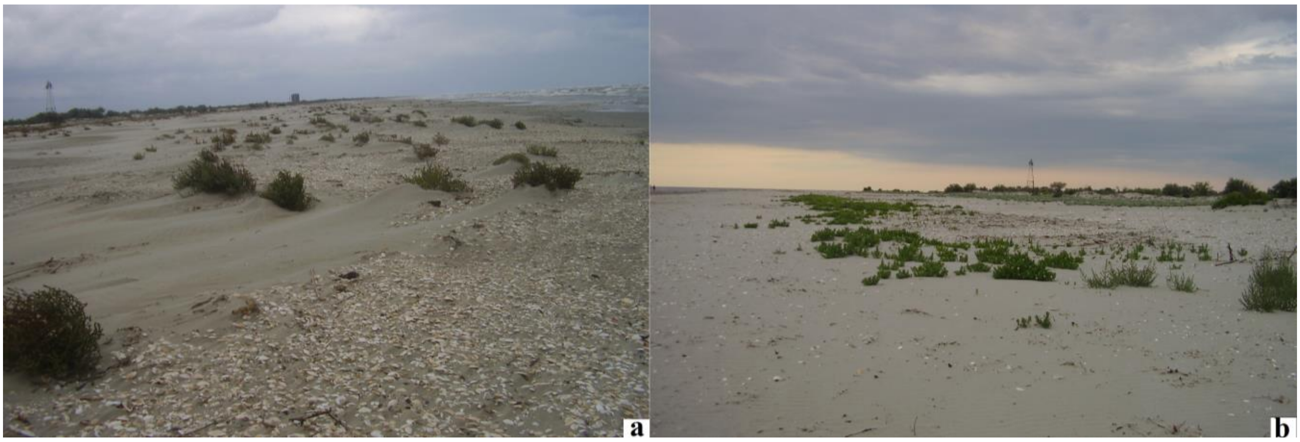

Fig. 5: Drift line habitat with *Salsola kali* subsp. *ruthenica* (a) and *Argusia sibirica* (b)

b) The berm (upper beach and embryo dunes)

The upper beach is populated by annuals *Salsola kali* subsp. *ruthenica, Xanthium strumarium* subs**.** *italicum* L., the biennial *Eryngium maritimum* L.*,* and herbaceous perennials *Convolvulus persicus* L*.* and *Leymus racemosus* subsp. *sabulosus* L*.*

In the southern sector of the study area, close to the mouth of Sf. Gheorghe arm of the Danube river, on the landward side of the beach, after more than a decade, a new ridge of incipient foredune were initiated around both pioneer annuals and perennial plants (*Salsola kali* subsp. *ruthenica, Eryngium maritimum, Convolvulus persicuss*, *Leymus racemosus* subsp. *sabulosus* Tzvelev*.*, *Xantium strumarium* subsp. *italicum*)*.* This process is normally taking in account the pattern of the foredune development near the river mouth discharge site on a wave dominated shoreline (Psuty, 2004).

c) The foredunes

The floristic diversity of foredune is higher than of the high beach and embryo dunes, but species richness has varied along the entire shore. Following, taxa were recorded and listed regardless of their frequency: *Eryngium maritimum, Convolvulus persicus*, *Corispermum nitidum* Kit., *Euphorbia seguieriana* Neck*.*, *Leymus racemosus* subsp. *sabulosus*, *Secale sylvestre* Host, *Petasites spurius* (Retz.) Rchb., *Xanthium strumarium, Salsola kali* subsp. *ruthenica* (Iljin) Soó*, Polygonum arenarium* Waldst. et Kit.*, Cynodon dactylon L (Pers.), Artemisia tschernieviana* Besser, *Centaurea arenaria L.*, *Medicago marina* L., *Aeluropus littoralis* subsp. *littoralis, Ephedra dystachya* L, *Helichrysum arenarium* subsp. *ponticum*, *Cuscuta* sp., *Linaria genistifolia* (L.) Mill. subsp. *genistifolia*, *Scolymus hispanicus* L., *Scabiosa ucranica* L., *Cakile maritima* ssp*. euxina,* but the major foredunes plant species along the entire analyzed shore are *Eryngium maritimum* L*, Convolvulus persicus* L., *Xanthium strumarium* L., *Salsola kali* subspp. *ruthenica*, and *Secale sylvestre* Host. The lee sides of foredunes are bordered by a bush belt composed by the dominant species of *Hippophae rhamnoides* and *Elaeagnus angustifolia,* subsequently.

The occurrence of the sea buckthorn on the shore dune was noticed as sporadically early in the 20th century (Panțu, Solacolu, & Păucă, 1936), but it largely spread in the second half of former century after this shrub was used in afforestation works in order to stabilize the transgressive dune field from behind the shore (Ceuca & Bakos, 1985; Mănescu & Traci, 1995). We think that the forest plantation that was set up in the 1970s in the vicinity of the shore (Muşat, 1980) was the seed source of the sea

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buckthorn populations from shore back dunes. This assumption is based on documented seed dispersal effect of frugivorous birds, as well as on the ability of this thorny scrub to colonize rapidly open habitats via suckering and self-seeding (Li Thomas & Beveridge Thomas, 2003). Archive photos show that, in the1960, before afforestation works, the southern Sărăturile field landscape was defined by shifting dunes and a sand sheets transgressive field with very scarce vegetation (Muşat, 1980; Ceuca & Bakos, 1985). Technically, *Hippophae rhamnoides* has escaped from tree plantation and has displayed invasive behavior in the area of coastal dunes, but from the geomorphological point of view it has significantly contributed to the dune stabilization process.

Discussions

The sandy shore plant communities from the Danube delta show a certain degree of uniqueness within the Black Sea Basin, which is supported by various factors ranging from present geographical and physical characteristics to the past climatic events that drove dramatic changes of the Black Sea level and floristic migrations in the coastal zones. The synergy of all these features has made possible the occurrence of a wide range of species with different geographical distribution as well as of endemic species. This phytogeographic mix greatly increases the floristic value of the deltaic shore, contributing to define plant communities and systems not found elsewhere.

During the floristic surveys, *Cakile maritima* subsp. *euxina*, which is normally a drift line species, was found only on the fore dune toe and it was spread exclusively in the northern half of the Sărăturile shore. *Cakile maritima* subsp. *euxina* is endemic around the Black Sea (Rodman, 1974; Davy, Scott, & Cordazzo, 2006) and the Sea of Azov shore (Golub et al., 2006), being one of at least four subspecies distributed along the European coast lines (Ciccarelli et al., 2010), a fact that was confirmed by the morphologically distinct chemical races (Rodman, 1976). On the Romanian Black Sea coast, it is strictly annual and, consequently, it is wholly dependent on seeds for survival.

In the previous floristic studies (Ciocârlan, 1994), the occurrence of sea rocket along the Sărăturile shore was mentioned as sporadically and very rare, but it is known that this plant species tends to make ephemeral and shifting population depending on propagule dispersal by sea water and wind (Davy, Scott, & Cordazzo, 2006). Also, its fluctuating appearance and disappearance locally along a coast was noticed by Hewett (1970).

All *Cakile maritima ssp. euxina* individuals that were found during our field trip were vigorous, highly branched, and with light lavender flowers, maturated and in development fruit, which confirm the ability of this species to tolerate the foredunes environment (Boyd & Barbour, 1993). Also, all plant individuals were distributed as discrete units, being separated from each other by considerable distances, ranging between 50 and 100 meters. It should be noted that there were not identified dry stems from the previous year. This fact suggests that in the study area the occurrence of sea rocket is recent, and it migrates from the north to the south of Sărăturile shore. Given that the nearest sea rocket populations there are at Sulina, northwards of the study area, within the drift line habitat (Făgăraş, 2013), these population are the most probable seeds source for Sărăturile shore. Deciduous upper segments fruits of sea rocket, typically one-seeded, have been disseminated by the north longshore drift, and subsequently the swash have casted them on the back shore on the foredunes during of overwash events. This possibility is in agreement with the studies which have proved the role of marine currents as dispersal vectors of sea rocket (Fridrikson, 1966; Barbour & Rodman, 1970; Heyligers, 2007; Gandour, Hessini, & Abdelly, 2008; Cousens et al., 2013) due to its well adapted fruit for sea water dispersal, long seeds viability (Maun & Payne, 1989; Cordazzo, 2006; Heyligers, 2007; Ciccarelli et al., 2010), and seed bank persistence at least 2 years in foredunes (Boyd & Barbour, 1993).

Human trampling and cattle grazing are the major circumstances which would certainly reduce the probability of the successful establishment of *Cakile* seedlings on the beach that is close to the Sf. Gheorghe mouth and that is more exposed to human disturbances, but there are likely to develop stands along the insulated northern half of the shore in the coming years, especially since along Sulina shore *Cakile* populations are increasing and expanding.

Despite of the wide spread natural distribution of *Ammophila arenaria* on the European temperate upper beach and foredune, this main dune-building plant species (Wiedemann & Pickart, 2004; Maun, 2009) and ecosystem engineer do not occur on the Romanian Black Sea coast. Although during the past century it was noticed at Sulina (Prodan, 1935), its occurrence was never confirmed later on, there (Ciocârlan, 1994, 2000; Făgăraş, Anastasiu, & Negrean, 2010) or anywhere else on the Romanian coast. Along the Romanian Black Sea coast, this plant species is replaced by the ecologically equivalents *Elymus farctus* subsp. *bessarabicus* (Savul. & Rayss) Melderis, *Elymus elongatus* subsp. *ponticus* (Podp.) Melderis, *Elymus athericus* (Link) Kerguélen, *Leymus sabulosus* (Bieb.) Tzelev., *Elymus pycnanthus* (Godr.) Melderis, *Leymus racemosus* (Lam.) Tzvelev_that are the main perennial dune grasses on the Romanian Black Sea coastal zone, but along the study area only *Elymus farctus* subsp.

bessarabicus, *Elymus elongatus* subsp. *ponticus*, *Elymus athericus*, *Leymus sabulosus* (Bieb.) Tzelev were identified and all have been sparse. Besides, although these *Elymus* species are dune building grass (Greipsson & Davy, 1996), they are less effective than *Ammophila arenaria.* According to Barbour (1977), the marram grass has twice root density of *Elymus*, which significantly increases its sand trapping ability and enhances the reinforcement power and stabilization of the sand dunes.

These perennial and rhizomatous grass forms small clumps on the embryonic dunes crest and the foredunes that are equally distinctive and eye-catching because of its stems with very broad bluish-green leaves and long whitish spikes. Infrequently, along the seaward edge, seedlings of *Elymus* grow in rows on the berm, both parallel and perpendicular to the shoreline. These seedlings form a semipermeable obstruction which causes precipitation of sand grains, and thus small embryo dunes and incipient foredune are created.

Competitive interactions with other species for nutrient resources and the absence of safe-sites for germination after the invasion of different species could be other causes for low dominance of *Elymus* in the study area as it has been claimed for different congener species in certain European coastal areas (Greipsson & Davy, 1996). Furthermore, due to paucity of palatable species they are overgrazed by cattle and rabbits. However, in the absence of any dominant beach grass, the foredunes from the study area have a general smooth profile and not a steep one as it is in case of dunes with *Ammophila*.

Among the perennials and sand stabilizers, *Convolvulus persicus L.* (Persian bindweed, sand bindweed) tends to become widely spread and a dominant species on Sărăturile shore. This plant species is endemic around the Black Sea and Caspian Sea coasts, where it grows on mobile sands. In the study area, on the fore dunes it makes monospecific stands as well as associations with *Eryngium maritimum*, *Centaurea arenaria*, *Corispermum nitidum*, *Secale sylvestre, Euphorbia seguieriana*, *Elymus farctus* (Viv.) Melderis subsp. *bessarabicus* (Săvul. et Rayss.), and with the invasive weed *Xantium strumarium* L. Extremely rare before 1990s (Ciocârlan, 1994), in last two decades *Convolvulus persicus* it has spread almost on the entire Sărăturile shore (Strat, 2005, 2009), where it makes the *Convolvuletum persici* (Borza 1931) Burduja 1968 association (Sanda, Ollerer, & Burescu, 2008 frequently, especially on the top and landward side of foredunes.

Being firmly anchored in the sandy substrate and as a result of its sand burial tolerance and guerilla growth form of the vegetative reproduction, *C. persicus* is able to accumulate the wind-blown sand, to create nuclei of mini-dunes around of clump of stems, particularly to stabilize the sand substrate, and, in the absence of tall perennial grasses, it tends to play a critical role in controlling the size and the morphology of foredunes. Without any other dominant rhizomatous competitors, the deltaic shore between Sulina and Sf. Gheorghe distributaries mouths is the optimal habitat for *C. persicus*. Furthermore, this plant species is the ecologically equivalent of the others representatives of Convolvulaceae family that are typical for sandy shores, similar to *Ipomoea pes-caprae* (Devall, Thien, & Platt, 1991) and *Ipomoea imperati* (Leonard& Judd, 1999) from tropical coasts (Devall et al., 1991), and *Calystegia soldanella* from temperate European (Di Sacco & Bedini, 2015) and American coasts (Wiedemann & Pickart, 2007). Also, *C. persicus* is present on the landward edge of the prograding beach as a consequence of rhizomes growing from foredunes toward beach. Its occurrence on the drift line is associated with the shore zones with dune scarp and the erosional beaches. But in contrast to *Ipomea pes-caprae* and *Calystegia soldanella* which are glabrous plants, all above ground parts of *C. persicus* are pubescent, densely covered with very short hairs and thereby the plant has grayish-green color and a soft velvety texture (Fig. 6a). Below-ground, spreading rhizomes make a complicated network which can be followed up to 2.5 m depth and 5-6 m horizontally. In this way, the perennial below – ground plant parts contribute to the reinforcement of the sand dunes.

After the floristic survey, the surface covered by *C. persicus* populations in the study area was estimated at around 3.4 hectares which means that, based on previous data (Strat, 2005, 2009), in the last 10 years this plant species has spread out its area of occupancy more than twice. Its contribution to the general plant cover ranges from 5 to 60%. However, *C. persicus* gives to foredunes a distinctive physiognomy (Fig. 6b) which can be hardly found somewhere among the other shore dunes along western Black Sea coast for at least two reasons: Persian bindweed has been constantly a rare taxa on the Black Sea coast and, most of the coastal shifting dunes, that are its habitat, have been dramatically disturbed by human activities in the last decades (Tzonev et al., *2005*; Kavgaci, 2007; Făgăraş, Anastasiu, & Negrean., 2010; Stancheva et al., 2011; Aykurt & Sümbül, 2014). Consequently, the plant is critically endangered in Bulgaria (Petrova, 2011), when only one surviving population is composed of few hundreds of stems that cover around 1000 m^2 (Vladimirov, Feruzan, & Tan, 2012), as well as in Turkey (Őztürk et al., 1998). However, under these circumstances, we consider that the Danube delta shore is the optimal habitat that exists at the western border of the geographic range of *C. persicus*, and this shore could be considered a veritable refuge for this plant.

Fig. 6: Convolvulus persicus (a) and seaward side of foredune populated by *Convolvulus persicus* and *Eryngyum maritimum* (b)

Taking the above into consideration, we suggest that foredunes from the Danube Delta coast that are vegetated by *C. persicus*, along with the Pontic elements (*Artemisia tschernieviana, Centaurea arenaria, Centaurea pontica),* to be described as "Pontic shore dunes with *Convolvulus persicus* L. habitat" type. Furthermore, because *Ammophila arenaria* do not occur on the northwestern Black sea coast, it can be stated that the foredunes with *C. persicus* are the equivalent of "Shifting dunes along the shoreline with *Ammophila arenaria* habitat" type, which is portrayed by Habitats Directive (Natura 2000 code 2120) and that was originally described for the Atlantic, North Sea, Baltic Sea and Mediterranean Sea coasts.

Although in the Danube Delta Biosphere Reserve there are other three sites with *Convolvulus persicus* populations (Dihoru & Negrean 1976 a; Ciocârlan, 1994; Strat, 2005, 2009; Făgăraș, 2013) and another one is located in the southern part of the Romanian Black Sea coast, which is the site where this plant species was recorded for the fist time in Romania and the Black Sea coast (Săvulescu, 1915), at the present time, coroborating the information gained from literature with our field investigation, we are of the opinion that within the Sărăturile shore there are the largest populations that are spread along the foredunes from the entire western Black Sea coast. Therefore, this dune habitat type has to be monitored and preserved, but for the effective protection and conservation it should be taken into account ecological data, life history, demography and genetic data related to *Convolvulus persicus* as well as the medium and the long-term evolution of the deltaic coast-line, the main threats of shore dunes, including invasive species, present and future human impacts. Besides, from the geomorphological point of view, due to its still high naturalnees, the Sărăturile shore could be a key site for coastal foredune type from the Romanian Black Sea coast.

Currently, there are no nature management activities in the coastal dunes area from the study site and though the human disturbance is low for now, the main threats of the foredunes habitat are the cattle and horse grazing, and the tourism activities. According to Sørensen et al. (2009), there are three mechanisms by which plants are affected by mammal grazing: removal of foliar tissue (defoliation), return of nutrients via dung and urine (fertilization), and trampling. On the other hand, documented studies have shown that the long-term management of grazing by domestic livestock on sand dune vegetation has a positive effect on species diversity, plant communities and habitat condition (Plassmann, Jones, & Edwards-Jones, 2010).

The traditional way of pasturage within the Danube delta, including the study area, is to let animals free outside the village, without any herdsman, to fend for themselves. Foredunes are grazed especially during the warm season. Consequently, at the end of the summer the palatable plant species are overgrazed and animals start to graze another plant species which are normally avoided, like *Xanthium strumarium*. During the summer months, frequently, both ungulates – cattle and horses - cross dunes and the beach to get at the sea where they lay on the swash zone for cooling and drinking seawater, which increase the trampling intensity. Furthermore, animals take shelter in the shade of shrubs that are scattered on dunes, and horses roll, take dust baths and scratch the soil surface. Also, large amounts of dung remain on the dunes and beach. Therefore, at the end of the summer, the impact of grazing is readily apparent along of the entire foredunes ridge.

Although there is not any tourism infrastructures on the shore, tourists prefer this area precisely because of its still outstanding wildness. But if in the communist era the deltaic shore was practically untouched by humans because, technically, being national border it was a forbidden place, in the last decade the tourist flows have been increased dramatically, although there are not any facilities for sunbathing, camping or other leisure facilities. On the other hand, horse riding and all-terrain vehicle riding tend to become very popular recreational activities during summer. Under these circumstances, the most exposed site to human pressure is the southern part of Sărăturile shore, stretching 3 km along the coast, from Cape Buival to north.

Conclusion

Plant spectra of beach-dune system from Sărăturile shore (the Danube delta) does conform to a conspicuous series of parallel bands, although the vegetation zonation is usually very compressed and the embryonic and mobile dunes plant species tend to be intermingled. The best represented life forms are hemicryptophytes (39%) and therophytes (31%), but dune builder rhizomatous grasses are very rare.

Based on literature survey, the dominant diagnostic species are different from those of the other European and even from the other areas of the Black Sea coast. The regional flora (Pontic, Pontic-Mediterranean and Ponto-Caspian elements) and the general environment have a prevailing role in determining foredunes habitats.

Species richness is higher in the drift line and upper beach from the southern sector than in the northern sector of the shore and vice versa on the landward side of foredunes. Five plant species are spread across the entire beach-dune system from the Danube delta – *Salsola kali* subsp. *ruthenica*, *Eryngium maritimum*, *Convolvulus persicus*, *Xanthium strumarium*, and *Elymus farctus* - but only the first three occur constantly in each morphological feature along the entire shore. Psammophytes species with predominantly coastal distribution – namely *Euphorbia seguieriana*, *Centaurea arenaria*, *Corispermum nitidum*, *Artemisia tschernieviana*, *Ephedra distachya*, *Scabiosa ucrainica*, *Petasites spurius*, *Medicago marina*, *Helycrisum arenarium*, *Linaria genistifolia* (L.) Mill. subsp. *genistifolia* - occur only on the top and landward side of foredunes, along with inland species that are frequently found in other vegetation types. Several species are infrequent (*Plantago coronopus*, *Plantago maritima*, *Tripolium panonicum* (Jacq.) Dobrocz, *Euphorbia peplis*, *Cakile maritima* subsp. *euxina*, *Scolymus hispanicus*, and *Ephedra distachya*).Since *Convolvulus persicus* makes monospecific associations, it is a characteristic species for other communities, and its populations cover a large area of foredunes, this regional endemic plant species defines a unique habitat type, both within the Danube delta and the western Black Sea coast. Accordingly, in conjunction with the particular shore dune morphology, bioclimatic and biogeographical criteria, we suggest that this habitat to be named "Pontic shore dunes with *Convolvulus persicus* L." Regarding the above proposal, and taking in account the occurrence of another threatened plant species also, this shore has to be protected and preserved as a natural refuge for the sand bindweed. This regional endemic plant species is threatened because in the whole its geographical range it has an extremely local distribution and its populations are in decline as a result of negative human impacts in the coastal areas. In the study area, the main threats of *Convolvulus persicus* are summer tourism, cattle and horse grazing. The animals cause trampling impacts, both over plant community and shore microforms, which increases the vulnerability of dunes. However, future studies have to take into account that the domestic livestock grazing, carefully managed, could be a conservation management manner of this beach-dune system.

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References

Aykurt, C., & Sumbul, H. (2014). Taxonomic revision of the genus Convolvulus L. (Convolvulaceae) in Turkey. *Biological Diversity and Conservation,* 7(2), 1-28

Barbour, M. G. (1977). Seedling ecology of Cakile maritima along the California coast. *Bulletin of the Torrey Botanical Club, 97*, 280-289

Barbour, M. G., & Rodman, J. (1970). Saga of the west coast sea rockets: Cakile eddentula ssp. californica and C. maritima. *Rhodora, 70*, 370-386

Bondar, C., Roventa, V., & State, I. (1973). *Marea Neagră în zona litoralului românesc. Monografie hidrologică.* Bucureşti: Institutul Naţional de Meteorologie şi Hidrologie (in Romanian)

Bogdan, O. (2008). Clima. In P. Gâştescu & R. Ştiucă (eds) *Delta Dunării - Rezervaţie a Biosferei (*pp 85–93). CD Press, Bucureşti

Boyd, R.S., & Barbour, M. G. (1993). Replacement of *Cakile edentula* by *C. maritima* in the strand habitat of California. *Am.Midl. Nat., 130*, 209-228

Braun-Blanquet, J. (1932). *Plant Sociology. The study of plant communities* (First edition ed.). (G. D. Fuller, H. S. Conard, Eds., G. D. Fuller, & H. S. Conard, Trans.). Chicago

Brown, A. C., & Mc Lachlan, A. (2006). *The Ecology of Sandy Shores* (2nd ed.). Academic Press

Buffa, G., Fantinato, E., & Pizzo, L. (2012). Effects of Disturbance on Sandy Coastal Ecosystems of N-Adriatic Coasts (Italy). In S. G. Lameed (Ed.), *Biodiversity*

Enrichment in a Diverse World (pp. 339-372). InTech. doi:10.5772/48473

Carter, R.W.G., & Wilson, P. (1990). The geomorphological, ecological and pedological development of coastal foredunes at Magilligan Point, Northern Ireland. In K.F. Nordstrom, N.P., Psuty, & R.W.G., Carter (eds) *Coastal dunes: form and process* (pp. 129-158). Chichester. John Wiley

Ceuca, G., & Bakos, V. (1985) Măsuri de ameliorarea în vederea impădueririi grindului fluviomaritim Sărăturile de la Sf. Gheorghe Deltă. Delta Dunării. *Studii şi comunicări de entomologie*, 2, 47-59

Chapman, V. (2013). *Coastal vegetation* (2nd edition). Elsevier

Ciccarelli, D., Balestri, M., Pagni, A., & Forino, L. (2010). Morpho-functional adaptations in Cakile maritima Scop. subsp. maritima: comparation of two different morphological types. *Caryologya, 63*(4), 411-421

Ciocârlan, V. (1994). Flora Deltei Dunării. Cormophyta. Bucureşti: Ceres

Ciocârlan, V. (2000). Flora ilustrată a României. Pteridophyta et Spermatophyta. Bucureşti: Ceres

Cordazzo, C. V. (2006). Seed characteristics and dispersal of dimorphic fruit segments of Cakile maritima Scopoli (Brassicaceae) population of southern Brazilian coastal dunes. *Revista Brasil. Bot., 29*(2), 259-265

Cousens, R. D., Ades, P. K., Mesgaran, M. B., & Ohadi, S. (2013). Reassessment of the invasion history of two species of Cakile (Brassicaceae) in Australia. *Cunninghamia, 13*, 275–290. doi: 10.7751/cunninghamia.2013.005

Crawford, R. (2008). Plants at the Margin: ecological limits. Cambridge. Cambridge University Press

Davidson, N. C., Laffoley, D. A., Doody, J. P., Way, L. S., & Key, R. (1991). Nature conservation in estuaries in Great britain. UK: Nature Conservancy Council

Davinson-Arnott, R. (2010). Introduction to coastal processes and geomorphology. New York. Cambridge University Press

Davis, R.A., & Fitzgerald, D.M. (2004). Beaches and Coasts. Blackwell Publishing

Davy, A. G., Scott, R., & Cordazzo, C. V. (2006). Biological flora of the British Isles:Cakile maritima Scop. *Journal of Ecology, 94*, 695-711. doi:doi: 10.1111/j.1365-2745.2006.01131.x

Deidun, A., Saliba, S., & Schembri, P.J (2009). Considerations on the ecological role of wrack accumulations on sandy beaches in the Maltese Islands and recommendations for their conservation management. Proceedings of the 10th International Coastal Symposium, Portugal. *Journal of Coastal Research,* Special Issue, 56, 410-414

Devall, M.S., Thien, L.B., & Platt, W.J. (1991). The ecology of *Ipomoea pes-caprae*, a pantropical strand plant. In: *Proceedings of the Symposium on Coastal Sand Dunes* (September 13-14, 1990, Guelph, Ontario). University of Guelph, Guelph, Ontario, Canada.

Devillers, P., Devillers-Terschuren, J., & Ledant, J.-P. (1991). CORINE biotopes manual. Vol. 2. Habitats of European Community. Luxembourg: Ofice for Official Publication of the European Communities

Dihoru, G., & Negrean, G. (1976)a. Flora of the Danube Delta. *Peuce., 5,* 217-251

Dihoru, G., & Negrean, G. (1976)b. Sintaxoni specifici Deltei Dunării. *Peuce, 5,* 101-108

Dihoru, G., & Negrean, G. (2009). Cartea Roşie a plantelor vasculare din România. Bucureşti: Editura Academiei Române

Di Sacco, A., & Bedini, G. (2015). Demography and reproductive performance of *Calystegia soldanella* on a sandy seashore in Tuscany, Italy. *Botany*, 93(2), 101-108. doi 10.1139/cjb-2014-0167

Doing, H. (1985). Coastal fore-dune zonation and succcession in various parts of the World. *Vegetatio, 61*, 65-75

Doody, J.P. (1991). *Sand Dune Inventory of Europe*. Peterborough, Joint Nature Conservation Committee/European Union for Coastal Conservation

Doody, J. P. (2012). Sand dunes conservation, management and restoration. Springer Science & Buisness Media

Doroftei, M., Oprea, A., Nicolae, S., & Sârbu, I. (2011). Vascular wild flora of Danube Delta Biosphere Reserve. *Scientific annals of the Danube Delta Institute, 17*, 1-37

Durán, O., & Moore, L. J. (2013). Vegetation controls on the maximum size of coastal dunes. *Proceedings of the National Academy of Sciences of the United States of America,* 110 (43), 17217-17222. doi: 10.1073/pnas.1307580110

EEA (1999). State and pressures of the marine and coastal Mediterranean environment. E. Papathanassiou & G. P. Gabrielidis (Eds.), European Environment Agency, Environmental assessment series 5, 1-137. Available from http://reports.eea.eu.int/ENVSERIES05/en/envissue05.pdf

Everard, M., Jones, L, & Watts, B. (2010). Have we neglected the societal importance of sand dunes? An ecosystem services perspective. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20, 476–487. doi: 10.1002/aqc.1114

Făgăraş. M., Anastasiu, P., & Negrean, G., (2010). Rare and threatened plants in the Black Sea coastal area between Cape Midia (Romania) and Cape Kaliakra (Bulgaria). *Botanica Serbica,* 34 (1), 37-43

Făgăraș, M. (2013). Habitats with conservation significance and psammophilous plant associations from Sulina beach (Danube Delta Biosphere Reserve). *Analele Ştiinţifice ale Universităţii „Al. I. Cuza" Iaşi, s. II a. Biologie vegetală, 59*(2), 85-98

Făgăraș, M. (2014). Psammophilous plant associations from the coastal area of theBblack Sea between Periboina and Periteașca (Danube Delta Biosphere Reserve). *Annals of the University of Craiova - Agriculture,Montanology, Cadastre Series, 44*, 89-100

Fridrikson, S. (1966). The pioneer species of Vascular plants in Surtsey. Cakile edentula. *Surtsey Research Program Report, 2*, 63-65

Frosini, S., Lardicci, C., & Balestri, E. (2012). Global change and response of coastal dune plants to the combined effects of increased sand accretion and nutrient avaibility. *PLoS ONE, 7*(10), e47561. doi:10.1371/journal.pone.0047561

Gandour, M., Hessini, K., & Abdelly, C. (2008). Understanding the population genetic structure of coastal Cakile maritima: seed dispersal and the role of sea currents in determining population structure. *Genetic Research, 90*(2), 167-178

Géhu, J.-M., Uslu, T. (1989). Données sur la végétation littorale de la Turquie du Nord-Ouest. *Phytocoenologia,* 17 (4), 449-505

Gheskiere, T., Vincx, M., Weslawski, J. M., & Degraer, S. (2005). Meiofauna as descriptor of tourism-induced changes at sandy beaches. *Marine environmental research, 60*, 245-265

Giosan, L., Bokuniewicz, H., Panin, N., Stanica, A., & Postolache, I. (1999). Longshore sediment transport pattern along the Romanian Danube Delta coast. *Journal of Coastal Research, 15*(4), 859-871

Golub, V. B., Laktionov, A. P., Sorokin, A. N., & Nikolaicyk, L. F. (2006). Coobtestva klassa Cakiletea maritimae na Azovskom poberejaie tamanckogo poliostoba. *Izvestia samarsckozo naycnocentra Poccuuskoii akademii nayk, 8*(1), 305-315

Greipsson, S., & Davy, A. J. (1996). Germination of Leymus arenarius and its significance for land reclamation in Iceland. *Annals of Botany, 73*(4), 393-401

Hanganu, J., Dubyna, D., Zhmud, E., Grigoraş, I., Menke, U., Drost, H., Ştefan, N., & Sârbu, I. (2002). Vegetation of the Biosphere Reserve Danube Delta - with Transboundary Vegetation Map on a 1:150,000 scale. Danube Delta National Institute, Romania; M.G. Kholodny - Institute of Botany & Danube Delta Biosphere Reserve, Ukraine and RIZA, The Netherlands. RIZA Rapport 2002.049 (2002)

Heslenfeld, P., Jungerius,P.D., & Klijn, J.A. (2004). European coastal dunes: Ecological values, threats, Opportunities and Policz development. In M. L. Martínez & Norbert P. Psuty, Coastal Dunes: Ecology and Conservation (pp 335-354). Berlin. Spinger Science & Business Media

Hesp, P.A. (1983). Morphodynamics of incipient foredunes in New South Wales, Australia. Brookfield M, Ahlbrant T (eds). *Aeolian processes and sediments*. Amsterdam. Elsevier, 325-342

Hesp, P.A. (1989). A review of biological and geomorphological processes involved in the initiation and development of incipient foredunes. *Proc R Soc Edinb, B96*, 181-201

Hesp, P.A. (2004). Coastal dunes in the tropics and temperate regions: location, formation, Morphology and vegetation processes. In Martinez M.L., & N.P., Psuty (eds.) *Coastal dunes, Ecology and conservation. Ecological studies*. Berlin. Springer, 24-49

Hesp, P. A. (2013). A 34 year record of foredune evolution, Dark Point, NSW, Australia. *Journal of Coastal Research, 65*(Special Issue), 1295-1300. doi: 10.2112/SI65-219.1

Heyligers, P. C. (2007). The role of currents in the dispersal of introduced seashore plants around Australia. *Cunninghamia, 10*(2), 167-188

Hewett, D.G. (1970). The colonization of sand dunes after stabilization with marram grass (Ammophila arenaria). Journal of Ecology*,* 58, 653-668

INS (Institutul Naţional de Statistică din România). (2013) Rezultatele finale ale Recensământului din 2011: Tab 13. Populația stabilă după religie – județe, municipii, orașe, comune. Accesed 7 July 2016 from http://www.recensamantromania.ro/wp-content/uploads/2013/07/sR_TAB_13.xls

Kavgaci, A. (2007). Sand-dune vegetation of Igneada coast in the Thracian part of Turkey. *Hacquetia,* 6(2), 171-182. doi:10.2478/v10028-007-0010-z

Lee, J. A., & Ignaciuk, R. (1985). The physiological ecology of strandline plants. *Vegetation, 62*, 319-326

Leonard, R.I., & Judd, F.W. (1999). The Biological Flora of Coastal Dunes and Wetlands. Ipomoea imperati (Vahl.) Griseb. Journal of Coastal Research, 15(3), 645-652

Li Thomas, S.C., & Beveridge Thomas, H.J. (2003). Sea Buckthorn (*Hippophae rhamnoides* L.): Production and Utilization. NRC Research Press

Maun, M. A., & Payne, A. M. (1989). Fruit and seed polymorphysm and its relation to seedling growth in the genus Cakile. *Canadian Journal of Botany, 67*, 2743-2750

Maun, A. M. (2004). Burial of plants as a selective force in sand dunes. In M. L. Martinez, & N. P. Psuty (Eds.), *Coastal dune ecology and conservation.* (Vols. Ecological studies, vol 171, pp. 119-135). Berlin: Springer-Verlag

Maun, A. M. (2009). *The biology of coastal sand dunes.* Oxford: Oxford University Press

Mănescu, M., & Traci, C. (1995). Afforestation technologies of the sandy soils in the Danube Delta. *Analele ICAS,* 43(1), 65-85

Mihăilescu, S., Strat, D., Cristea, I., & Honciuc, V. (2015). Raportul sintetic privind starea de conservare a speciilor și habitatelor de interes Comunitar din România. București: Editura Dobrogea

Montreuil, A.-L., Bullard, J. E., Chandler, J. H., & Millet, J. (2013). Decadal and seasonal development of embryo dunes on an accreting macrotidal beach: North Lincolnshire, UK. *Eart surface Processes and Landforms, 38*(15), 1851-1868

Muşat, I. (1980). Planting and maintaining technologies for forest cultures on the sandy soils of the zone Sf. Gheorghe–Ivancea. *Analele ICAS,* 37(1), 47-56

Őztürk. M., Yücel, E., Yarci. C., Celík, A., & Aksoy, A. (1998). Plant diversity in the Turkish Black Sea region and strategies for its conservation. In V Kotlyakov, M. Uppenbrink, & m. Metreveli (eds) *Conservation of the Biological Diversity as a Prerequisite for Sustainable Development in the Black Sea Region.* NATO ASI Series, 46, 155-173, Kluwer Academic Publishers

Packhman, J. R., Willis, A.J. (1997). *Ecology of dunes, salt marsh and shingle.* Berlin: Springer Science & Buisness Media

Pakeman, R. J., & Lee, J. A. (1991). The ecollogy of strandline annuals Cakile maritine and Salsola kali. I. Environmental factors affecting plant performance. *Journal of ecology, 79*, 143-153

Pallis, M. (1915). The structure and history of Plav: the floating fen of the Delta of the Danube. *Linnean Journal of Botany, XLIII*, 233-286

Panțu, Z., Solacolu, T., & Păucă, A.(1936). Contribuțiuni la flora Deltei Dunării. *Mem. Sect. St. Acad. Rom*, 11(2), 73-130

Petrova, A., & Apostolova, I. (1995). Rare plant species on coastal sand dunes and sand beaches in Bulgaria status and conservation problems. In A. Salman, H. Berends, & M. Bonazountas (eds.), *Coastal Management and Habitat Conservation. proceedings of the 4th EUCC Congress, Marathon, Greece. I*, pp. 453-458. Leiden: EUCC

Petrova, A. (2011). Convolvulus persicus L. In Paev D, Vladimirov V, &Water BA (eds). *Red Data Book of the Republic of Bulgaria (Vol I, Plants &Fungi).* http://e-ecodb.bas.bg/rdb/en/vol1/Conpersi.html. Accesed 26 January 2014

Plassmann, K., Jones, M.L.M., & Edwards-Jones, G. (2010). Effects of long-term grazing management on sand dune vegetation of high conservation interest. *Applied Vegetation Science*, 13(1), 100–112. doi:10.1111/j.1654-109X.2009.01052.x

Popescu, A., & Sanda, V. (1976). Contribuţii la cunoaşterea vegetaţiei psamofile din Delta Dunării. *Peuce*, 5, 193-216

Prodan, I. (1935). Conspectul Florei Dobrogei. *Bul. Acad. Agron. Cluj*. Cluj-Napoca. Tipografia Naţională

Psuty, N. P. (2004). The Coastal Foredune: A Morphological Basis for Regional Coastal Dune Development. In M. L. Martínez, & N. P. Psuty, *Coastal dunes. Ecology and conservation* (pp. 11-28). Berlin Heidelberg: Springer-Verlag

Rivas-Martinez, S., Penas, A., & Dias, T. (2004). Bioclimatic map of Europe: Bioclimates. Retrieved May 14, 2014, from http://www.globalbioclimatics.org/form/bimed.htm

Rodman, J. E. (1974). Systematics and evolution of the genus Cakile (Cruciferae). Harvard University Herbaria.

Rodman, E. J. (1976). Diferentiation and migration of cakile (Cruciferae): seed glucosinolate evidence. *Systematic Botany, 1*(2), 137-148

Rodwell, J.S. (2000). *British plant communities: Volume 5, Maritime communities and vegetation of open habitat*. Cambridge. Cambridge University Press

Roman, N. (1992). Contribuții la cunoașterea florei Rezervației Biosferei Delta Dunării. *Analele Ştiinţifice ale Institutului Delta Dunării* (51-56). Tulcea

RCMGG (Romanian Center for Marine Geology and Geoecology) (1994). *Monitoringul ecologic al sistemului Dunăre-Deltă-Litoral-Marea Neagră. Bucuresti*. Centrul Român de Geologie şi Geoecologie Marină

Sanda, V., & Popescu, A. (1992). Contribuţii la cunoaşterea structurii fitocenozelor de pe grindurile din Delta Dunării. *36*(2), 129-136

Sanda, V., Ollerer, K., & Burescu, P. (2008). *Fitocenozele din Romania. Sintaxonomie, structură, dinamică şi evoluţie.* Bucureşti: ArsDocendi, Universitatea din Bucureşti

Salisbury, E.J. (1952). Downs and Dunes: their plants life and its environment. London. George Bell & Sons.

Săvulescu, T. (1915). Convolvulus persicus L. en Roumanie. *Bulletin de la Section Scientifique de L'Académie Roumaine*, IV, 69-70

Stancheva, M., Ourviku, K., Palazov, A., Rivis, R., Kont, A., & Stanchev, H. (2011). Sand dune destruction due to increased human impacts along the Bulgarian Black Sea and Estonian Baltic Sea. *Journal of Coastal Research* (Procedings of the 11th International Coastal Symposium, Szczecin, Poland), 64, 324-328. http://www.ics2011.pl/artic/SP64_324-328_M.Stancheva.pdf. Accesed 12 July 2015

Short, A. (1996). The role of wave height, period, slope, tide range and embaymentisation in beach classifications: a review. *Revista Chilena de Historia Natural*, *6,* 589-604

Short, A.D. & Hesp, P. (1982). Wave, beach and dune interaction in southeast Australia. *Marine Geology,* 48, 259-284

Sørensen, L.I., Mikola, J., Kytöviita, M.–M, & Olofsson, J. (2009). Trampling and spatial heterogeneity explain decomposer abundances in a sub-arctic grassland subjected to simulated reindeer grazing. *Ecosystems*, 12, 830–842

Strat, D. (2001). *Litoralul lagunar al Mării Negre. Studiu de geomorfologie*. PhD thesis. University of Bucharest (unpublished)

Strat, D. (2005). *Convolvulus persicus* – o specie în expansiune pe ţărmul deltaic Sărăturile. Comunicări de geografie, 8, 86-94, Editura Universităţii din Bucureşti

Strat, D. (2007). Beach and sand dune species plant of deltaic shore between Cape Buiva-Câşla Vădanei (Sărăturile marine field). *Revista de Geomorfologie, 7*, 34-51

Strat, D. (2009). Rare and threatened plant species and types of habitats on Saraturile shore - Danube Delta. *Studii si cercetari stiintifice, Biologie, Seria Biologie Vegetală, 16*, 69-75

Strat, D. (2010). Trends in climate and bioclimate of Saraturile beach ridges plain - Danube Delta. *Analele Universităţii Ovidius, Seria Geografie, 5*(1), 17-30

Strat, D. (2015). Changes in thermal growing season length on the Danube Delta coast in the first decade of the XXIth century. *Analele Universității din Oradea. Fascicula Protecția Mediului*, XXV, 279-286

Tătui, F., Vespremeanu-Stroe, A., & Preoteasa, L. (2013) The correlated behavior of sandbars and foredunes on a nontidal coast (Danube Delta, Romania). Journal of Coastal Research, 65, 1874-1879. http://ics2013.org/papers/Paper4164_rev.pdf

Tutin, T., Heywood, V., Burges, N., Valentine, D., Walters, S., & Webb, D. (1964-1980). *Flora Europaea* (Vols. I-V). Cambridge: Cambridge University Press

Tzonev, R., Dimitrov, M., & Roussakova, V. (2005). Dune vegetation of the Bulgarian Black Sea coast. *Hacquetia, 4*(1), 7-32

Uslu, T., & Gehu, J. M. (1989). Syntanxonomic units and flora of Turkish coastal dunes. *Proceedings of the second International Colloquy on the Mediterranean Coasts and Protection of the Environment, Council of Europe*, (p. 42). Strasbourg

Vespremeanu, E. (1987). *Probleme de geomorfologie marină*. București. Tipografia Universității din București

Vespremeanu, E. (2004). Morfologia reliefului Deltei Dunării în ultimii 40 ani. *Sudii şi cercetări de oceanografie costieră, I*, 31-60. Bucureşti: Editura Universităţii din Bucureşti

Vespremeanu-Stroe, A., Preoteasa, L. (2007). Beach-dune interactions on the dry-temperate Danube delta coast. *Geomorphology*, 86, 267-282

Vespremeanu-Stroe, A., Cheval, S., & Tătui, F. (2012). The wind regime of Romania - characteristics, trends and North Atlantic Oscillation Influences. *Forum Geografic. Studii şi cercetari de geografie şi protecţia mediului, XI*(2), 118-126. doi:http://dx.doi.org/10.5775/fg.2067-4635.2012.003.d

Vladimirov, V., Feruzan, D. & Tan, K. (2012) New floristic records in the Balkans: 19. Phytologica Balcanica 18(2): 205-230. http://www.bio.bas.bg/~phytolbalcan/PDF/18_2/18_2_14_Vladimirov_&_al.pdf. Accessed 10 July 2015

Wiedemann, A., & Pickart, A. (2004). Temperate zone coastal dunes. In M. Martinez, & N. Psuty (Eds.), *Coastal Dunes. Ecology and conservation* (pp. 53-66). Berlin: Springer

Wrigth, J. (1927). Notes on strand plants. II. Cakile maritima Scop. *Transactions of the Botanical Society of Edinburgh, 19*(4), 389-401

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Derivation of ecological indicators for assessing landscape health and habitat disturbance in Lower Barpani watershed of Assam (India)

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Abstract

Landscape health is a primary concern for management of resources and restoration of habitats of various fauna and avifauna in watershed. We derived landscape health index using Landsat Thematic Mapper satellite data of 1987 and 2011. Standard precipitation index, normalized difference water index, normalized difference moisture index, normalized difference barren land index, normalized difference vegetation index, human disturbance, height, slope, land use/ land cover were integrated to assess landscape health and habitat disturbance in Lower Barpani watershed in India. Landscape health was categorized into five groups, i.e. very good, good, moderate, poor and very poor.
Spatial-temporal variation of landscape health revealed that the area under very good health has degraded from 45% in 1987 to only 1% registering a decrease of 97.26%. The area under good, moderate, poor and very poor categories of landscape health experienced positive change. Habitat disturbance in forests and wetlands has also increased due to shifting agriculture, deforestation and cultivation in wetlands. Remotely sensed indices of landscape health and habitat disturbance can effectively be utilized for prioritizing ecological restoration across space at various scales.

Keywords: *landscape health, habitat disturbance, remote sensing, GIS, watershed*

Rezumat. Derivarea indicilor ecologici pentru evaluarea sănătății peisajului și deranjarea habitatelor în bazinul inferior al râului Barpani, Assam (India)

Sănătatea peisajului este un element extrem de important pentru managementul corespunzător al resurselor și pentru restaurarea habitatelor naturale dintr-un bazin hidrografic. Cu ajutorul datelor satelitare oferite de Landsat Thematic MApper din 1987 și 2011, a fost determinat indicele sănătății peisajului. Pentru evaluarea sănătății peisajului și a gradului de deranjare a habitatelor naturale din bazinul inferior al râului Barpani din India, am realizat o analiză integrată a indicelui standardizat al precipitațiilor, indicelui normalizat de diferențiere a umidităații, indicelui normalizat de diferențiere a terenurilor neproductive, indicelui normalizat de diferențiere a vegetației, intervenția antropică, înălțimea, panta, modul de utilizare a terenurilor. Starea de sănătate a peisajului a fost împărțită în cinci categorii, i.e. foarte bună, bună, moderată, proastă și foarte proastă.
Variațiile spațiale și temporare ale sănătății peisajului indică faptul că arealul cu o sănătate foarte bună a peisajului s-a restrâns de la 45%, cât ocupa în 1987, la doar 1%, ceea ce implică o scădere cu 97,26%. Celelalte patru categorii au înregistrat o creștere a suprafețelor. Degradarea habitatului forestier și a zonelor umede s-a accentuat ca urmare a agriculturii itinerante, defrișărilor și luării în cultură a zonelor umede. Utilizarea teledetecției pentru evaluarea sănătății peisajului și deranjării habitatelor poate fi foarte eficientă pentru prioritizarea corespunzătoare a reconstrucției ecologice a spațiului la diferite scări.

Cuvinte-cheie: *sănătatea peisajului, deranjarea habitatelor, teledetecție, SIG, bazin hidrografic*

Introduction

Watershed is a natural unit of planning and development for enhancing ecology, biodiversity and livelihood in a holistic manner. Watersheds possessing freshwater ecosystems assume greater significance in social development (Naiman et al., 1998; Liu et al., 2008), but anthropogenic activities induced development within watersheds have negative impact on ecosystem structures, processes, and functions (Western, 2001). Human intervention with freshwater ecosystem may cause loss to keystone species and functional groups. It may also result in high rate of nutrient turnover, low level of resistance, high porosity of nutrients and sediments. Therefore, any restoration scheme of aquatic ecosystem should be made keeping in view the relation between watershed changes and corresponding impact on aquatic ecosystem and congenial habitat environment especially wetlands and forests (Kramer et al., 1997; Beaulieu et al., 1998; Oglethorpe & Sanderson, 1999; Roe & van Eeten, 2002). Anthropogenic activities have deleterious effects on forests and wetlands (Tiner, 2004). Availability of data on the condition of river and stream corridors, wetlands buffer zones and general environmental condition for whole watershed is requisite for strategic planning and management. Land use/land cover transformation, environmental pollution and fragmentation in forest are affecting health of flora and fauna (Ortigosa et al., 2000). Excessive hunting and poaching are also responsible for the extinction and decline of several species in many places (Dobson, 1995). Several studies have advocated the significance of maintaining vegetated buffers along streams and wetlands for fish and wildlife habitats (Osborne & Kovacic, 1993; Spackman & Hughes, 1995; Kilgo et al., 1998; Semlitsch &

Jensen, 2001). Hence, it is important to conserve the remaining suitable habitat and precisely manage these units for the survival of species (Duncan et al., 1995).

Monitoring and assessment of landscape changes and ecological implications has attracted the attention of many scholars globally (Malczewski et al., 2003; Lichtenberg & Ding, 2008; Suo et al., 2008; Zha et al., 2008; Shanwad et al., 2012). A number of studies have demonstrated the significance of landscape change in analyzing the environmental and ecological dynamics (Kumar, 1999; Sujatha et al., 2000; Jones et al., 2002; Jabbar et al., 2006; Tejpal, 2014). Irrational use of natural resources without any conservation scheme is a significant contributing factor for the watershed degradation. Deforestation and population pressure in the hills of Karbi Anglong district resulted in rapid change of the land use/land cover in the recent times. Boro paddy cultivation in the wetlands also aggravated watershed degradation by reducing wetland area in Nagaon district. Therefore, restoration of wetlands and sustainable use of resources is necessary for the management of ecological footprints of the landscape.

Several scholars have attempted to explore site specific indicators for assessing and monitoring landscape ecological conditions in watersheds. Aspinall and Pearson (2000) proposed landscape ecological indicators based on land cover matrix, biophysical conditions and biophysical trends. Rapport et al. (1998) evaluated landscape health through integrating societal goals and biophysical processes. Recently, the study of the relationships between land uses and water quality characteristics were considered spatial configuration to assessing landscape ecological health (Lee et al., 2009). Many scholars have attempted to analyze the impact of landscape transformation on habitat. Tiner (2004) proposed habitat extent and habitat disturbance indicators for assessing watershed condition. Ortigosa et al. (2000) described habitat suitability model in GIS environment by making use of meteorological, morphological, trophic, vegetation and anthropogenic indicators. Groom et al. (2006) explored the application of image data in specific landscape elements, general landscape habitats and landscape types and structures. Menon and Bawa (1997) examined application of remote sensing, GIS and landscape ecology approach to wildlife conservation. They used land use/land cover, habitat fragmentation, socio-economic drivers of land use/ land cover change, deforestation indicators for conservation planning. Osborne et al. (2001) presented landscape scale habitat model using high resolution satellite data and GIS. In this study, we have derived a set of remotely sensed indicators of 'landscape health' and 'habitat disturbance' to assess the general ecological condition of Lower Barpani watershed in Assam, India.

Study area

The Barpani River is a tributary of *Kopili* River of central Assam in India. Lower Barpani watershed is located mostly in Nagaon district and in some hilly terrain of Karbi Anglong district of Assam (Fig. 1).

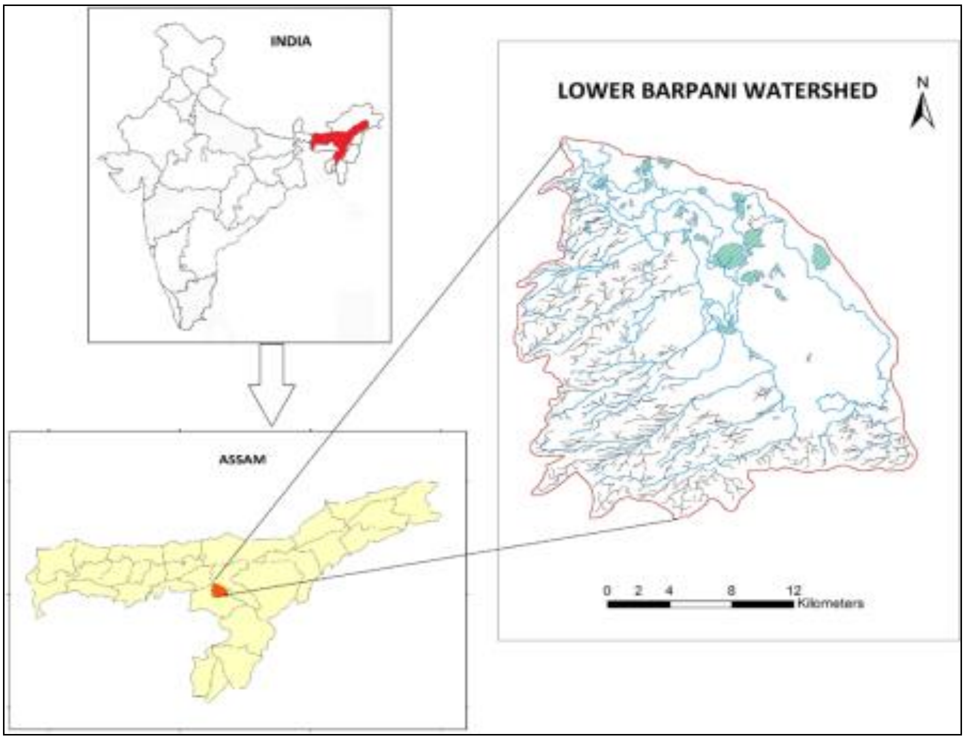

Fig. 1: Location of study area

The watershed extends from 25^0 52' N to 26^0 11' N latitudes and from 92^0 29' E to 92^0 44' E longitudes and covering an area of 47,272 hectares. All India Soil and Land Use Survey (1990) delineated watershed code of Lower Barpani River as 3B2A5.

The study area experiences monsoon type of climate enjoying average annual rainfall ranging from 1,000 mm to 2,000 mm. About 68% of the annual rainfall occurs during June – September with July being the rainiest month of the year (Department of Agriculture Assam, 2012). Topography of the study area is mostly plain in Nagaon district and undulating surfaces are dominant in Karbi Anglong district. Forests spread over undulating surface of Karbi Anglong district and cover 41% of the total watershed area. Agriculture is the dominant activity in the watershed where it shares almost 46% of total watershed area. Numerous wetlands are found in the plain region of Nagaon district which are surrounded by agricultural fields and settlements. Agriculture is also practiced in the wetlands during pre-monsoon season and locally known as *Boro* paddy cultivation.

Methodology

Landsat TM (Thematic Mapper) data of December 1987 and November 2011 were used in the present study. The watershed was demarcated using Survey of India Topographical sheets (83 B/12 and 83 B/13) based on the area and stream flow direction. Height and slope maps of the study area were prepared through ASTER DEM. Four meteorological stations, i.e. Chaparmukh, Lumding, Silchar and Guwahati were selected for collecting rainfall data for 1987 and 2011 (Statistical Handbook Assam, 1991, 2012). Different thematic layers were generated to analyze the health of the watershed. Land use / land cover classes were prepared to analyze the surface changes in both years. Other thematic layers like Normalized Difference Bare Land Index (NDBaI), Normalized Difference Moisture Index (NDMI), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Standard Precipitation Index (SPI) were generated to measure the intensity of these factors over the landscape. Rainfall is an important and basic indicator for assessing ecological status of the landscape. Intensity of precipitation was derived through Standard Precipitation Index (SPI) where positive SPI value indicates greater than median precipitation and negative value indicates less than median precipitation or drought condition (McKee et al., 1993). Standard Precipitation Index was calculated using equation (1):

$$SPI=\frac{\text{Rainfall(mm)-Mean Rainfall}}{SD} \qquad (1)$$

Normalized Difference Bare Land Index (NDBaI) is based on high dependence between bare soil and vegetation status. By combining both these, a range is derived. The status of vegetation and exposed soil condition can be assessed on a continuum ranging from high to low (Rikimaru et al., 2002). The index is expressed as:

$$NDBaI=\frac{(SWIR - Red) - (NIR - Blue)}{(SWIR + Red) + (NIR + Blue) + 1} \qquad (2)$$

NDMI is characteristics of different land use / land cover identified in near infrared and mid infrared band based on their moisture content (Wilson & Sader, 2002). Near infrared is sensitive to reflectance of leaf chlorophyll content while mid infrared to the absorption of leaf moisture (Gao, 1996). NDMI is calculated as:

$$NDMI=\frac{(NIR - MIR)}{(NIR + MIR)} \qquad (3)$$

NDVI is the widely-used vegetation index and is basically the difference of vegetation reflectance in Near Infrared and Red bands (Rouse et al., 1974). It may be enumerated as:

$$NDVI=\frac{(NIR - Red)}{(NIR + Red)} \qquad (4)$$

Many methods are used to delineate water like thresholding and spectral water index method using single band (Sakamoto et al., 2007). NDWI has advantage over these methods since water pixels can easily be discriminated using two bands and there are few chances of merging water pixels with pixels of other classes (Mcfeeters, 1996).

$$NDWI=\frac{(Green - NIR)}{(Green + NIR)} \qquad (5)$$

The landscape health index is an important tool assessing management and planning perspectives within watershed. We gave comparative weight to all the land use / land cover classes for examining the landscape health in the watershed. Water bodies which are significant features in watershed were put under highest weight category followed by agricultural land, vegetation, bare land and settlements. In order to get spatial pattern of Standard Precipitation Index, interpolation was done by ordinary kriging of spatial analysis and subsequently isopleths were prepared for study periods. The output raster layers were superimposed through weight overlay (Equation 6) method and the final landscape health map was generated. Landscape health is expressed here as:

$$LH=\left[\sum\left({C_1W_1}/{A}\right)\times 100+\left({C_2W_2}/{A}\right)\times 100+\ldots\ldots\ldots\left({C_nW_n}/{A}\right)\times 100\right] \quad (6)$$

Where,
LH = Landscape Health
C = Area under different classes (1-----------n)
W = Weight assigned to classes (1-----------n)
A = Total area of watershed

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Habitat disturbance (HD) in forests and wetlands was assessed as a function of different environmental factors (terrain morphology, land use, vegetation cover, meteorological conditions and spatial distribution of human activities). These factors determine the habitat disturbance for species and their distribution (Morrison et al., 1992). Height, slope, NDVI, SPI, NDMI and human disturbance layers were generated for assessing forest habitat disturbance. Height and slope layers were generated from DEM data and spatial distribution of rainfall was generated through interpolation of station data. Human disturbance layer was prepared by taking disturbance objects (roads, settlement, agriculture, etc.) and generating buffer according to their disturbance capability. Habitat disturbance in wetlands was assessed through NDWI, NDVI, SPI and human disturbance layers. Habitat disturbance index was then assessed through integrating all these layers and giving weight to each layer and following equation 7.

$$HD=\left[\sum (DI_1W_1)+(DI_2W_2)+\ldots\ldots\ldots(DI_nW_n)/N\right] \quad (7)$$

Where,
HD = Habitat disturbance
DI = Disturbance index of different layer (1--------n)
W = Weight assign to index (1--------n)
N = Total number of layers

Results and Discussions

Landscape Health (LH)

Five thematic layers, i.e. land use/ land cover, NDWI, NDMI, NDBal and NDVI were prepared and integrated to derive landscape health index. Six prominent classes of land cover during 1987 and 2011 were classified, i.e. agricultural land, *Jhum* cultivation, forest, built up area, barren land and water body. A close perusal of land use/ land cover maps across two dates shows that agricultural land has increased substantially followed by barren land, built-up and *Jhum* cultivation (Fig. 2).

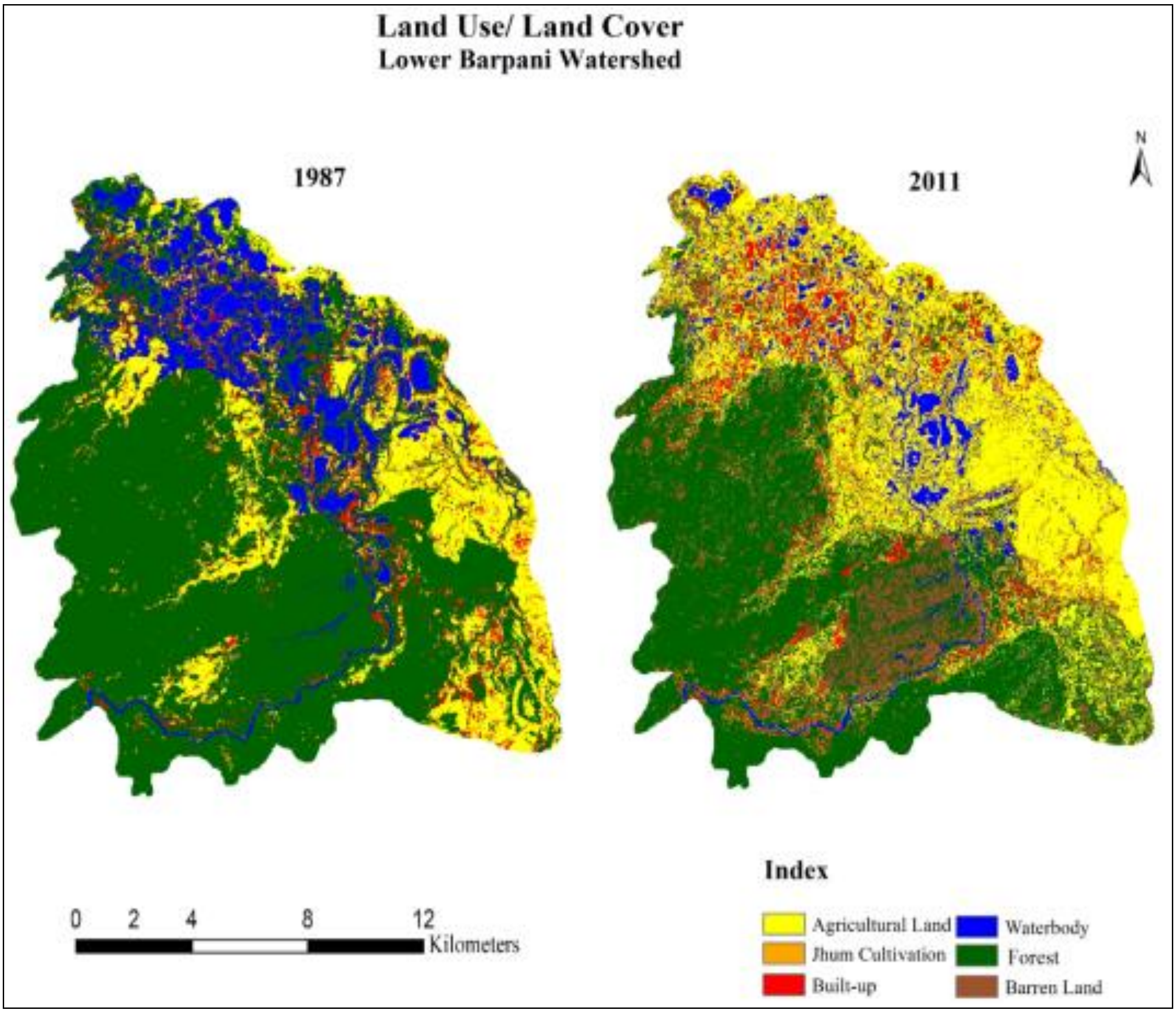

Fig. 2: Land use/ land cover change during 1987-2011 (also taken as indicator of landscape health)

Deforestation and agricultural practices in wetlands are significant causes of increase in agricultural area within the watershed (Fig. 2). A conspicuous change was observed in barren land. It has increased from 66 hectares to 3567 hectares in 2011, thus increasing 54 times since 1987, partially due to deforestation in Barpani Reserve Forest and partially due to non-utilization of this land for other activities such as agriculture and afforestation in particularly in the southern part of the watershed (Fig. 2). Deforestation due to *Jhum* cultivation (shifting cultivation) has also accelerated intensity of landscape degradation in the watershed.

Standard Precipitation Index (SPI) values over study area revealed almost drought like conditions during 1987, since SPI values were negative. Contrary study area experienced positive SPI values exerting great influence on land uses/ land cover during 2011. The values registered by the Normalized Difference Bare Land Index during 1987 showed larger area under barren land due to drought conditions; therefore, it was considered as a temporary barren land, but in 2011 its area increased due to deforestation and hence it was considered as a permanent barren land (Fig. 3a). The Normalized Difference Moisture Index indicated a significant amount of surface moisture during 1987 and 2011 (Fig. 3b). The area under vegetation showed less moisture in 1987 than 2011. Moisture was sufficiently available in wetlands in 1987, but it reduced to minimum in 2011 mainly because of practicing agriculture in wetlands.

Table 1: Area under Land use/ land cover and their change

Land use/land cover	1987		2011		Change	
	Area in Hectare	Area in Percentage	Area in Hectare	Area in Percentage	Area in Hectare	Percentage of Change
Agricultural land	9049	18.21	17424	35.07	+8375	+92.59
Jhum cultivation	198	0.41	529	1.06	+331	+158.54
Built-up	3337	6.72	4124	8.30	+787	+23.51
Water body	5471	11.01	2854	5.74	-2617	-47.87
Forest	31560	63.52	21183	42.64	-10377	-17.13
Barren Land	66	0.13	3567	7.18	+3501	+5423.07

Source: Authors' calculations from land use/ land cover classification

The spatial-temporal distribution of the Normalized Difference Vegetation Index shows variation in vegetation. It can be clearly seen from the map that NDVI is low in agricultural landscape due to larger extent of fallow land in 1987 (Fig. 3c) the status of surface vegetation Condition in 2011 was found very good due to agricultural activity in that year. Some area under forest and wetland was transformed into agricultural land. This condition of land transformation contributed negative weight to assessing landscape health and habitat disturbance.

The Normalized Difference Water Index revealed a significant decrease in the area under surface water bodies during the study period (1987-2011). In 1987, wetlands were filled up with water and they provided nutrition to watershed and helped in ground water recharge, while in 2011 NDWI showed a reduction in area under water bodies though the rainfall this particular year was better than the preceding year (Fig. 4a).

Practice of agriculture in wetlands and deforestation retarded water holding and ground water recharge capacity of watershed. Alteration in the landscape affected aquatic and forest wildlife habitat through destruction and degradation in the watershed. Table 1 shows that area under forest and water body (mostly waterlogged wetlands) has decreased during the study period. Fragmentation and reduction of habitat by human developmental activities created major problems for maintaining habitat suitability (Fig. 4b).

The spatial and temporal analysis of landscape health (LH) shows degradation in landscape (Fig. 5 and Table 2). Very good status of LH has decreased from 45% in 1987 to 1% in 2011 registering a decrease of 97%.

Jhum cultivation in the south western and western part of watershed affected landscape health to a great extent. Jhum cultivation is a shifting agriculture practiced by clearing forest in the hilly slope and when soil fertility is reduced after two to three years, then another land is cleared for cultivation. This practice has not only degraded forest cover, but it has also increased soil erosion. Good status of ecological health has conspicuously augmented from 18% in 1987 to 52% in 2011, experiencing an increase of 186%. This tremendous increase in the category was gained from very good status.

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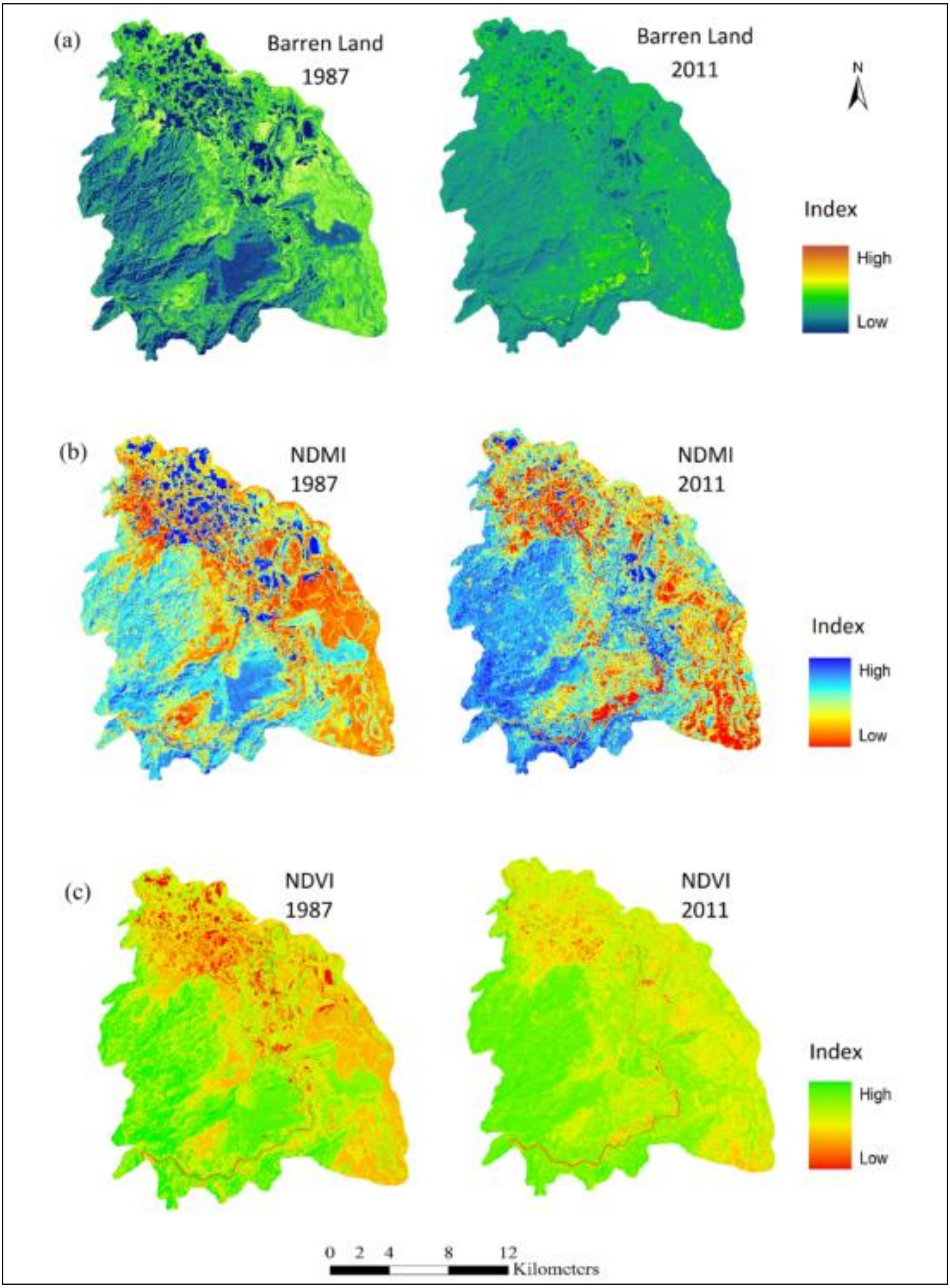

Fig. 3: Indicators of landscape health: (a) barren land, (b) surface moisture and (c) vegetation cover
Indicators of habitat disturbance in forest: (b) surface moisture and (c) vegetation cover.
Indicators of habitat disturbance in wetland: (c) vegetation cover

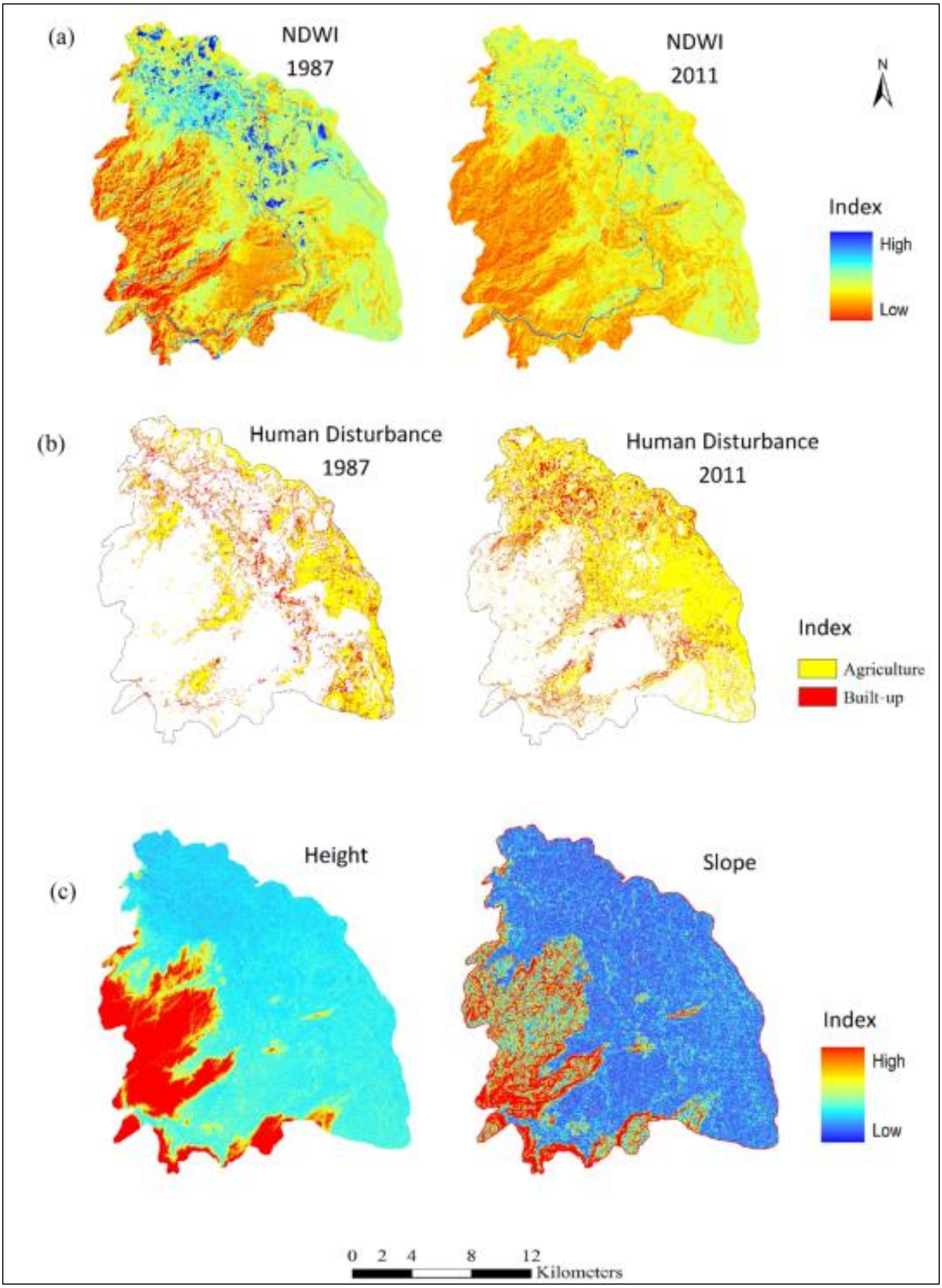

Fig. 4: Indicator of landscape health: (a) surface water.
Indicators of habitat disturbance in forest: (b) human disturbance and (c) height and slope.
Indicators of habitat disturbance in wetland: (a) surface water and (b) human disturbance

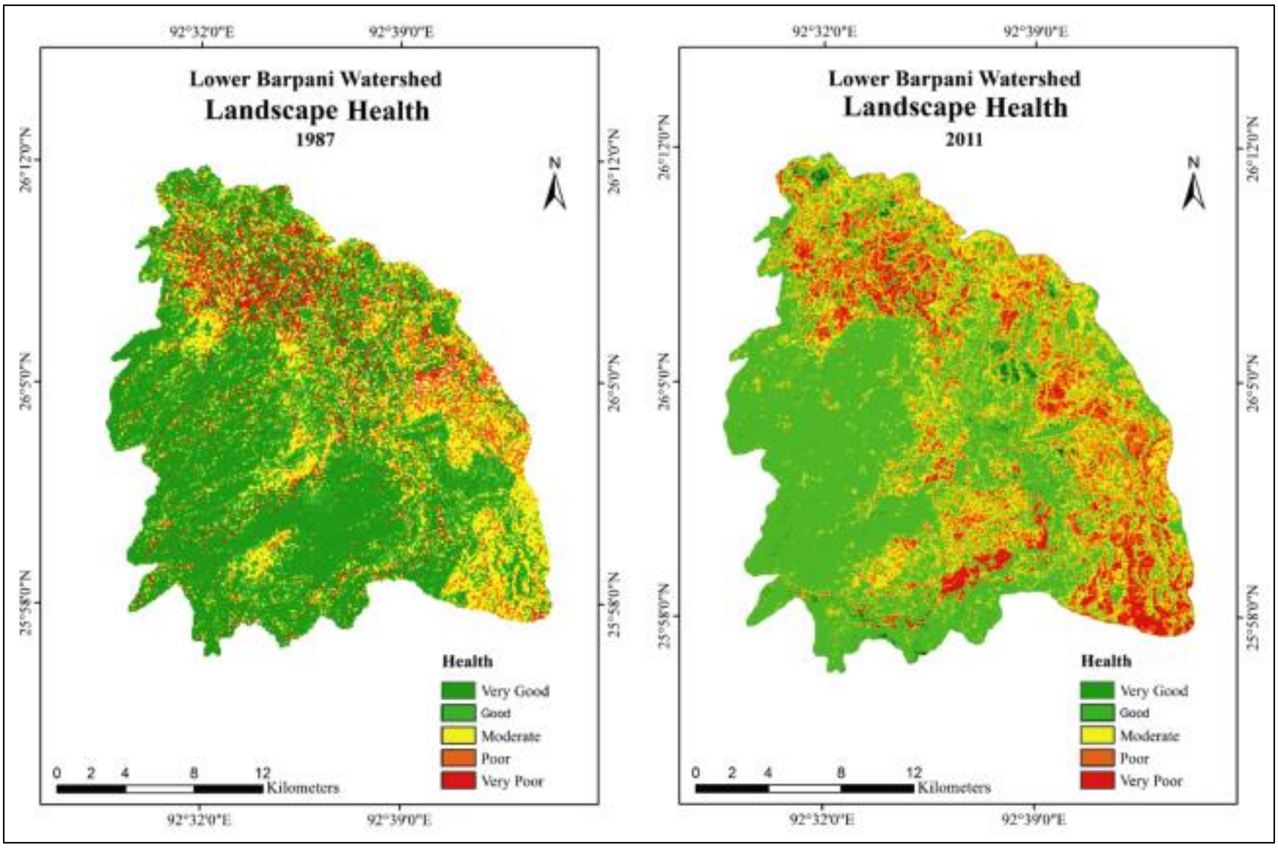

Fig. 5: Landscape health (1987-2011)

Table 2: Area under landscape health

LEH index	1987 (in %)	2011 (in %)	Percentage of Change
Very good	45.27	1.24	-97.26
Good	18.08	51.74	+186.17
Moderate	21.46	23.84	+11.09
Poor	10.80	16.74	+55.00
Very poor	4.38	6.43	+46.80

Source: Authors' calculation from LH map

Nearly half of the watershed has good status of landscape health while the rest is under moderate, poor and very poor categories of LH. Area under poor ecological heath has increased from 10.1% in 1987 to 16.7% in 2011. It has occurred mainly in northern and eastern parts of the watershed due to the occupancies of wetlands for agricultural purposes. Very poor status has also increased from 4% in 1987 to 6% in 2011. The change in this category was observed in those areas where landscape has been transformed into agriculture and built-up. Moderate ecological status has remained same during 1987-2011.

Habitat Disturbance

Application of habitat disturbance indicators during 1987-2011 helped in analyzing extent of habitat area within the watershed. Habitat disturbance in forests and wetlands has been assessed in this study (Table 3). Of the total forest area of the watershed (41%), only 9% was disturbed free in 1987 and further reduced to 4% in 2011 (Fig. 6). Thus, a loss of 57% area has threatened the habitat of wild Asiatic elephant, leopard, wild cat, wild pigs, and barking deer during 1987-2011. Consequently, many animals sought new habitats and food sources which triggered conflict between humans and wild animals. Field visit revealed that such conflict is a common problem in south western part of the watershed. Many villages namely Rajagaon, Lutumari, Madhabpara and Singimari are under frequent attack of wild elephants. The elephants move out for food and damage agricultural crops.

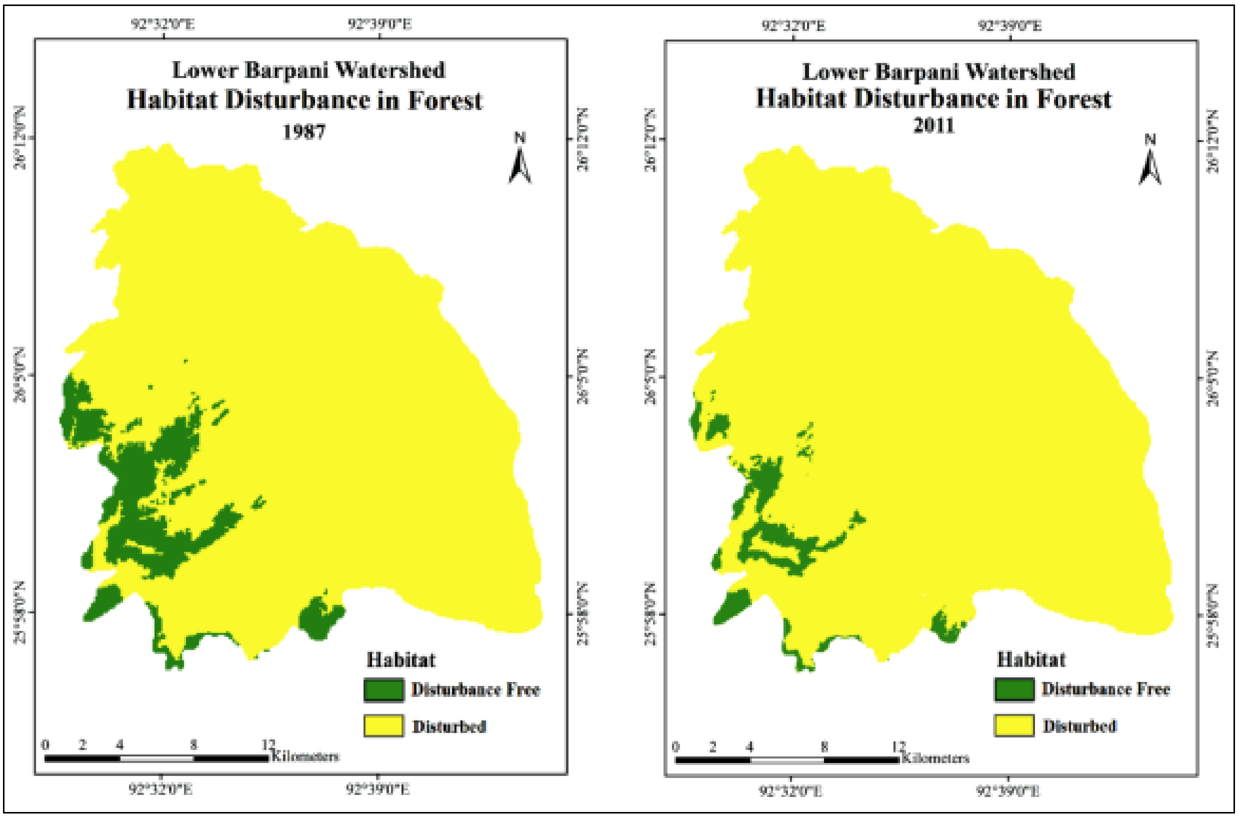

Fig. 6: Habitat disturbance in forests (1987-2011)

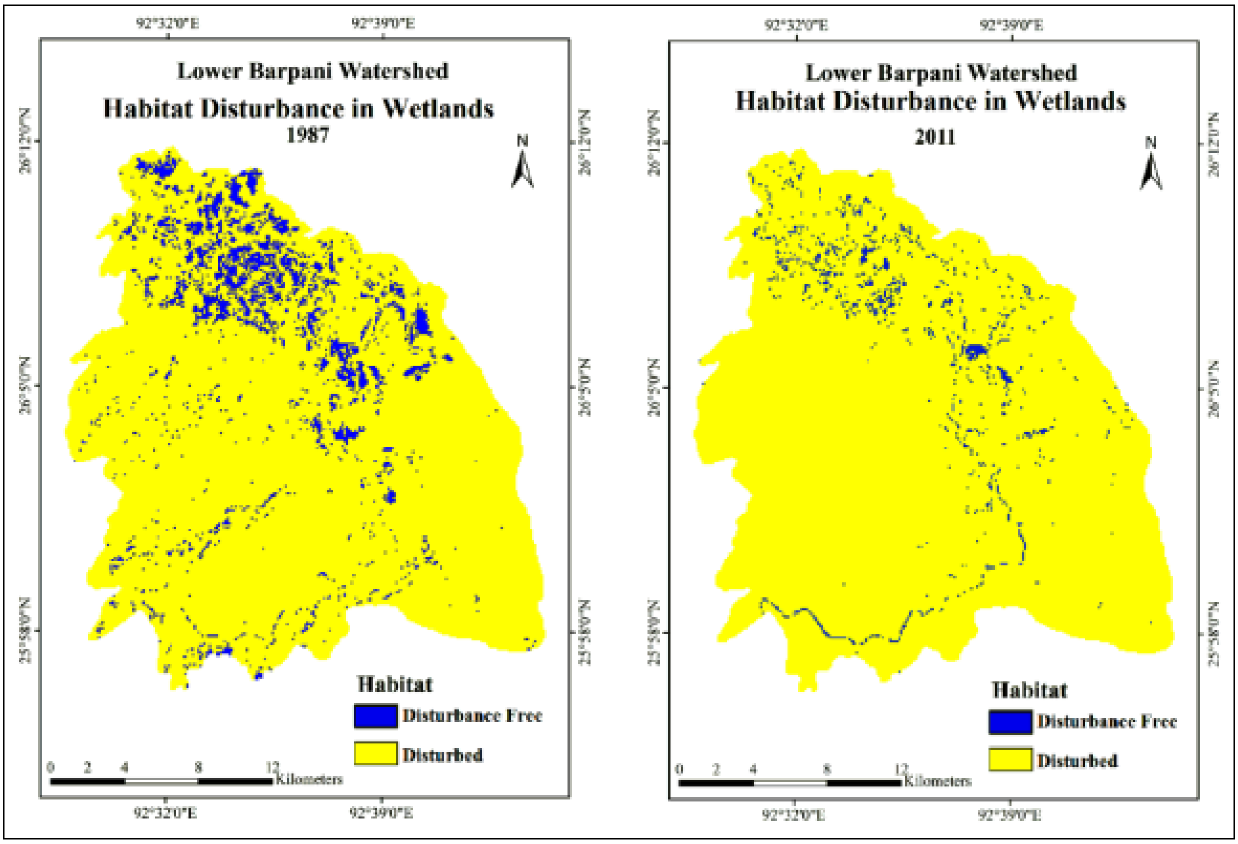

Fig. 7: Habitat disturbance in wetlands (1987-2011)

Table 3: Area under disturbed free habitat within watershed

Habitat	1987 (%)	2011 (%)	Percentage of Change
Forest	9.08	3.90	-57.04
Wetland	5.44	2.51	-53.86

Source: Authors' calculation from disturbance map

Wetlands experienced a loss of 53.8% habitat area of varied avifauna and aquatic animals during 1987-2011 (Fig. 7). These wetlands have transformed into agricultural fields over the years. Wintering of major species of avifauna mainly migratory birds, i.e. geese, ducks, kingfisher, herons, shanks, terns and cranes in the watershed has been reduced. These wetlands are also a source of livelihood and food for local inhabitants through fishing and hunting. Water holding capacity has reduced and ground water level has lowered due to human intervention in wetlands affecting surrounding landscape. These wetlands require urgent attention for arresting environmental stability and ecological sustainability in the watershed.

Conclusions

Degradation of watershed landscape due to anthropogenic activities is a major consequence to habitat disturbance in forests and wetlands. Habitat disturbance in forests in the watershed resulted in conflict between man and wild animals. Also, agricultural activity in wetlands and surrounding areas has reduced habitat for aquatic animals and avifauna.

Sustainable development of land and ecological management through participatory planning, generating awareness, building institutions and supporting integrated farm is the basic need of Lower Barpani watershed. Land cover changes in forests and wetlands have implications for biodiversity conservation and livelihoods and interrelationship between them in the watershed.

The current national and state policies along with the strategies being implemented by the government, multilateral agencies and other organizations need to focus on landscape ecology and habitat suitability.

Remotely sensed indices of landscape health and habitat disturbance provided a useful methodological framework of spatial-temporal monitoring and environmental assessment. The site-specific indicators based on weight overlay in GIS environment can effectively be helpful in assessing landscape health and habitat disturbance and prioritizing potential areas for ecological restoration at various scales in other areas.

References

All India Soil and Land Use Survey. (1990). Watershed Atlas of India. Ministry of Agriculture, Govt. of India: New Delhi

Aspinall, R. & Pearson, D. (2000). Integrated geographical assessment of environmental condition in water catchments: Linking landscape ecology, environmental modelling and GIS. *Journal of Environmental Management,* 59(4), 299-319

Beaulieu, J., Bennett D., Kraft, S. & Sengupta, R. (1998). Ecological–economic modeling on a watershed basis: a case study of the cache river of southern Illinois. *American Journal of Agricultural Economics,* 80(5), 14 p.

Department of Agriculture. (2012). District-wise Rainfall Data. Government of Assam. http://www.agriassam.in/rainfall/rainfall.htm. Accessed 02 February 2015

Dobson, A. P. (1995). *Conservation and Biodiversity.* Scientific American Library: New York

Duncan, B. W., Breininger, D. R., Schmalzer, P. A. & Larson, V. (1995). Validating a Florida scrub jay habitat suitability model, using demography data on Kennedy Space Center. *Photogrammetric Engineering and Remote Sensing,* 11(61), 1361–1370

Gao, B. C. (1996). NDWI-A normalized difference water index for remote sensing of vegetation liquid water from space. *Remote Sensing of Environment,* 58, 257-266

Groom, G., Mucher, C. A., Ihse, M. & Wrbka, T. (2006). Remote sensing in landscape ecology: experiences and perspectives in a European context. Landscape Ecology, 21, 391-408

Jabbar, M. T., Shi, Z., Wang, T. & Cat, C. (2006). Vegetation change prediction with geo information techniques in three gorges area of China. *Pedosphere,* 16(4), 457-467

Jones, C., Palmer, R. M., Motkaluk, S. & Walters, M. (2002). *Watershed Health Monitoring: Emerging Technologies*. CRC press, London

Kilgo, J. C., Sargent, R. A., Chapman, B. R. & Miller, K. V. (1998). Effects of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. *Journal of Wildlife Management,* 62(1), 72-83

Kramer, R. A., Richter, D. D., Pattanayak, S. & Sharma, N. P. (1997). Ecological and economic analysis of watershed protection in Eastern Madagascar. *Journal of Environmental Management,* 49(3), 277-295

Kumar, A. (1999). Sustainable utilization of water resources in watershed perspective – a case study in Alaunja watershed, Hazaribag, Bihar. *Journal of the Indian Society of Remote Sensing*, 27(1), 13-22. doi: 10.1007/BF02990771

Lee, S. W., Hwang, S. J., Lee, S. B., Hwang, H. S. & Sung, H.C. (2009). Landscape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics. *Landscape and Urban Planning,* 92(2), 80-89

Lichtenberg, E. & Ding, C. (2008). Assessing farmland protection policy in China. *Journal of Land Use Policy,* 25, 59-68

Liu. Y., Guo, H., Yu, Y., Dai, Y. & Zhou, F. (2008). Ecological-economic modeling as a tool for watershed management: A case study of Lake Qionghai watershed, China. *Limnologica,* 38, 89-104

Malczewski, J., Chapman, T., Flegel, C., Walters, D., Shrubsole, D. & Healy, M. A. (2003). GIS multi-criteria evaluation with ordered weighted averaging (OWA): case study of developing watershed management strategies. *Environmental Planning,* 35(10), 1769-1784

Mcfeeters, S. K. (1996). The use of the normalized difference water index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing,* 17, 1425-1432

McKee, T. B., Doesken, N. J. & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. 8th Conference on Applied Climatology, Anaheim, California, January 17-22

Menon, S. & Bawa, K.S. (1997). Applications of Geographic Information Systems, Remote-Sensing, and a Landscape Ecology Approach to Biodiversity Conservation in the Western Ghats. Current Science, 73(2), 134-145

Morrison, M. L., Marcot, B. G., & Mannan, R. W. (1992). *Wildlife-Habitat Relationships. Concepts and Applications.* The University of Wisconsin Press: Madison, WI

Naiman, R. J., Magnuson, J. J. & Firth, P. L. (1998). Integrating cultural, economic, and environmental requirements for fresh water. *Ecological Applications,* 8(3), 569–570

Oglethorpe, D. R. & Sanderson, R.A. (1999). An ecological–economic model for agri-environmental policy analysis. *Ecological Economics,* 28(2), 245–266.

Ortigosa, G. R., De Leo, G. A. & Gatto, M. (2000). VVF: integrating modelling and GIS in a software tool for habitat suitability assessment. *Environmental Modelling & Software,* 15, 1-12

Osborne, L. L. & Kovacic, D. A. (1993). Riparian vegetated strips in water-quality restoration and stream management. *Freshwater Biology,* 29, 243–258

Osborne, P. E., Alonso, J. C. & Bryant, R. G. (2001). Modelling landscape-scale habitat use using GIS and remote sensing: a case study with great bustards. *Journal of Applied Ecology,* 38 (2), 458-471

Rapport, D. J., Gaudet, C., Karr, J. R., Baron, J. S., Bohlen, C., Jackson, W., Jones, B., Naiman, R.J., Norton, B. & Pollock, M.M. (1998). Evaluating landscape health: integrating societal goals and biophysical process. *Journal of Environmental Management,* 53(1), 1-15

Rikimaru, A., Roy, P. S. & Miyatake, S. (2002). Tropical forest cover density mapping. *Tropical Ecology,* 43(1), 39-47

Roe, E. & van Eeten, M. (2002). Reconciling ecosystem rehabilitation and service reliability mandates in large technical systems: findings and implications, of three major US ecosystem management initiatives for managing human- dominated aquatic-terrestrial ecosystems. *Ecosystems,* 5(6), 509–528

Rouse, J. W., Haas, R. H., Schell, J. A. & Deering, D. W. (1974). Monitoring vegetation systems in the Great Plains with ERTS. Third Earth Resources Technology Satellite–1 Syposium. Volume I: Technical Presentations, NASA SP-351(I), 309-317

Sakamoto, T., Nguyen, N. V., Kotera, A., Ohno, H., Ishitsuka, N. & Yokozawa, M. (2007). Detecting temporal changes in the extent of annual flooding within the combodia and the Vietnames Mekong delta from MODIS time series imageries. *Remote Sensing of Environment,* 109(3), 295-313

Semlitsch, R. D. & Jensen, J. B. (2001). Resolving the distinction between buffer zone & core habitats around wetlands: Missouri Chapter of the Society for Conservation Biology. *The Glade* 4(17), 10–11

Shanwad, U. K., Gowda, H. H., Prabhuraj, D. K., Reddy, K.A. & Laxmikant, B.P. (2012). Impact assessment of watershed programme through remote sensing and geographical information system. *Journal of the Indian Society of Remote Sensing,* 40(4), 619-628

Spackman, S. C. & Hughes, J. W. (1995). Assessment of minimum stream corridor width for biological conservation: species richness and distribution along mid-order streams in Vermont, USA. *Biological Conservation,* 71, 325–332

Statistical Hand Book Assam. (1991) Directorate of Economics and Statistics, Government of Assam: Guwahati-28

Statistical Hand Book Assam. (2012) Directorate of Economics and Statistics, Government of Assam: Guwahati-28

Sujatha. G., Dwivedi, R. S., Sreenivas, K. S. & Venkaratathan, L. (2000). Mapping and monitoring of degraded lands in a part of Jaunpur district of Uttar Pradesh using temporal space-bone multispectral data. *International Journal of Remote Sensing.* 21(3), 519-531

Suo, A. N., Xiong, Y. C., Wang, T. M., Yue, D. X. & Ge, J. P. (2008). Ecosystem health assessment of the Jinghe river watershed on the Huangtu Plateau. *Ecological Health,* 5, 127-136

Tejpal, (2014). Monitoring ecological health of Dohan watershed in Aravali hills of Rajasthan and Haryana. *Punjab Geographer,* 10, 3-22

Tiner, R. W. (2004). Remotely-sensed indicators for monitoring the general condition of natural habitat in watersheds: an application for Delaware's Nanticoke River watershed. *Ecological Indicators,* 4, 227-243

Western, D. (2001). Human-modified ecosystems and future evolution. Proceedings of the National Academy of Sciences of the United States of America. 98(10), 5458–5465

Wilson, E. H. & Sader, S. A. (2002). Detection of forest type using multi dates of Landsat TM imagery. *Remote Sensing of Environment,* 80, 385-396

Zha, Y., Liu, Y. S. & Deng, X. Z. (2008). A landscape approach to quantify land cover change in Yulin, Northwest China. *Environmental Monitoring and Assessment* 138:139-147. Doi: 10.1007/s10661-007-9751-x

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Demographic Development of Settlements in the South Banat County / District

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Abstract

The demographic development of Vojvodina settlements takes place in accordance with the laws of the urbanization process, which is manifested in two phases: the first - after the Second World War until the beginning of the 80's of the 20th century, which is characterized by a polycentric polarization, and the second – monocentric polarization, which is still present. Since the settlements leave a fundamental mark on the cultural landscape and are the main carriers of the functional organization and focal transformation of geospace, the paper analyzes spatial-demographic and functional determinants of development of the settlement network of the South Banat County (district) on the basis of quantitative and qualitative indicators.
The settlement network includes 94 settlements distributed on the territory of 8 municipalities: Pančevo[1], Vršac, Kovin, Alibunar, Bela Crkva, Kovačica, Opovo and Plandište. The time period of the analysis and statistical survey of demographic components in the settlement network is observed through three inter-census periods, as follows: 1981-1991, 1991-2002 and 2002-2011. The analysis of demographic components has indicated that two poles of population concentration dominate within the network of settlements in this district: Pančevo (a sub-centre of the Belgrade - Novi Sad metropolitan area) and Vršac in comparison to other urban centres and the municipality centres.

Keywords: *South Banat county, settlement network, natural and mechanic movement of population, spatial-demographic transformation of settlements*

Rezumat. Dezvoltarea demografică a așezărilor din districtul Banatul de Sud

Dezvoltarea demografică a așezărilor din Voievodina se face în concordanță cu legile procesului de urbanizare, ce s-a manifestat în două etape: prima, începută după cel de al doilea război mondial, a ținut pană la începutul anilor 80 din secolul al XX-lea, și s-a caracterizat printr-o polarizare policentrică; cea de a doua etapă, care continuă și în prezent, este cea a polarizării monocentrice. Întrucât așezările lasă o amprentă fundamentală asupra peisajului cultural, fiind totodată principalul determinant al organizării funcționale și transformărilor spațiului geografic, lucrarea de față analizează dezvoltarea spațial-demografică și funcțională a rețelei de așezri din districtul Banatul de Sd, pe baza unor indicatori cantitativi și calitativi.
Rețeaua de așezări cuprinde 94 de localități grupate în 8 municipalități: Pančevo[2], Vršac, Kovin, Alibunar, Bela Crkva, Kovačica, Opovo and Plandište. Datele statistice pentru componentele demografice ale rețelei de așezări sunt analizate pentru trei perioade inter-censuare, respectiv 1981-1991, 1991-2002 și 2002-2011. Analiza componentelor demografice a indicat existența a doi poli de concentrare a populației, ce domină rețeaua de așezări a districtului: Pančevo (un sub-centru al zonei metropolitane Belgrad-Novi Sad) și Vršac.

Cuvinte-cheie: *Banatul de Sud, rețeaua de așezări, mișcarea naturală și migratorie a populației, transformări spațio-demografice ale așezărillor*

Introduction

Socio-economic processes, based on the dynamic changes in the spatial and socio-economic mobility of population from rural settlements to urban or to municipal and regional centres, as well as from less developed to more developed areas of the country, from primary to secondary and tertiary or quaternary activities influenced the spatial and demographic transformation of the settlements of South Banat County / District. The main driver of these processes was urbanization whose stages followed each other successively from the Second World War to the beginning of the 80's of the 20th century, and from the 80's until today. In the first phase of urbanization, with certain modifications and customization in accordance with the historical and geographic conditions, when rapid industrialization started too, the settlements of the South Banat County / District were characterized by a concentration of functions. Since then, the industry, along with its side effects, influenced this rapid increase in municipal and urban population. The number of inhabitants of the county / district increased from 279,092 to 340,189 people from 1948 to 1981. The Town of Pančevo had the main contribution to the demographic growth (an increase from 70,943 to 123,791 inhabitants). The rural population declined from 178,672 to 167,710 residents, while the share of urban population increased from 36% to 50.7%. The second phase of urban development of the South Banat County / District is characterized by continuous depopulation induced by a mechanical movement of the population and the ongoing reduction of natural increase, which had a negative character in all communities at the beginning of the 21st century.

[1] Under the Law on Territorial Organization of the Republic of Serbia from 2007 Pančevo municipality was given the status of a town, and in 2016, Vršac was given the status of a town

[2] Conform Legii Organizării Spațiului Republicii Serbia, din anul 2007 Pancevo are statut de oraș, iar Vrsac din anul 2016.

Consequently, all the municipalities in general were affected by the process of depopulation as well as other settlements in the observed geospace except the settlement of Ritiševo in Vršac municipality that was the only one to record an increase in the number of inhabitants from 2002 to 2011.

The issue of socio-economic and spatial mobility of the population of both Serbia and Vojvodina is quite well studied in the geographic and demographic literature. (Ilić, 1970; Đurić, 1971; Ginić, 1978; Ćurčić, 1979, 1985, 1987; Spasovski, 1983; Spasovski, Janić, 1990/91; Đurđev, 1995; Tošić, 1999; Krunić, 2012. etc.), so that the focus of this paper will be on determining the changes in the development and distribution of the population of the South Banat County / District, which took place in the period 1981-2011.

Research Methodology

In both former and future, spatial-demographic development, all demographic phenomena and processes are interpreted using synthesizing indicators with the aim of identifying qualitative and quantitative characteristics of the population. The analysis of natural and mechanical movement of the population is based on the available census data and vital statistics of the Statistical Office in Belgrade and the available theoretical literature. However, for a more detailed analysis of dynamic changes of the population inter-census changes are not enough. A more detailed picture of a certain territory or any settlement or time period is obtained on the basis of analysis of more complex indicators. The types of population movements present one of the more complex indicators, which are determined by linking the changes in the overall population trends with changes in its migration and natural components.

Applying the well-known W. Clark model of types of population movement, which was introduced into Yugoslav literature in the 70's of the 20th century, and which was repeatedly applied in the scientific and professional practice (Friganović, 1972/73; Tošić, 1999; Nejašmić, 2005; Vojković, 2007; Tošić, Krunić, Milijić, 2009; Nevenić, 2013), in the geospace of the South Banat County / District, eight types of population movements have been identified. These are the four emigration types: emigration (E1), depopulation (E2), extreme depopulation (E3), total depopulation (extinction E4), and four immigration types: expansion through immigration (I1), regeneration through immigration (I2), weak regeneration through immigration (I3) and extremely weak regeneration through immigration (I4).

Changes in the natural movement of population

An important determinant of demographic development of each territory and its settlements is the natural movement of the population. From the analysis of the indicators of the components of natural movement of population within the settlements in the South Banat County / District it can be concluded clearly that in the period from 1981 to 1991 the municipalities of Bela Crkva (0.21 ‰), Kovin (0.93 ‰), Opovo (0 27 ‰) and the Town of Pančevo (3.87 ‰) had a positive rate of natural increase overall, while in the next two inter-census periods (1991-2002 and 2002-2011) in all the analyzed municipalities it had a negative value. This is the result of a successive reduction in birth rate and an increase in mortality rate, both in rural and urban settlements, in total and individually and in municipal centres as well.

In the inter-census period of 1981-1991, in all settlements of the South Banat County / District 42,603 children were born, out of which 22,301 (52.3%) were born in urban areas. The highest number of children was registered in the heart of the district - the Town of Pančevo (16,940), and the lowest in Opovo (1490). Consequently, the average birth rate is the highest in the Town of Pančevo (13.60 ‰). At the same time, on the territory of the South Banat County / District 39,924 individuals died overall, of which 17,900 in urban settlements. The highest mortality rate was 14.88 ‰ in the municipality of Plandište, and the lowest in the Town of Pančevo (9.73 ‰). A positive average rate of natural increase of population was recorded in the municipalities of Bela Crkva, Kovin, Opovo and Pančevo. When individual settlements are observed, it is concluded that 28 of them have a positive and 66 a negative natural increase. The highest positive rate of natural increase is recorded in the settlements on the territory of the Town of Pančevo – Jabuka (7.16 ‰) and Kačarevo (6.09 ‰), and the lowest in the village Stari Lec (-34.99 ‰) in the municipality of Plandište.

Between the censuses of 1991 and 2002, the process of depopulation of a large number of settlements continued. In fact, compared to the previous inter-census period, in all 94 settlements in the eight municipalities of the South Banat County / District, 36,680 children were born (5,923 less in relation to the previously analyzed period), while in urban settlements, fewer children were born – 19,943. Meanwhile, 50,325 people died, of which 24,336 in urban settlements. There was a negative average population growth rate for all the municipalities in the South Banat County / District. Thus, it can be concluded that all settlements in the South Banat County / District recorded an absence of population growth during this inter-census period. Individual observation throughout the studied territory showed that only two villages on the territory of the municipality of Bela Crkva: Kusić (1.89‰), and the Crvena Crkva (2.60‰) exhibited

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positive values of natural increase. The settlement of Kusić is a borderline village next to Romania, while Crvena Crkva is a suburb area, the parts of which merged with the municipal centre in the morphological sense.

In the last inter-census period 2002-2011, this process was even more intense. In all the settlements of the studied territory 26,758 children were born, while in urban settlements there were born 15,721. During the same period, 41,148 people died, out of which 21.097 inhabitants in the urban areas. The numbers of births and deaths clearly indicate that the population growth in all communities of the observed territory has a negative value. Even more alarming is the emergence of settlements exhibiting a phenomenon of denatality. In certain years of this period, not a single child was born in some settlements. This is the case of Laudonovac settlement in the municipality of Plandište where only one child was born, and Vršački Ritovi on the territory of the municipality of Vršac in which three children were born.

The consistency of these processes caused the gradual ageing of the population, both in Serbia and in South Banat County / District. The average age of the population in the county / district in 2011 was 41.9 years, which shows that the population is somewhat older than in Serbia, where the average population age in 2010 was 41.4 (Lukić, 2013). The municipality of Alibunar had the oldest population, whose average resident was 44.7 years old. The analysis of the average age of settlements population clearly indicates that the oldest population lives in the settlement of Vršački Ritovi on the territory of the municipality of Vršac (the average age is 53.1 years), and Banatski Sokolac in the municipality of Plandište (51.1 years). At the same time, the population in the peri-urban belts has, so to say, a more favourable age structure compared to the periphery of the settlements. Regarding the average age of the population in these settlements, the question arises whether the future spatial and functional development in these settlements should be adjusted to the current population situation or directed towards demographic revitalization of rural settlements and areas?

The migration balance of population

Second, but no less important determinant of demographic development of each territory and the settlements situated on it is the spatial movement of people or the migration balance. Taking into account that spatial movement of people is a dynamic process that does not have a constant intensity, it is understandable that during the analyzed period, changes in both absolute values and in average rates of its components are observed - emigration and immigration, i.e. the migration balance.

Analysing the relationship between the immigration and the emigration components of population dynamics in relation to the types of settlements, there are less evident and more evident differences in annual rates and the absolute values of their migration balances between the municipal centre and all other settlements and between the villages individually. During the 1981-1991 inter-census period, there was registered a negative rate of migration balance in all municipalities in the South Banat County / District. At the same time, in most other settlements within the studied territory, the ratio of immigrant and emigrant residents was negative. A positive migration balance was recorded in only 8 villages: Plandište (2.85 ‰), and Stari Lec (8.85 ‰) in the municipality of Plandište, Vlajkovac (2.09 ‰) and Izbište (0.93 ‰) in the municipality of Vršac, Bavanište (2.04 ‰) in Kovin, Baranda (0.78 ‰) in the municipality of Opovo, Kovačica (0.58 ‰), Omoljica (0.23 ‰) in the Town of Pančevo, these settlements exhibited immigration, while more than 86 settlements displayed emigration. Of the emigration villages, the lowest rates of migration balance were registered in the following settlements: Šumarak (-72.20 ‰) in the municipality of Kovin, Laudonovac (-43.75 ‰) in the municipality of Plandište, Vršački Ritovi (-39.47 ‰) in the municipality of Vršac and Češko Selo (-30.56 ‰) in the municipality of Bela Crkva.

During the next inter-census, 1991-2002, emigration slowed down. A positive rate of migration balance was recorded in all municipalities except Bela Crkva (-2.77 ‰) and Alibunar (-0.35 ‰). It is interesting that during this inter-census period the number of rural settlements with a positive migration balance increased. The analysis of the rate of migration balance at the settlement level clearly indicates that 52 settlements have a positive rate of migration balance, while 42 have a negative rate of migration balance. The highest spatial distribution of immigration settlements was recorded in the municipalities of Opovo (100%), Plandište (86%) and Pančevo (80%), and emigration Bela Crkva (100%). Of all immigration settlements, the highest values of the average rates of migration balance were recorded in Stari Lec (40.68 ‰) and Banatski Sokolac (11.95 ‰) in the municipality of Plandište, while the emigration villages with the lowest values were Vršački Ritovi (-44.90 ‰) in the municipality of Vršac and Laudonovac (-29.48 ‰) in the municipality of Plandište.

By monitoring the impact of migration balance in the overall movement of the population of the municipality as a whole, municipal centres and other settlements overall and individually in the period from 1991 to 2011, it is evident that it was constantly declining and weakening. Consequently, the continuous decrease in migration balance, with the exception of the municipality of Vršac (0.23 ‰) continued in the period from 2002 to 2011. sixteen settlements registered positive values of the average annual rates, while 78 settlements had a negative rate. Their maximum values were in Vatin (16.85 ‰), Vlajkovac (6.69 ‰), Kuštilj (5.15 ‰) and Veliko Središte (4.60 ‰) in the municipality of Vršac, and the lowest - the negative ones in Vršački Ritovi (-86.81 ‰) and Kaluđerovo (-31.47 ‰) in the municipality of Bela Crkva. Between the last two censuses (2002-2011) it was only the municipality of Vršac and its nine settlements that had the attribute of an immigration centre.

Types of population movements

By applying W. Clark's model of types of population movement in the period from 1981 to 2011 on the territory of the South Banat County / District, conclusions on the trends in the distribution of population as well as the future directions of spatial-demographic development can be obtained. Application of this model in the settlements of the South Banat County / District led to the identification of eight types of population movements, four exodus types and four immigration types. From the analysis of the indicators on the roles of natural and migration components in the overall movement and distribution of the population of some settlements, we can conclude that the number of settlements whose population is evolving and maintaining itself through immigration increased from 8 to 52during the 1981-2002 period. It is also evident that the number of emigration settlements decreased from 86 to 42 during the same period (Table 1).

Table 1: Changes in the number of settlements of South Banat County / District by type of population movement in the period from 1981 to 2011

Types of movement	Trend	1981-1991	1991-2002	2002-2011
I1	Expansion through immigration	4	2	-
I2	Regeneration through immigration	1	5	1
I3	Weak regeneration through immigration	-	5	-
I4	Extremely weak regeneration through immigration	3	40	15
Overall immigration type		**8**	**52**	**16**
E1	Emigration	5	-	-
E2	Depopulation	7	1	-
E3	Extreme depopulation	13	1	-
E4	Extinction	61	40	78
Overall emigration type		**86**	**42**	**78**

During the period from 1981 to 1991, most settlements belonged to the type of extinction (E4), and from 1991 to 2002 most settlements belonged to the type of extremely weak regeneration through immigration (I4) and total depopulation (E4). If spatial distribution of immigrant settlements in the South Banat County / District is observed, their concentration is noted mostly in the settlements on the territories of the following municipalities: Opovo, Pančevo and Plandište. During the next inter-census period, from 2002-2011, the number of immigrant settlements decreased, while the domination of settlements that have the character of emigration emerged, i.e. those that are affected by the process of extinction (E4) or total depopulation (Fig. 1).

The process of total depopulation includes all settlements on the territory of the municipalities of Kovačica and Kovin. The only settlement in the municipality of Vršac - Ritiševo exhibits a trend of regeneration through immigration (I2), and the remaining 15 settlements that belong to the type of extremely weak regeneration through immigration are distributed on the territories of the following municipalities: Bela Crkva – the settlement of Banatska Subotica, Vršac – Vatin, Veliko Središte, Vlajkovac, Vršac, Jablanka, Kuštilj, Mesić and Pavliš, Pančevo – Ivanovo, Omoljica and Pančevo, Plandište – Barice, Alibunar – Nikolince and Opovo – Sefkerin.

The fact that 55.9% of the total population of this macro unit live in the emigration settlements indicates a significant reduction in demographic potential. In all municipalities in the South Banat County / District, and presumably in all emigration municipalities in Serbia, indigenous population dominates. According to the 2011 census in the South Banat County / District 58.03% of inhabitants lived in the settlements in which they had been born, followed by 15.99% who had moved from settlements of other districts, while 9.52% had moved from the settlements of the former republics of the Socialist Federal Republic of Yugoslavia. The highest number of indigenous population is registered in the municipality of Kovačica (74.3%), and the lowest in the Town of Pančevo (52.9%) – the industrial centre of the county / district, which has been facing, like most industrial towns that were unprepared for the rapid transformations, social and demographic problems since the 90s of the 20th century (Miletić, Lukić, Miljanović, 2011).

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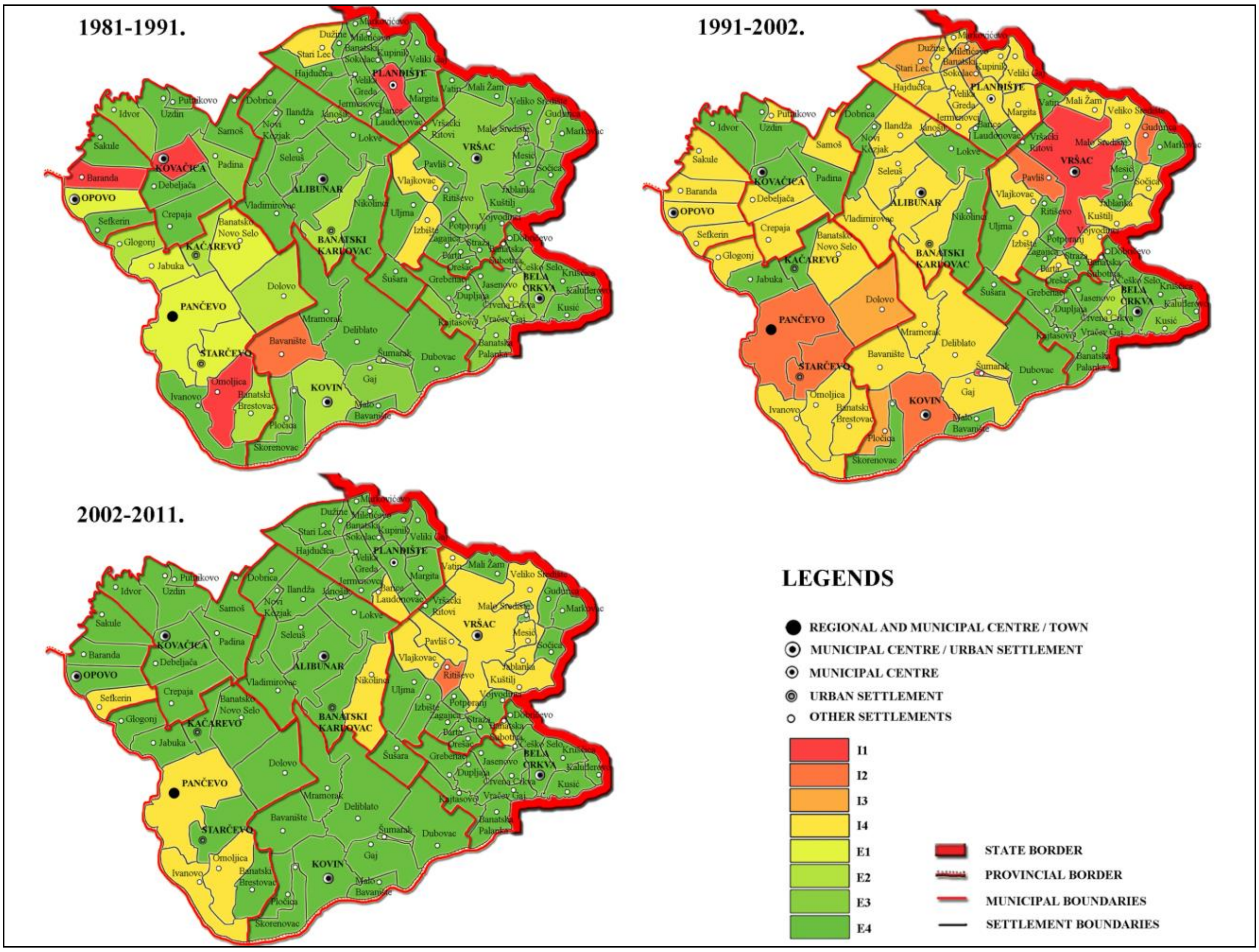

Fig. 1: Types of population movement in the settlements of the South Banat County / District for the period 1981–2011

The average annual population growth in the period 1981-1991 was recorded only in the Town of Pančevo, totalling 147 residents at a rate of 1.18‰ (birth rate 3.87‰, and the rate of migration balance -2.69‰). Similarly, from 1991 to 2002, the overall average annual population growth was recorded in the centre of the district - Pančevo (420.7 residents at a rate of 3.37‰), which was the result of a negative rate of natural increase (-2 15‰) and a positive rate of migration balance (5.52‰). This relationship between the components of population movement indicates that the main bearer of the population growth of the municipality is immigration only, albeit weak. From 2002 to 2011, a decrease in the population of 20,207 or 2,245 people annually in all municipalities in the South Banat County/ District was recorded. Since 1981, negative demographic developmental tendencies especially in the rural settlement network of South Banat County/ District have had implications, among other things, on the size of the population of settlements.

Table 2: Population size of rural settlements in the South Banat County / District in 1981, 1991, 2002 and 2011

Population category	Number of settlements			
	1981	1991	2002	2011
Hamlets (thorp villages) (up to 100 inhabitants)	2	2	3	5
Small villages (from 101-500)	16	19	21	25
Medium villages (from 501-1000)	12	13	13	15
Big villages (from 1001-2000)	26	29	26	20
The biggest villages (more than 2001 inhabitants)	27	20	20	18

From 1981 to 2011, the basic characteristics of the development of rural settlement network in the South Banat County/ District were the continuous demographic depopulation and fragmentation of the majority of settlements i.e. decrease of the number of settlements of the highest population category and the increase of the number of thorp, small and medium villages. Comparing the current state of the rural settlements according to their population size with the situation in 1981, 1991 and 2002, a succession is observed in demographic defragmentation of the settlements. According to their population size in 1981, the highest number of settlements belonged to the categories of big and the biggest villages (63.8%), in 1991 (59,0%) and in 2001 (55,4% of the total number of rural settlements). The intensity of demographic depopulation and defragmentation can be best illustrated by the fact that in 2011 the highest number of settlements was in the population category of small settlements. The intensity of the depopulation process is best seen in the fact that in 2011 as many as 83% of the total number of settlements were dying out.

Conclusion

The intensity of immigration-emigration relations in the South Banat County / District was influenced by the processes of industrialization and urbanization, which led to the establishment of poles of population distribution: concentration and depopulation. Therefore, the general trend of immigration settlements in Serbia, both municipal and urban centers, and other (rural) settlements, can be observed in this macro unit as well.

Mutual relations of "demographic forces" of the municipal centres in the South Banat County / District, according to the analyses presented clearly indicate the dominance of two major urban settlements - Pančevo and Vršac, i.e. the two poles of population concentration, which have different types of population movements. Changes in the natural and spatial movement of the population in the geospace of the South Banat County / District, as well as changes in mutual relations of these two components in the period from 1981 to 2011, led to emigration of a large number of young working-age population from rural areas on one hand, and the concentration of this contingent of the population in urban areas and municipal centres on the other. At the beginning of the analysed period, depopulation was evident as well as a decline or delay in population growth that was caused by a noticeable emigration of population, and during the next period depopulation of these settlements continued due to a negative natural growth. Today, in the geospace of the South Banat County / District the emigration settlements of the type of population extinction (E4) exhibit a dominant share (83%). Such negative demographic processes will continue in the future if further planning of settlement development does not slow them down or possibly stop them altogether.

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References

Ćurčić, S. (1979). Promena broja stanovnika Vojvodine tokom poslednjih sto godina. *Zbornik radova PMF-Univerziteta u Novom Sadu*, 9, pp. 629-645

Ćurčić, S. (1985). Proces sekundarne urbanizacije u Vojvodini. *Zbornik radova PMF-Univerziteta u Novom Sadu*, 15, pp. 103-116

Ćurčić, S. (1987). Migracije i demografski polaritet u Vojvodini. *Zbornik radova PMF-Univerziteta u Novom Sadu*, 17, pp. 73-93

Đurđev, B. S. (1995). Posleratno naseljavanje Vojvodine. *Metodi i rezultati demogeografske analize naseljavanja Vojvodine u periodu 1945-1981*. Novi Sad: Matica Srpska

Đurić, V. (1971). Urbana i industrijska revolucija kao činilac strukturne i funkcionalne transformacije prostora. *Zbornik radova PMF Univerziteta u Beogradu – Geografskog zavoda*, 18, pp. 175–183

Friganović, M., (1978). Demogeografija – stanovništvo sveta. Zagreb: Školska knjiga

Ginić, I. (1978). Dinamika urbanizacije u SR Srbiji. *Stanovništvo*, 16(1–4), pp. 44–77

Ilić, J. (1970). Karakteristike funkcionalnih odnosa između gradova i okoline sa posebnim osvrtom na Srbiju. *Stanovništvo,* 8(3–4)

Krunić, N. (2012). Prostorno-funkcijski odnosi u mreži naselja Vojvodine, Doktorska disertacija, Univerzitet u Beogradu, Geografski fakultet

Krunic, N. (2012). Demografski aspekti savremene prostorno-funkcijske organizacije mreže naselja Vojvodine. *Demografija*, (IX), pp. 121–146

Lukić, V. (2013). Population Trends in Serbia and the Implications for Settlement System. *Forum geografic*, XII(1), 67-74. doi: 10.5775/fg.2067-4635.2013.070.i

Miletić, R., Lukić, V., Miljanović, D., (2011). Deindustrialization and Structural Changes in Commuting Flows in Serbia. *Forum geografic,* X(2), 244–254. doi: 10.5775/fg.2067-4635.2011.009.d

Nejašmić, I. (2005). Demogeografija: stanovništvo u prostornim odnosima i procesima. Zagreb: Školska knjiga

Nevenić, M. (2013). Funkcionalno urbani region instrument policentričnog razvoja Srbije. Beograd: Geografski fakultet, doktorska disertacija

Spasovski, M. (1983). Demografske i urbanogeografske pojave i procesi u opštinama Požega, Arilje i Ivanjica. Beograd: Geografski fakultet, doktorska disertacija

Spasovski, M., Janić, M. (1990/91). Demografski razvoj i populacioni potencijali planinske oblasti i oblasti nizija i pobrđa Jugoslavije. *Stanovništvo*, (3–4)(1–2), pp. 159–176

Tošić, D. (1999). Prostorno-funkcijski odnosi i veze u nodalnoj regiji Užica, Doktorska disertacija, Univerzitet u Beogradu, Geografski fakultet

Tošić, D., Krunić, N., Milijić, S. (2009). Istraživanje prostorne organizacije mreže naselja u funkciji izrade prostornog plana opština Južnog Pomoravlja. *Demografija*, (6), pp. 173–194

Vojković, G. (2007). Stanovništvo kao element regionalizacije Srbije. Beograd: Srpsko geografsko društvo

*** (2013). 2011 Census of Population, Households and Dwellings in the Republic of Serbia, MIGRATIONS, Data on municipalities and towns, Federal Bureau of Statistics, Belgrade.

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Evaluation of geoheritage models – analysis and its application on the loess profiles in Vojvodina region

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Abstract

The touristic value of geoheritage sites has an important role in the decision of the tourists to visit certain destination. Also, the same site can help the people working in tourism to decide about the investments in certain geosite. In order to avoid subjectivity in assessing the value, several quantitative evaluation methods of objects are created, which criteria don't differ too much. Mostly scientific values, representativeness, wholeness as well as tourist equipment are being evaluated. Evaluation models aim to draw attention to the current conditions and the potential every evaluated geosite has. this paper presents an analysis of the chosen quantitative models of geoheritage evaluation, where their effectiveness is checked by the evaluation of three loess - paleosol profiles in Vojvodina, from the Geoheritage List of Serbia. The differences between the models are influenced by the degree of accuracy in the assessment, where for some models, the criteria is not clear when assigning the ratings.

Keywords: *geoheritage, evaluation models, loess profiles*

Rezumat. **Evaluarea modelelor de geo-patrimoniu – analiză și aplicare pe profilele de loess din regiunea Voivodina**

Valorea turistică a geositurilor de patrimoniu are un rol important în decizia turiștilor de a vizita o anumită destinație. De asemenea același sit poate ajuta actorii din turism să decidă despre investițiile ce trebuie făcute în anumite geosit-uri. Pentru a evita subiectivitatea în evaluarea valorilor au fost create metode cantitative de evaluare a obiectivelor, neexistând prea multe criterii de diferențiere. Sunt evaluate valorile științifice, reprezentativitatea, integritatea precum și infrastructura turistică.. Modelele de evaluare au ca scop atragerea atenției spre situația curentă și potențialul fiecărui geosit analizat. Lucrarea prezintă o analiză a modelelor cantitative de evaluare a patrimoniului geologic, iar eficiența lor este verificată prin evaluare a trei profile de loess din Vojvodina, ce fac parte din Lista Patrimoniului Geologic al Serbiei. Diferențe între modele este influențată de gradul de acuratețe al evaluării, pentru unele modele criteriile nefiind foarte clare când se atribuie valorile.

Cuvinte-cheie: *geo-patrimoniu, modele de evaluare, profile de leoss*

Introduction

Natural resources, unlike anthropogenic ones, have the possibility of uprading in order to attract tourists. Rarity and representativeness, as well as educative and aestetic values contribute to tourist value of a certain natural resource.

The geoheritage study has practical significance in the effective protection of geoheritage, the local ecological environment, the popularization of earth science and the promotion of local economy in the way of sustainable development.

Over the past two decades, there have been several attempts to evaluate the geological heritage, but in different contexts, such as, for example, environmental impacts (Rivas et al. 1997, Coratza & Giusti 2005), the formation of geological heritage list of objects (Serrano & González-Trueba, 2005), tourism promotion (Pralong, 2005), or the management of National parks (Pereira et al., 2007).

In order to reduce subjectivity, many quantitative methods have been developed, and are largely based on several criteria, of which three are the most important: rarity, representativeness and integrity (Grandgirard, 1999).

Methods and Models have the role of drawing the attention to the current situation, but also to the possibility that each geosite has, in order to make the planning process easier for the managers and the tourism supply could be properly formed on those localities which possess a chance for development.

The subject of this paper is a comparative overview and evaluation of quantitative methods of ranking the objects of geological heritage in the case of middle Pleistocene loess-paleosol sequences in Vojvodina.

Geological and geomorphological framework

Loess profiles are unique terrestrial records of paleoclimatic and paleoecological conditions. The most complete loess profiles are located in China and in Europe, specifically in the valley of the Danube. In Serbia, loess profiles are in the form of five mutually separated loess plateaus, whereby it is possible to follow the paleo- climatic conditions up to a million years ago (Markovi et al., 2001, 2003, 2004, 2008, 2011) (Fig. 1). Based on the research and proven scientific and educational significance that the loess - paleosol sequences have, the last years have been devoted to geoconservation and protection of these geosites. Particularly are significant works of Gray (2004, 2008a, 2008b), Hose (2008), who set the base of geoconservation, as well as the work of Lukić et al (2009) and Vasiljević (2011a, 2011b). In order to make the significance of loess - palaeosol sequences of Vojvodina widespread, authors like Marković et al., 2001; Hose, 2008; Jovanović & Zvizdić, 2009; Jovanvić & Gaudenji, 2009; Vasiljević et al., 2011a; Vasiljević et al., 2011b; Vujičić et al., 2011. note certain loess- paleosol sequences as an opportunity for geotourism development.

It is not possible for all the loess profiles to be renovated and used as geosites, or even if it were possible, it would not be economically viable. Firstly, it is necessary to quantitatively and qualitatively assess the loess profiles, as well as their potential importance for geotourism.

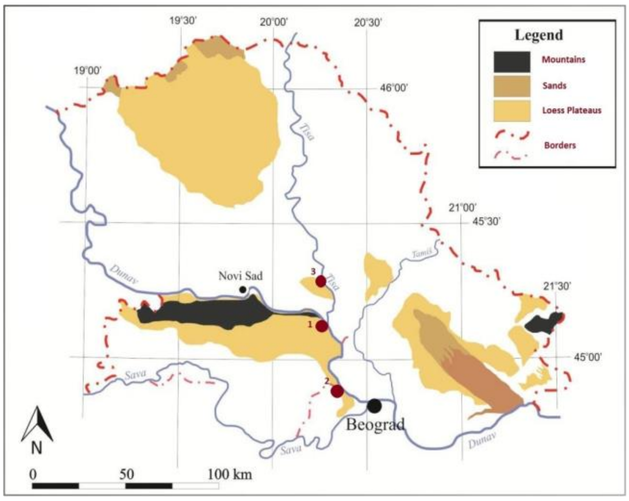

Fig. 1: The geographical position of investigated loess geosites in the Republic of Serbia (1-Čot, 2-Batajnica (Danube), 3-Feudvar)

The most promising loess profiles, when the possibility of the development of geotourism based on loess profiles is being estimated, are the loess profile in Stari Slankamen (especially loess profile Čot), loess profile Batajnica and loess profile of Stara Ciglana Ruma and Titel Hill.

Methodology

It is possible to find a large number of methods to quantitatively assess the geological heritage objects and these methods can mostly be found in foreign literature.

The first methods have been developed in the seventies of the twentieth century by Linton (1968), Leopold (1969). Some have suggested morphometric measurements, while the other methods are more subjective.

There is a rich literature devoted to geotourism (generally by geologists and geomorphologists) by which the attractiveness of many geotourism objects are assessed. Many attributes such as type and age of geological formations (including geomorphological factors and nature influenced formations), geographical location, etc. are considered in the assessment process as well as transport accessibility, tourism infrastructures, economic and many other factors (Bruschi & Cendrero, 2005).

The methods of evaluation of the geological heritage vary in relation to the criteria taken during the evaluation, but most methods include representativeness, rarity and integrity, while the ecological, scientific, educational and cultural values are taken into account depending on the purpose of the study (not cited at references. Precise analysis of geological heritage requires an integrated process, which includes analysis of scientific aspects, tourism and management.

Acceptance of subjectivity in the assessment (based on the opinion of experts) is an inevitable part in the overall evaluation process that is presented on the basis of defining a series of successive steps to facilitate the establishment of clearly stated criteria. These steps include:

- Identification of criteria;
- Definition of indicators to measure each criterion;
- Establishing a range of values for each indicator;
- Confirmation.

Five models of evaluation will be presented in this paper, and they will be well analyzed in the case of medium-Pleistocene loess profiles of Vojvodina. Such a comprehensive comparison should provide a clear view of the advantages and disadvantages of quantitative evaluation methods.

This paper deals with the comparison of five different methods of evaluation, in order to reduce the factor of subjectivity:

1. The Assessment of the Attractiveness (Value) of Geosites (Rybár, 2010);
2. The Dynamic Model of the Assessment of Attractions of Geosites in the Tourism Market (Hadžić et al., 2010);
3. Method of Evaluation of Scientific and Additional Value of Geosites (Reynard, 2005);
4. The Preliminary Model of Valorization of Geosites (Gam) (Vujičić et al., 2011);
5. The Assessment of Values of the Loess Profiles (Jovanović & Zvizdić, 2009).

The models were selected based on their compatibility to apply to specific types of objects of geological heritage. It has been taken into account that the models are different, so the advantages and disadvantages of each model can be noticed.

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The methods were tested on loess profiles, as well as on geosites of the same kind and similar features.

Results

The comparative analysis includes only the quantitative part of each method, while the introductory parts, such as the basic information, are presented in the original papers listed in References.

The assessment of the attractiveness (value) of geosites

In order to assess the attractiveness of the sites of geotourism a model has been formed by Fisher (Rybár, 2010), where he estimates the value of objects, helping the tourists to decide whether to visit certain destination or not, by valuing the individual elements of each tourist site. In this way, geotourists receive information about the degree of attractiveness, the number of visitors, as well as the scientific significance of the sites and object that they want to visit.

Table 1 shows the parameters that are being measured (graded), as well as the system in which the evaluation is being done. In order to avoid subjectivity, an explanation has been given for each evaluation.

Table 1The results of evaluation of loess profiles in Vojvodina region

CRITERIA/SITE	GL_1 **Čot**	GL_2 **Bata-jnica**	GL_3 **Feudvar**
Main geological characteristics	6	6	5
Uniqueness	8	5	4
Access to the site	7	5	8
Scientific publications	8	8	8
Terms of observation	5	5	5
Safety	8	8	8
Availability of information on the Internet	8	5	2
Visual value of the site	8	6	6
Additional services	0	0	0
Site in the field of tourism	8	0	0
Sum	66	48	46

Source: Rybar, 2010

Each of the parameters is being evaluated according to the enclosed principle, and the final summation may amount to a maximum of 80.

If the geosite received the ratings that exceed 40 (i.e., a half), it is considered that the site worths a visit, and that meets most of the criteria that are important for geotourists. If the site has not reached 40 points, it is not recommended to geotourists, or does not possess great value (Rybár, 2010).

This quantitative model of evaluation of objects of geological heritage is quite simple, but extremely fair, considering that the precise guidelines that are being used to evaluate are provided to be realistic, without excessive subjectivity of the assessor.

The model covers all the essential elements to be taken into account when deciding on the choice of destinations and can very easily be applied to the loess profiles.

As seen in the table, all three geosites have gone through the process of evaluating all ten criteria, respectively, in order to calculate their sum. All three geosites crossed the threshold of 40 points, which means that each of them represents a site that is worthy of attention of geotourists. Loess profile Čot received the highest number of points (66), making it the best ranked geosite among the examined loess profiles.

The dynamic model of the assessment of attractions of geosites in the tourism market

As a starting point of the planning process of tourism marketing, it is necessary to develop a model of tourism evaluation of geosites.

This model would not only satisfy the curiosity of tourists, but would clearly define destination (site) as well, in order to distinguish it from similar territories. The model was presented at the conference Geotrends 2010 by Hadzic et al. (2010).

The value and importance of geosites is being determined by the evaluation of three main indicators: scientific value, added value and need for protection, which is associated with the level of degradation and vulnerability.

This model also provides the ability to compare geosites based on the final results of the evaluation (Hadzic et al., 2010).

Table 2 presents all the indicators and sub-indicators which are being evaluated. The importance of each sub-indicator has been assessed by scores from tourists ranging from 0 to 1, where 0 is very bad, and 1 is the best score the geosite can get. This score is then being individually multiplied by the grade given by the expert, in the range from 1 to 5. The sum of all these assessments gives a final judgment on a particular geosite which is the subject of interest.

This model, when compared to the previous one, is much more extensive, since there are more sub-indicators to be taken into account in the process of evaluation of geosites.

In addition, this model includes a review of tourists in the evaluation process.

Each of the three loess profiles has undergone the evaluation process according to this model, and the results were somehow different compared to the previous model.

Table 2: Results of evaluation of geosites according to criteria

GEOSITE	GL_1	GL_2	GL_3
	Čot	Batajnica	Feudvar
SCIENTIFIC VALUE	35.25	30. 5	32
Rarity	5	3	5
Wholeness	5	5	2. 5
Representativeness	3	1. 5	3
Diversity	2. 25	1. 5	3
Other geological characteristics	5	5	5
Scientific knowledge	5	4. 5	4. 5
Educational interest	5	5	5
Rarity on a national level	5	5	4
ADDITIONAL VALUES	36.5	22.5	37.2
Scientific value	5	4	5
Ecological value	2.4	2.8	3.6
Experiential component	4.5	2	1.5
Representativeness of the geosite	1.5	1.6	2.8
Connection with the works of art	0.3	0.1	4.5
Connection with the economic development of the local communities	3.0	1.2	1.2
The possibility of organizing cultural events	0.2	1	5
Interpretative value	1.6	1.8	1.6
Additional natural and cultural values	5	3	5
Quality of management	2.5	0.6	0.2
Equipment and technical support on the geosite	1.2	0	0.4
Accessibility	4	1.2	2.4
Visibility	5	3.2	4
Sum	71.75	53	69.2

Source: Hadžić et al., 2010

According to this model, loess profile Čot has received the highest rating, while the profile of Batajnica received the lowest ratings. The reasons for this may be various.

Firstly, the subjectivity in this model is reduced by the fact that one part of the overall assessment opinion consists of opinions made by tourists. On the other hand, the guidelines for assessment have not been specified correctly in this model, unlike the previous one, where a clear description of what is meant has been provided for each assessment.

Also, the range of assessment that the tourists give is not specified and ranges from 0 to 1, where there are a large number of options, and the failure of central tendency can easily be made. Thus, the lack of this model certainly lies in the ambiguity estimation that is provided for each sub -indicator.

Certainly, the boundaries between scientific significance have not been clearly defined in this model, as well as other values, such as the ecological value or the protection of geological heritage sites.

The experiential component is not a stand-alone indicator, but is located within the additional value of the geosites, although it should represent a special indicator that would include sub- indicators: interpretative value, representativeness, visibility, etc.

Method of evaluation of scientific and additional value of geosites

The model of evaluation of scientific and additional values of geosites has been proposed in the paper by Reynard and Associates (Reynard et al., 2007). This model uses a table divided into six parts, each with a number of sub- criteria (Table 3), whereby the right evaluation was carried out in the third and fourth part of the table. The quantitative values are reported by grade from 0 to 1, where 0 indicates that the test has no value, and 1 indicates that it has the highest possible value.

The scientific value of geosites can be obtained by adding all four sub-criteria and dividing them by number 4. The same applies to the additional values (ecological, aesthetic, cultural and economic), whose sub- criteria is being added and divided by the number of sub -criteria.

Table 3 shows all the sub -criteria, as well as the estimates obtained in the process of evaluation of the three loess profiles. Cultural value of geosites differs in that its sub- criteria are not being divided with their number, because in most cases it happens that the geosite has only one of the four geosites, and the highest value is being taken for the purposes of evaluation.

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The total value of the loess profile is being determined not only by quantitative indicators in Table 3, but also by qualitative descriptions of global and educational importance, the possible threats to the site, as well as management measures related to the destination, i.e. the site.

If we take a look at the table, it is clear to conclude that the loess profile Čot has the largest scientific significance, as well as the added value, followed by the Feudvar loess profile, while the worst ranked is the loess profile in Batajnica.

The combination of qualitative and quantitative evaluation significantly hinders objectivity and reality in the ranking, as well as the subsequent use of the data that has been collected.

Table 3: The results of evaluation of geosites according to criteria

GEOSITE	GL_1	GL_2	GL_3
	Čot	Batajnica	Feudvar
Scientific value	1	0.6	0.75
Wholeness	1	1	1
Representativeness	1	0.5	0.5
Uniqueness	1	0.5	0.75
Paleographic value	1	0.5	0.75
Ecological value	0.4	0.05	0
Ecological impact	0.3	0.1	0
Protection of the site	0.5	0	0
Aesthetic value	0.25	0.13	0.08
Lookouts	0	0	0
Contrasts, vertical development	0.5	0.25	0.15
Cultural value	0.75	0.5	1
Religious value	-	-	-
Historical value	-	-	1
Artistic value	-	-	-
Geohistorical value	0.75	0.5	-
Economic value	0	0	0

Source: Reynard et al., 2007

The preliminary model of valorization of geosites (gam)

In order to assess the value of the loess profiles, the preliminary model of geosites valorization (GAM) proposed by Vujicic et al (2011) has been used. This model shows the valuation of geosites, and should assist in the process of planning and sustainable management of natural resources, as well as the transformation of the natural resources in tourism destinations.

The assessment consists not only of the inventory of sites, but also on the proposal of protection, promotion and monitoring (Pereira et al., 2007). The methodology is based on several existing models and is being presented in two main groups of values (Main Values) and additional (Additional Values), which are divided into indicators and sub - indicators. The first group consists of three groups of values, namely: scientific / educational (VSE), landscaping / aesthetic (VSA) and environmental / conservational (VPR), while the second group, added value, consists of functional (VFN) and tourism values (VTR). If we take all the facts that have been presented so far into account, it can be concluded that there are 12 sub- indicators of the main values and 15 sub- indicators for the additional values (Table 4). All sub- indicators are marked from 0 to 1 (Vujicic et al., 2011).

Based on the proposed inventory of geosites, each individual geosite passes through the evaluation process until the final result is obtained (Table 4). Since the resultant of the model appears at the end of the graph, which consists of nine fields in which the proposed geosites can be classified according to their similarity with the essential characteristics of tourism in terms of main and additional values whose values are presented on the X and Y axes. These fields are marked with Z (i, j) (i, j = 1, 2, 3), on the basis of evaluations which are obtained from the previous evaluation process.

The main lines that create fields for X axe have a value of 4, and for the Y-axis the value of 5. This means that if, for example, the sum of the main values is 7, and an additional 4, the proposed geosite will be place within the field Z21, which indicates an intermediate level of the value of main and low added value (Figure2).

Such a model could be of great importance and could help to protect the natural heritage, and tourism management would have an easier job when it comes to the assessment of the current and future state of the geosites.

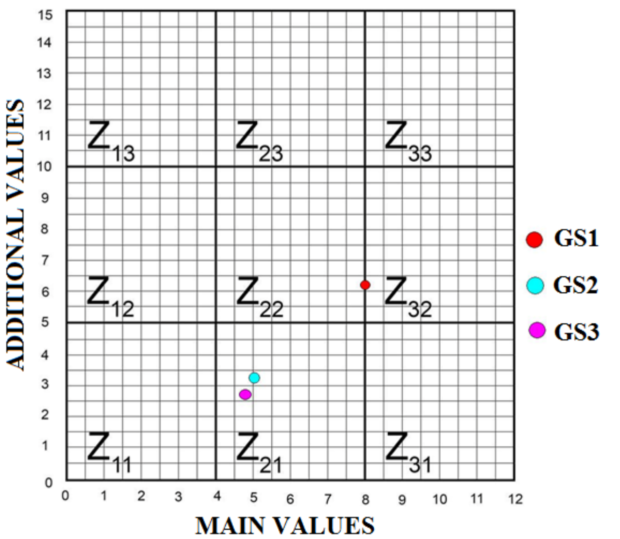

Fig. 2: The layout of geosites according to the GAM model

Table 4: Scheduling the proposed geosites in a specified field of GAM model according to the sum of obtained values

Main Values						GS_1	GS_2	GS_3
Grade	*0*	*0.25*	*0.5*	*0.75*	*1*			
Scientific/Educational values (VSE)						3.75	2	1.75
Rarity	Common	Regional	National	International	The only occurence	3.75	2	1.75
Representativeness	None	Low	Moderate	High	Utmost	1	0.5	0.5
Knowledge on geoscientific issues	None	Local publications	Regional publications	National publications	International publications	1	0.5	0.5
Level of interpretation	None	Moderate level of processes but hard to explain to non-experts	Good example of processes, but hard to explain to non-experts	Moderate level of processes but easy to explain to common visitor	Good example of processes and easy to explain to common visitor	1	1	0.5
Scenic/Aesthetic values (VSA)						1.25	1.25	1.25
Viewpoints	None	1	2 do 3	4 do 6	More than 6	0	0	0
Surface	Small	-	Medium	-	Large	0	0	0
Surrounding landscape and nature	-	Low	Medium	High	Utmost	0.25	0.25	0.25
Environmental fitting of sites	Unfitting	-	Neutral	-	Fitting	1	1	1
Protection (VPr)						3	1.75	2.5
Current condition	Totally damaged as a result of human activities	Highly damaged as a result of natural processes	Medium damaged (with essential geomorphologic features preserved)	Slightly damaged	No damage	0.5	0.25	0.25
Protection level	None	Local	Regional	National	International	075	0	0.75
Vulnerability	Irreversible (with possibility of total loss)	High (could be easily damaged)	Medium (could be damaged by natural processes or human activities)	Low (could be damaged only by human activities)	None	0.75	0.5	0.5
Suitable number of visitors	0	0 to 10	10 to 20	20 to 50	More than 50	1	1	1
Additional Values						6.25	3.25	2.75
Grade	*0*	*0.25*	*0.5*	*0.75*	*1*			
Functional values (VFn)						3	2.25	1.75
Accessibility	Inaccessibl e	Low (on foot with special equipment)	Medium (by bicycle)	High (by car)	Utmost (by bus)	0.75	0.5	0.5
Additional natural values	None	1	2 to 3	4 to 6	More than 6	0.5	0.25	0.5
Additional anthropogenic values	None	1	2 to 3	4 to 6	More than 6	0	0	0.25
Vicinity of emissive centres	More than 100 km	100 to 50 km	50 to 25 km	25 to 5 km	Less than 5 km	0.5	0.5	0.25
Vicinity of important road network	None	Local	Regional	National	International	1	1	0.25
Additional functional values	None	Low	Medium	High	Utmost	0.25	0	0
Touristic values (VTr)						3.25	1	1
Promotion	None	Local	Regional	National	International	0.5	0	0
Annual number of organized visits	None	Less than 12 per year	12 to 24 per year	24 to 48 per year	More than 48 per year	0	0	0
Vicinity of visitors' centres	More than 50 km	50 to 20 km	20 to 5 km	5 to 1 km	Less than 1 km	0	0	0
Interpretative panels	None	Low quality	Medium quality	High quality	Utmost quality	0.5	0	0
Annual number of visitors	None	Low (less than 5000)	Medium (5001 to 10 000)	High (10 001 to 100 000)	Utmost (more than 100 000)	0	0	0
Tourism infrastructure	None	Low	Medium	High	Utmost	0.25	0	0
Tour guide service	None	Low	Medium	High	Utmost	0	0	0
Accommodation	More than 50 km	50 to 25 km	25 to 10 km	10 to 5 km	Less than 5 km	1	0.5	0.25
Restaurants	More than 25 km	25 to 10 km	10 to 5 km	5 to 1 km	Less than 1 km	1	0.5	0.75

Source: Vujičić et al., 2011

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Based on the sum value, it can be concluded that the loess profile Čot in Stari Slankamen has the highest scores, followed by loess profile in Batajnica, while the Feudvar loess profile got the lowest ratings (Fig. 2). Geosites have a high level of core values in all three cases, i.e. the sites are very representative and possess uniqueness on a global scale, and have a low level of additional value, so the future actions should be directed towards the development of tourist attractions that are in close conjunction with the loess profiles but also to the development of tourism infrastructure.

As it can be seen from the chart, geosite 1 - loess profile Čot is located in the field Z32 and represents the best ranked geosite. Based on this chart, each potential geotourist can easily assess whether the certain geosite is worth visiting. This method of evaluation shows great advantages in comparison to previous models, because the evaluation process is clearly defined, so the errors that can arise due to the subjectivity are reduced to a minimum. The GAM model contains 27 sub-indicators, which means that the evaluation process is very detailed, in comparison to other models. As an advantage, this model emphasizes the ability to adapt to different types of geological heritage sites that are being evaluated.

On the other hand, this model needs to be improved. The opinion of the visitors has to be taken into account. In the paper written by Tomic & Božić (2014), GAM model was modified with respect to the role of spectators or geotourists. However, as these loess profiles are still not enough visited, GAM modified version of the model cannot be taken into account in the evaluation process of loess profiles.

The assessment of values of the loess profiles

The methodology applied for the valuation of certain characteristics of the loess profiles is a customized methodology by Reynard (Reynard et al., 2007), with the division of the internal and external factors according to Čomi (2002). Estimatations range from 1 to 3, wherein the score 1 has highest value, and grade 3 the lowest (Jovanovi & Zvizdić, 2009).

Table 5 shows that all categories that are being analyzed, and due to their large number, the mean value is being taken, in order to constitute a representative indicator.

The indicators are divided into internal and external factors, whereby the internal are being constituted by specific qualities and values that the tourist sites have. External factors are those that greatly affect tourist flows that are directed to geosites and determine their position in the tourism market (Čomi, 2002).

Table 5 shows the evaluation of the value of selected loess profiles in Vojvodina, where it was concluded that external factors were evaluated better than internal, and that the loess profiles received the highest marks because of their proximity to the emissive centre, elements of urbanization and infrastructure. Lower grades were given to the loess profiles based on inherent characteristics and peculiarities.

Table 5: Estimated value of selected loess profile

Category	GL_1	GL_2	GL_3	SUM
INTERNAL FACTORS				
Urbanization	2	2	2	2
Infrastructure				
Urban	1	2	2	1.67
Transport	1/2	1/2	1/1	1.33
Inherent characteristics				
Condition	2	2	2	2
Representativeness	1	1	1	1
Rarity	1	2	2	1.67
Paleographic value	1	1	1	1
Equipment and Services				
Quality	1	2	2	1.67
Quantity	2	2	2	2
The offer /demand	2	2	2	2
EXTERNAL FACTORS				
Accessibility	1	1	2	133
The proximity of the emitting centres	2	1	2	1.67
Specificity				
Ecological value	1	3	1	1.67
Aesthetic value	1/1	1/1	1/2	1.17
Educational value	1	1	1	1
Potential economic value	1	2	1	1.33
OVERALL SIGNIFICANCE	1.33	1.61	1.56	

Source: Jovanović and Zvizdić, 2009

As it can be seen from the table, the loess profile Čot received the highest marks, while the loess profile Batajnica got the lowest. If we take a look at the categories, representativeness and paleogeographic and educational value are best assessed, and the worst is the quality of tourism services on the sites, from which it is possible to conclude that the profiles possess exceptional tourism potential, and it is necessary to take advantage of improving the quality of infrastructure.

When compared to all the other models, this model presented some highlights because it is tailored specifically for loess profiles, while others are generally universal and may have wider application. This, of course, does not mean that the model of estimated value of the loess profile, with certain modifications, could not find its use in the evaluation of other objects of geological heritage.

Discussion - quaternary deposits evaluation

The purpose of the evaluation model of geological heritage sites is to reduce the subjectivity of factors that influence the results, which would be gotten by the descriptive method. Models are being presented in numerical evaluation of certain indicators. Ranking of the models of evaluation does not exist, given that some models prove to be extremely useful in certain situations, while others can be quite useless. Depending on the purpose of the research, the appropriate method is being selected. However, there are methods that are more detailed than the others, and they may prove amenable to the study in most situations.

Methods used in the analysis are based on several different criteria. Most methods of evaluation of sites of geological heritage are divided into scientific and added value. Scientific values usually include uniqueness, completeness and representativeness, and additional values are generally associated with environmental, educational and cultural significance (Table 6).

Table 6: The criteria most frequently used in the analyzed methods

Criteria	Method 1	Method 2	Method 3	Method 4	Method 5
Scientific value	x	x	x	x	x
Education		x		x	x
Uniqueness	x	x	x	x	
Completeness		x	x		
Representativeness		x	x	x	x
Interpretation	x	x		x	
Aesthetic values	x		x	x	x
Surroundings				x	
Protection		x	x	x	x
Level of degradation					
Vulnerability				x	
Economic value		x	x		x
Touristic value	x			x	
Urbanisation		x		x	x
Infrastructure	x	x		x	x
Quantity			x		x
Archaeological value			x		x
Promotion	x				

However, the scientific importance is in the centre of each evaluation model. All the methods, as can be seen from the tables above, show similar results, although many criteria are rather left to subjective assessment. Although the quantitative analysis has been established, subjectivity is an element that cannot be rejected, given that the assessment of the significance of individual elements depends directly from the perception of assessors. This is particularly evident in the evaluation of aesthetic components in most of the models. Therefore, further evaluation of the value is based on the contact with the same site, so the values that are obtained are less accurate.

Loess profile Čot in Stari Slankamen (Fig. 3) was ranked in the category of natural resources of Serbia in 2007. Further activities in the direction of categorization of natural resource, physical protection of sites from degrading factors, regulation or any use for the purposes of tourism has not been conducted. Revealing the secrets of the ice age, the loess profiles of this interesting Srem village are not important only to the scientists, but with using modern ways of presentation they could become attractive to many tourists of special interests. An attractive thematic museum ,,Loessland" is planned to be built here in the future.

In terms of scientific values, which are largely the same for all models, Čot received the most values, which means that in terms of representativeness, uniqueness, integrity, as well as scientific and educational value, this is the top-ranked loess profile. The uniqueness of this profile is reflected in the fact that it is one of only three lower Pleistocene profiles in the world and that at a depth of about 36m is the Paleomagnetic border, which has been discovered only in this profile in the region. Consequently, its large scientific and educational importance is evident, because it represents a unique example for studying and displaying to a wider audience.

When the aesthetic component model is being analysed, it is known that almost all the models include this component, and that it is largely the result of subjective perceptions. Loess profile Čot can certainly impresses every visitor with its magnificence, so the values that this profile received are the highest.

The next component which appears in all models is the environmental impact or the current situation and the existence of adequate protection of the site. In this category, Čot got the highest marks in relation to the other two sites that were evaluated, considering that it is the only loess profile (which is subject to evaluation), which is protected by the state. Since 2007 it has been declared a Natural Monument in the Republic of Serbia, which reduced the certain activities that could lead to its degradation to a minimum.

Another large group of value indicators of geological heritage sites are additional values, which are mainly related to tourism infrastructure, as well as the additional values that support the development of a destination. Loess profile Čot, in addition to its core values, can complement the tourist offer and other attractions nearby, together with another loess profile in Surduk between Novi and Stari Slankamen, and then the Danube and the Tisza Rivers, Slanača mineral source, Belegiš islands, Zagrada fishing village, as well as the remains of a Roman settlement Acumincum (Accumincum). The number of additional tourist attractions certainly increases the value of the geosite, and extends the length of stay of tourists in the city.

Tourist infra- and supra- structure stand out among other additional values that are exposed to the evaluation process. Generally, in all models, the geosites received significantly worse scores in the terms of equipment of tourism infrastructure, than when it comes to scientific values. This means that the Republic of Serbia, and even local government, still has not recognized the importance of these sites, although there were indications that this could change soon. The Tourist Organization of Indjija, on the initiative of prof. Slobodan Markovic launched the project ,,Loessland" in 2008, for the purpose of tourism promotion of loess profile Čot. This project envisages the construction of a museum next to the loess profile, as well as the opening of a large number of accommodation and catering facilities, the construction of marine access for tourists that would come to Stari Slankamen via Danube, as well as the opening of a tourist information centre. It also envisages the establishment of cooperation with local travel agencies, which would include this site in their offer, as a first step towards the development of geotourism in Serbia.

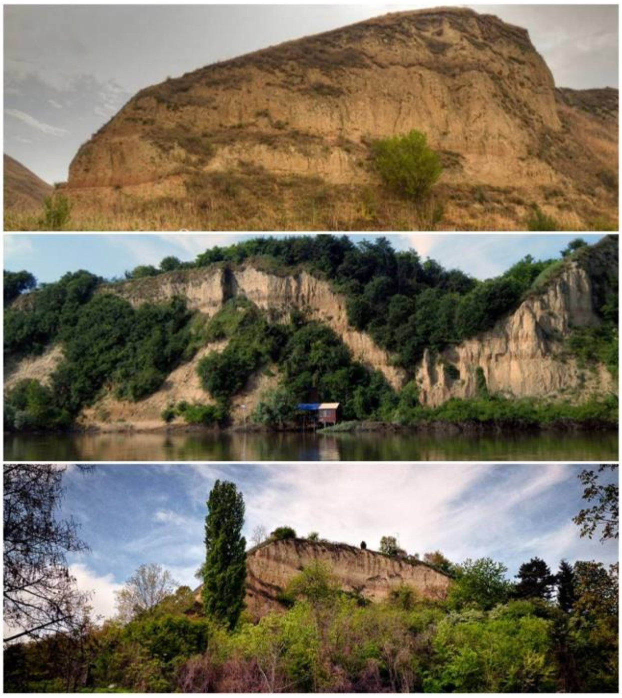

Photo: Jovanovic M.

Fig. 3: Loess profiles (from the top to the bottom) Feudvar, Batajnica – Danube and Cot

However, in the comparison, when it comes to added value, loess profile Čot got the highest marks in relation to the other two geosites, although these values are far from high, speaking in general. Following the chart of GAM models, it is clear that, in the future, more funds need to be invested in infrastructure and promotion of geosites.

All models, except the first one, take the economic value of geosites into account, which represents the amount of the financial resources generated from the visits to the geosites. To date, none of the analyzed loess profiles charges tickets for visitors (there are only few visitors, or no visitors at all). Some models, such as the last one (model which assesses the value of the loess profiles), estimates the economic value on the assumption that the loess profiles are found within the loess geopark, of whose proclamation of some intensive talks have been led over the last years.

If we look at the overall importance of loess profile, we get to the unambiguous conclusion that in all five models, this loess profile is the best ranked, and that it should definitely be the first facility of its kind when it comes to the investment in the geological heritage.

Loess profile Batajnica is located 15 km northwest of Belgrade, on the right bank of the Danube and is recognized as one of the most complete records of paleoclimatic opportunity for the Middle and Upper Pleistocene. Its loess -paleosol sequences are over 40m high with paleolands in which they recorded paleoclimatic and paleoecological changes over the past 620,000 years. Two horizons of tuffits have been identified in this profile, which emphasizes its chrono-stratigraphic importance (Markovi et al., 2009).

At the site of **Batajnica - Danube** (Fig. 3) contemporary geomorphic processes such as leaching, landslides and vertical tear are highly expressed and most intense in late winter and early spring, due to the absence of vegetation. The scientific significance of loess profile Batajnica is reduced when compared to the loess profile Čot, and according to some sub-criteria, in relation to the profile Feudvar on Titel Hill as well. The reason for this certainty lies in the fact that, although it is one of the most complete middle Pleistocene loess profiles in Vojvodina, in many ways it cannot be considered as a unique phenomenon. This loess profile cannot be proud of high grades in terms of representativeness as well. What makes this loess profile stand out is the ability to follow through the direct leaching processes and landslides, and therefore its value is being increased.

When it comes to the protection of this natural resource, for now it all ends on a proposal of protection of loess profile Kapela, while the loess profile Danube still stays without the protection proposals. It can be expected that a decision on protection of this loess profile will be made in the future, which will prevent future anthropogenic degradation in a certain way. Aesthetically speaking, the loess profiles are integrated into the surrounding environment, and for these sub- indicators it definitely got the highest grades.

In terms of added value, the situation is very bad, as is the case with other analyzed loess profiles. Loess profile Batajnica is the worst ranked by almost all criteria, and in almost all models of evaluation. If we consider the additional tourism values, only the Danube River is in the vicinity of the geosite, and the accessibility of the profile itself is almost impossible. In terms of tourism infrastructure, nothing has been built so far, so it cannot be spoken about the economic value of the loess profile.

The difference between loess profile Batajnica and loess profile Feudvar resulting in additional values is one that relates to roads and emissive areas. Specifically, the E-75 international road passes near the loess profile, while the loess profile Feudvar has an unfavourable position, since it is in the immediate vicinity of the local roads, rarely of regional importance.

In the general ranking, loess profile Batajnica received higher scores compared to loess profile Feudvar in two models (according to the Ribar and the detailed GAM model), while according to the other three models it was in the last place. Given that there are not very big differences between localities Batajnica and Feudvar, positive results can be achieved both of the loess profiles with successful management.

Loess profile Feudvar (Fig. 3) is about 3km away from the village Mošorin. The fossil record indicates that the loess is packed in the middle of the wading environment (Jovanovi, 2012). The presence of the layer of tuffits represents a unique phenomenon in the Republic of Serbia and represents an extremely important geochronological marker for paleogeographic reconstruction of Titel loess plateau, as well as the correlation with loess localities in the Pannonian basin (Horvath, 2001).

At the top of the section are the remains of settlements from the Bronze Age, which highlights the importance of loess profiles for the development of human society (Jovanovic & Zvizdić, 2009).

The scientific value of loess profile Feudvar is certainly high, considering that this profile is one of the most representative loess profiles of Titel loess plateau. As layer of tuffits can be found only on this profile, its value is certainly high. Therefore, the scientific value of loess profile Feudvar should get higher scores in all models in relation to the loess profile Batajnica. However, despite the representation and uniqueness, loess profile could not surpass the loess profile Čot.

Aesthetic and ecological values are not at a high level, because the loess profile is not regulated. The whole area of Titel hill is under the tate protection as a Special nature reserve, although the progress in the prohibition of certain acts in a protected natural area is not regulated, which certainly affects the aesthetic component, as well as the ecological value of loess profile. In addition to anthropogenic pollution, to the construction of embankments on the Tisza river, loess profile has been subject to direct erosion of the river.

When the additional values are being analyzed, the situation is considerably worse than with the previous two sites. In terms of additional tourist values, regardless of whether they are natural or cultural, the loess profile can boast with several lens profiles, archaeological sites and the Tisa river, which has contributed to the overall placement under the state protection.

Access to the site is almost completely disabled and tourist infrastructure consists of information signs that suggest that the site is under the state protection. Even though there is a guardian of this natural resource, little funds are being invested in the promotion of tourism. Management does not seem to recognize that the SRP "Titel hill" has the ability to achieve great economic benefit if it has the proper way of use.

The declaration of Titel hill geopark will happen in the near future, the sites will be used for tourism purposes, although currently, the chances for that are very small.

The final assessment of the site shows a remarkable tourist potential, and a very bad current position in the tourism market.

If the results of the evaluation of loess profiles in Serbia were compared with the results of the evaluation of loess profile in China, no significant difference would be noticed, except for the scientific value and the degree of protection of geosites they require. Loess profiles of China are already known to the wider public and have the outstanding scientific value (they enable the reconstruction of climatic conditions in the past more than 2 million years ago), aesthetic value (impressive creations of nature, different geomorphological forms), educational value and protection (geoconservation) they have extremely high marks in all models of evaluation, given that there is no criterion in which Serbia loess profiles could compete with the Chinese loess.

Conclusions

It is obvious that the purpose of evaluation model of geosites is to help in the process of planning and directing funds into profitable geosites.

However, such models can help in the decision-making process of choosing the destination by tourists. Models of evaluation of sites of geological heritage can assure that the tourists get acquainted with the characteristics of each individual site, where they are offered the possibility of comparison of the sites according to the required characteristics. This way, tourists get help in the decision-making process on the selection of sites they want to visit, because the quantitative indicators are being used to show the detailed characteristics of each locality, and since the qualitative description, the site is no longer sufficient, this method certainly has the potential to live on the tourism market.

The detachment of scientific value from the additional elements show that some simple diagrams can indicate the geosites to the potential tourists, and to enable them to choose the destination they will visit according to their needs and desires. For example, if potential tourists want to visit a particular geosite in order to deepen their knowledge, the graph will look for the best ranked sites according to the geo-scientific values. Conversely, if tourists want to enjoy the natural and cultural values, it will seek for those sites that received the highest scores in terms of complementary tourist values and cultural significance. Also, if accommodation and meals represent an essential component of vacation for some tourists, it will provide them with the opportunity to compare sites (destinations), and choose according to this criterion.

If the results are displayed graphically, thus the orientation of tourists is greatly facilitated, but of tourism workers as well. Most importantly, comparisons that were made are not only the result of subjective opinion of a few tourists, but experts in the field of geotourism, which is certainly more representative and more valid.

It is obvious that not all the values of geological diversity can be used for the purpose of geotourism, mainly the objects of geological heritage of certain values are being exploited (according to various criteria). To select objects of geological heritage it is necessary to make an inventory and evaluation of these facilities as potential geosites. The co-existence of different types of geological heritage and the definition of different terms for more or less the same concept does not facilitate the development of assessment methods.

To confirm the validity of the proposed methods of evaluation of the sites, their application to selected loess profile in Vojvodina has been executed. Almost all the methods showed identical results in the assessment of tourist interest of the three loess profiles. The aim of this paper was to compare selected assessment methods of geosites. Different quantitative methods were selected due to fact that it is possible to compare different criterion on which the models are based.

The results show that using different assessment methods on selected loess profiles gives different results and geosite rankings. Based on this fact, further research in the field of geosite assessment is needed for geotourism planning and management as discussed in this paper.

The results show that all the models have certain values and faults that could be used to measure the component that the management needs. Most of the models (including those not analyzed in this paper) are based on several criteria, and therefore there are no significant differences between geosite evaluation models. However, having in mind that every geosite is different, it is necessary to personalize evaluation models, at least by the type of geosite in order to make a proper insight in the advantages certain geosites have. In the future, evaluation models should be modified to meet these requests. This means that if a certain geosite has high main criteria values, such as representativeness, scientific value, aesthetic, if it is about sensible geological features, such as loess, they could be easily degraded (erosion, illegal construction etc). That is why it is necessary to create the proper mean for geotourism development.

References

Bruschi V.M. & Cendrero A. (2005). Geosite evaluation: Can we measure intangible values?, Il Quaternario, *18(1),* 293-306

Coratza, P. & Giusti C. (2005). Methodological proposal for the assessment of the scientific quality of geomorphosites. – In: *Il Quaternario 18 (1)*, 307-313

Čomić, Đ. (2002). *Geografija zatvorenog kruga*, Viša hotelijerska škola, Beograd

Gray, M. (2004). *Geodiversity: Valuing and Conserving Abiotic Nature*. John Wiley and Sons, Ltd, UK

Gray, M. (2008a). *Geodiversity: developing the paradigm*. London: University of Geography Queen Mary, University of London

Gray, M. (2008b). *Geodiversity: A new paradigm for valuing and conserving geoheritage*. In: Geoheritage, Geoscience Canada, *35*, 51-59

Grandgirard, V. (1999). L'évaluation des géotopes – In: *Geologia Insubrica, 4*, 59-66

Hadžić, O., Marković, S.B., Vasiljević, Dj.A. & Nedeljković, M. (2010). *A Dynamical Model for Assessing Tourism Market Attractiveness of a Geosite.* 1st International Conference on Geoheritage & Geotourism Research GEOTRENDS, Novi Sad 24-26 June 2010. Abstract book: 23-25

Horvath, E. (2001). Marker horizons in the loesses of the Carpatian Basin. *Quaternary International*, *76/77*, 157-163

Hose, T. A. (2008). *Towards a history of Geotourism: definitions, antecedents and the future*. In: Burek, C.V. and Prosser, C.D. The History of Geoconservation. Geological Society of London, London, UK, 37-60

Jovanović, M. (2012). *Srednje pleistocene lesno-paleozemljišne sekvence Vojvodine*. PhD thesis, Prirodno-matematički fakultet, Departman za geografiju, turizam i hotelijerstvo, Novi Sad. In Serbian

Jovanović, M. i & Zvizdić, O. (2009). *Geonasleđe lesnih profila u Vojvodini*, DMIIZG ,,Branislav Bukurov". In Serbian

Leoplold, L.B. (1969). Landscape Aesthetics*. Nat.History, 10*, 35-46

Linton, D.L. (1968). The assessment of scenary as a natural resource - Scott. *Geogr. Mag.*, *84*, 218-238

Lukić, T., Marković, S.B., Stevens, T., Vasiljević, Đ., Machalett, B., Milojković, N., Basarin., B. & Obreht, I. (2009). The loess cave near the village of Surduk – an unusual pseudokarst landform in the loess of Vojvodina, Serbia. *Acta Carsologica*, 38 (2/3), 227-235

Marković, S.B., Mijović, D., Jovanović, M. & Kovačev, N. (2001). Geoheritage sites of Fruška gora mountain. *Nature Conservation*, *53 (1)*, 131-138. In Serbian

Marković, S.B., Kostić, N.S. & Oches, E.A (2004). Paleosols in Ruma loess section. *Revista Mexicana de Ciencias Geológicas*, *21 (1)*, 79-87

Marković, S.B., Bokhorst, M., Vandenberghe, J., McCoy, W.D., Oches, E.A., Hambach, U, Gaudenyi, T., Jovanović, M., Zoeller, L., Stivens, T. & Machalett, B. (2008). Late Pleistocene loess-paleosol sequences in Vojvodina region, North Serbia. *Journal of Quaternary Science*, *23*, 73-84

Marković, S.B., Heller, F., Kukla, G.J., Gaudenji, T., Jovanović, M. & Miljković, LJ. (2003). Magnetostratigrafija lesnog profila Čot u Starom Slankamenu*. Zbornik radova departmana za geogarfiju, turizam i hotelijerstvo, 32*, 20-28

Marković, S.B., Hambach, U., Stevens, T., Kukla, G.J., Heller, F., McDoy, W.D., Oches, E.A., Buggle, B. & Zöller, L. (2011). The last million years recorded at the Stari Slankamen (Northen Serbia) loess-paleosoil sequence: revised chronostratigraphy and long-term environmental trends. *Quaternary Science*. *30*, 1142-1154

Pereira, P., Pereira, D. & Caetano Alves M.I. (2007). *Geomorphosite assessment in Montesinho Natural Park (Portugal).* – In: Geographica Helvetica 62 (3), 159-168

Pralong, J.P. (2005). *A method for assessing tourist potential and use of geomorphological sites.* Géomorphologie: relief, processus, environnement, vol 3. relief, processus, environnement 3. Paris

Rivas, V., Rix, K., Frances, E., Cendrero, A. & D. Brunsden (1997. Geomorphological indicators for environmental impact assessment: consumable and non-consumable geomorphological resources. *Geomorphology*, *18*, 169-182

Reynard E. (2005). Géomorphosites et paysages. *Géomorphologie : relief, processus, environnement, 3*, 181-188

Rybár, P. (2010). Assessment of attractiveness (value) of geotouristic objects. *Acta Geoturistica*, *1 (2)*, 13-21

Serrano, E. & González-Trueba J.J. (2005). Assessment of geomorphosites in natural protected areas: the Picos de Europa National Park (Spain). *Géomorphologie. Formes, processus, environnement*, *3*, 197-208

Tomić, N. & Božić, S. (2014). A modified Geosite Assessment Model (M-GAM) and its Application on the Lazar Canyon area (Serbia*). Int. J. Environ. Res.*, *8(4)*, 1041-1052

Vasiljević, Dj.A., Marković, S.B., Hose, T.A., Smalley, I., Basarin, B., Lazić, L. & Jović, G. (2011a). The Introduction to Geoconservation of loess-paleosoil sequences in the Vojvodina region: Significant geoheritage of Serbia. *Quaternary International*, *240*, 108-116

Vasiljević, Dj.A., Marković, S.B., Hose, T.A., Smalley, I., O'Hara-Dhand, K., Basarin, B., Lukić, T. & Vujičić, M.D. (2011b). Loess towards (geo) tourism – proposed application on loess in Vojvodina region (North Serbia). *Acta geographica Slovenica*, *51(2)*, 390-406

Vujičić, M.D., Vasiljević, Dj.A., Marković, S.B., Hose, T.A., Lukić, T., Hadžić, O. & Janićević, S. (2011). Preliminary Geosite Assessment Model (GAM) and its Application on Fruška Gora Mountain, Potential Geotourism Destination of Serbia. *Acta Geographica Slovenica, 51(2)*, 361–377

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Geomorphosites with touristic value in the central – southern part of the Parâng Mountains

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Abstract

The aim of this study is to identify, assess and rank the geomorphosites with touristic potential from the central – southern part of the Parâng Mountains. The touristic assessment of geomorphosites was based on the method elaborated by J.P. Pralong in 2005, which was initially applied on two areas from the Alps. The touristic value of the geomorphological sites is the arithmetical mean result of four values (scenic, scientific, cultural and economic). For each value, points were scored, according to 4 – 6 criteria, highlighting, where necessary, the particularities generated by the studied area. The ranking of geomorphosites represents the base for their inclusion in promotional materials elaborated by authorities or private operators from the region. The promotion of landforms that have acquired a certain value represents, besides the promotion of cultural attractions, the starting point in the touristic development which the region aims at.

Keywords: *geomorphosites, assessment, touristic potential, Pralong method, Parâng, Gorj*

Rezumat. Geomorfosituri cu valoare turistică în partea central-sudică a Munților Parâng

Studiul de față urmărește identificarea, evaluarea și ierarhizarea geomorfositurilor cu valențe turistice din partea central – sudică a Munților Parâng. Evaluarea turistică a geomorfositurilor s-a bazat pe metoda elaborată de J.P. Pralong în anul 2005, ce a fost aplicată inițial pe două areale din Munții Alpi. Valoarea turistică a siturilor geomorfologice este rezultatul mediei aritmetice a patru valori (scenică, științifică, culturală și economică). Pentru fiecare din cele patru valori s-au punctat între 4 și 6 criterii, reliefându-se, acolo unde a fost cazul, particularitățile generate de arealul studiat. Ierarhizarea geomorfositurilor constituie baza includerii acestora în materialele de promovare elaborate de autorități sau operatori privați din regiune. Promovarea formelor de relief cărora li s-a asociat o anumită valoare, reprezintă, alături de promovarea resurselor antropice, punctul de plecare în dezvoltarea turistică spre care tinde regiunea.

Cuvinte-cheie: *geomorfosituri, evaluare potential turistic, metoda Pralong, Parâng, Gorj*

Introduction

The mountain tourism and the geomorphosites are in a state of reciprocal conditioning, the touristic development having as premises the geomorphosites' identification and promotion, but also, the emphasizing, the knowledge and the protection of geomorphosites are highlighted by the touristic development of the area.

Developing the theory issued in 1993, according to which the shapes considered as landmark were defined as geomorphological assets, Mario Panizza defined in 2001 the geomorphosites as geomorphological landforms that have acquired a scientific, cultural/historical, scenic/aesthetic, and/or a social/economic value, value which results from the perception or human exploitation (Reynard & Panizza, 2005). Geomorphosites are considered among the most important attractions of rural and montain areas (Coratza & De Waele, 2012), or a fundamental resource for geotourism (Kubalíková, 2013).

According to the intended purpose for which the identification and the assessment are performed (the touristic development or the protection of geomorphosites), European researchers have created more methods and criteria which point out the scientific value or the additional values of geomorphosites (Bruschi & Cendrero, 2005) (Coratza & Giusti, 2005), (Serrano & González-Trueba, 2005), (Zouros, 2005), (Pereira, Pereira, & Caetano Alves, 2007) & (Pereira & Pereira, 2010), (Reynard, Fontana, Kozlik, & Lausanne, 2007), (Erhartič, 2010). Another method for assessing the touristic potential of geomorphological sites was created and applied by J.P. Pralong in 2005 on Chamonix - Mont Blanc, France and Crans – Montana – Sierre, Switzerland, by assessing the touristic potential and also the exploitation of geomorphosites (Pralong, 2005).

Considerind the value of the geormorphosite very important for touristic capitalization (Comanescu, Nedelea, & Dobre, 2012, 2011, 2009), the method created by Pralong will be applied in an area with high touristic potential, with the aim of establish the touristic value of geomorphosites.

The central - south part of the Parâng Mountains (south west of Romania) is in a process of touristic expansion and necessitates, besides the promotion of cultural resources, highlighting of geomorphosites, too. Hereby, one should perform **the identification, the touristic assessment and the ranking of geomorphosites**.

The promotion of the selected geomorphosites by electronic means and through local touristic infrastructure will not only increase the number of visitors and tourists, but it will also direct the tourism flow toward geotourism.

Study area: The central – southern part of the Parâng Mountains

The Parâng Mountains are situated in the central – southern part of Romania, being surrounded by the Jiu Valley in the west, the Oltet Valley with the Oltet Gorge, in the east, the Lotru and Jiet Valleys in the north (Fig.1). The analysis from this study covers the central and southern part of the Parâng Mountains, included on the administrative territory of the Gorj county, up to the Urdele Pass (2145 m) and the Parângu Mare Peak (2519 m). The area covers a surface of 50,000 ha, having a length of about 30 km (Fig.2).

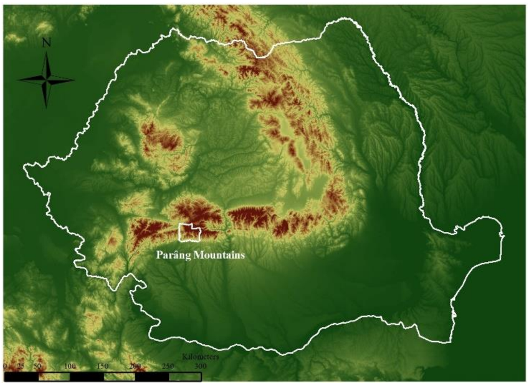

Fig. 1: The location of the Parâng Mountains in Romania

Fig. 2: Study area: The central – south part of Parâng Mountains

The landscape of the Parâng Mountains is dominated by crystalline schists (proterozoics, granitoides and hercinyan crystalline schists) on which glacial valleys and cirques have developed, and on the southern edge limestone segments appear, enabling the formation of gorges and caves on the rivers that cross the massive. Glacial valleys and cirques are more extended in the northern part of the Parâng Mountains, outside the current study area (Sliveiu, Roșiile, Ghereșu, Gâlcescu, Iezeru, Urdele, Dengheru Valleys), as in the central – southern part there are much smaller surfaces in the Valleys of Gruiu, Setea Mică, Setea Mare, Pleșcoaia, Gaura Mohorului, Mohoru. In the north side, there were also preserved glacial lakes, such as Roșiile or Gâlcescu.

Păpușa Peak (2136 m), with a well individualised pyramidal shape, guarding the north part of Rânca Touristic Area and the karst shapes from the southern edge are the representative images for the central and southpart of the Parâng. The Olteț Gorge (with steep slopes, closed at the base up to 4 – 5 meters and a level difference between upper part and the river's thalweg about 20 m), the Galben Gorges (with far slopes and detritus flows) and the Muieri Cave (formed by the dissolving of calcium carbonate by Galben river's water, along a fracture orientated north, north-west to south, south-east) are the most visited karst elements. The Muieri Cave, the first electrified cave in Romania (1963) is structured on 4 floors, having a length about 3,5 km. Only a section of 700 m is open to the public, the other part being accessible only to speleologists (Diaconu, Lascu, & Ponta, 1980). The cave is appreciated both for the visual aspect of special shapes created by old stream of the Galben river (The Little Dom, Altar Room, The Pulpit, The big Candelabrum, The Gory Stone, Guano Hall, Turkish Room etc.), as well as for the evidence it holds related to the morphoclimatic dynamics of the territory. The western limit of the Parâng Mountains consists in steep slopes, with a declivity over 45°, thus forming the Jiu Defile. Having a length of 33 km and an origin still incompletely elucidated, but considerared as an antecedent one, the defile has an important anthropic usage (European road an railway) and also a touristic one.

The territory chosen for the study is totally covered by protected areas, components of European Network of Nature Protection Areas - Natura 2000: ROSCI0128 The North of Eastern Gorj and partial ROSCI0188 Parâng. Also, the territory coincides with protected areas of national concern: the Olteț Gorge and the Polovragi Cave (monument of nature), a part of the Polovragi Forest (natural reservation), Ied Cave (monument of nature), Muieri Cave (scientific reservation), partially the Gâlcescu Couldron (natural reservation), Lainicilor Sphinx (monument of nature), Rafailă Stones (monument of nature) and partially over the National Park of the Jiu Defile. The south area of the Parâng Mountains generally lacks industrial buildings, except for some small hydroelectric power plants and the main option for economic development is considered as relying on tourism.

Methodology

The identification of geomorphosites. For the first step, the indentification of geomorphosites from the chosen area (central – south part of Parâng Mountains), we have ***studied specialized materials***, in which the creation and the structure of the Parâng Mountains were approached, as well as studies about touristic potential, correlated with ***the analysis of maps*** (geological, geomorphological, glacier related, topographic, hydrographic, touristic etc.) and satellite images.

The next step was the ***direct observation*** of geomorphosites – in situ, thereupon the local experts were consulted.

For the **assessment of the touristic potential of geomorphosites** from the North-East of the Gorj county, we have chosen to apply one of the most commonly used methods in Romania and also at European level – the method created by Jean – Pierre Pralong (Lausanne University, Switzerland). According to this method, the touristic assessment of geomorphosites includes four values: scenic, scientific, cultural and economic. The criteria and scales of scoring for each value have been established by Pralong also considering previous researches achieved and presented by Grandgirard in 1997, Quaranta in 1993, Coratza & Giusti in 2005, Rojsek & Rivas in 1995, Panizza in 1998 (Pralong, 2005). Hereby, Pralong has considered the tourist value of geomorphosites as arithmetic mean of the four values:

Vtour = (Vsce + Vsci + Vcult + Veco)/4, where:

Vtour = tourist value,
Vsce = scenic/aesthetic value,
Vsci = scientific value,
Vcult = cultural/historical value,
Veco = economic/social value.

$$Vsce = \frac{Sce1 + Sce2 + Sce3 + Sce4 + Sce5}{5}$$, where:

Sce1 = number of points from where the geomorphosite is visible, situated less than 1 km and accesible on foot,
Sce2 = average distance from the points specified at Sce1 up to the geomorphosite (m),
Sce3 = geomorphosites` surface (ha),
Sce4 = elevation (m), reported at all identical sites from the study area,
Sce5 = colour contrast between the site and the surroundings (one colour includes all its shades).

$$Vsci = \frac{Sci1 + Sci2 + (0.5 \times Sci3) + (0.5 \times Sci4) + Sci5 + Sci6}{5}$$,

where:

Sci1 = paleogeographical interest (the score is given according to the contribution of the site at the reconstruction of morphoclimatic evolution of the teritory),
Sci2 = representativeness,
Sci3 = area (%) – share of the site in whole area occupied by all identicals sites in the studied territory,
Sci4 = rarity (according the number of identical sites)
Sci5 = integrity,
Sci6 = ecological interest.

$$Vcult = \frac{Cult1 + (2 \times Cult2) + Cult3 + Cult4 + Cult5}{6}$$, where:

Cult1 = cultural and historical customs,
Cult2 = iconographic representations (paintings, drawings, engravings, photography) of site,
Cult3 = historical and archeological relevance,
Cult4 = religious and metaphysical relevance,
Cult5 = artistic and cultural events.

$$Veco = \frac{Eco1 + Eco2 + Eco3 + Eco4 + Eco5}{5}$$, where:

Eco1 = accessibility to site,
Eco2 = natural risk,
Eco3 = annual number of visitors in the region (the given score is identical for all sites of a same region; the annual number of visitors in the biggest resort from region is considered),
Eco4 = protection level,
Eco5 = attraction.

To some criteria, weightings were applied, by increasing score (Cult2 x 2), being considered more relevant, or by contrary, decreases (sci3, Sci4 x 0.5), being considered in relation with Sce3.

The modality for scoring, according to the 21 used criteria is presented in Table no.1.

Based on the results of the tourist assessment of geomorphosites, there emerged a hierarchy of geomorphosites, which will constitute the basis for the inclusion of geomorphological sites in the promotional materials, published by authorities, promoting associations or accommodation structures.

Table 1 Score given

Value	Criteria	POINTS				
		0	0.25	0.5	0.75	1
Scenic value	Sce1	-	1 point	2 or 3 points	4,5 or 6	>6
	Sce2	-	<50 m	51 – 200 m	201 – 500 m	>500 m
	Sce3	-	small	moderate	large	very large
	Sce4	nil	low	moderate	high	very high
	Sce5	identical colors	-	different colours	-	opposite colours
Scientific value	Sci1	-	low	moderate	high	very high
	Sci2	nil	low	moderate	high	very high
	Sci3	-	< 25	25 – 50	51 – 90	> 91
	Sci4	>7	5 – 7	3 – 4	1 – 2	unique
	Sci5	destroyed	strongly	moderately	weakly	intact

			deteriorated	deteriorated	deteriorated	
	Sci6	nil	low	moderate	high	very high
Cultural value	Cult1	without link	weakly linked	moderately linked	strongly linked	initiatory of customs
	Cult2	never represented	represented 1 – 5	represented 6 – 20	represented 21 – 50	represented >50
	Cult3	no vestige or building	weak relevance	medium relevance	high relevance	very high relevance
	Cult4	no relevance	weak relevance	medium relevance	high relevance	very high relevance
	Cult5	never	-	occasionally	-	at least once a year
Economic value	Eco1	>1 km of track	<1 km of track	by a local road	by a road of regional importance	by a road of national importance
	Eco2	uncontrollable	not controlled	partially controlled	controlled – residual	no risk
	Eco3	<10.000	10.000 – 100.000	0.1 – 0.5 milion	0.5 – 1 milion	>1 milion
	Eco4	complete	limiting	-	not limiting	no protection
	Eco5	-	local	regional	national	international

Source: after Pralong, 2005

Results and Disscusions

The series of geomorphological sites which bring a contribution in understanding the territory evolution is much bigger in the study area, but for this study, we selected the geomorhosites (in number of 14) with potential in the touristic exploitation of the region (Fig.3).

Among these, we evaluated 8 geomorphosites which can be accessible for tourists without special equipment. The results of the assessment are presented in table no.2 and in Fig. 4.

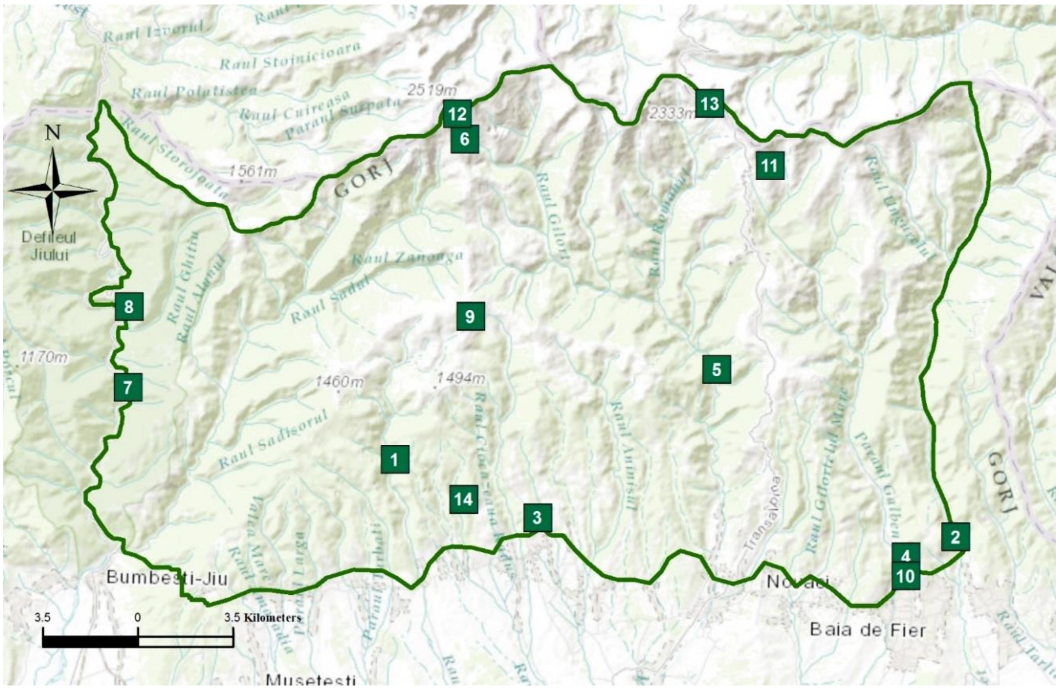

Fig. 3: The localization of geomorphosites

1- Blahnita Valley; 2 - Olteţului Gorges; 3 - Frunţi Plateau; 4 - Galbenului Gorges; 5 - Gilortului Gorges; 6 - Gilortului Springs; 7 - Jiului Defile; 8 - Lainicilor Sphinx; 9 - Molidvişu Peak; 10 - Muierilor Cave; 11 - Păpuşa Peak; 12 - Parângu Mare Peak; 13 - Urdele Pass; 14 - Waterfalls on Ghia river

By applying the method and scoring criteria established by Pralong (the first part of Pralong method, regarding tourist evaluation), it results an hierarchy which could be the basis for the touristic promotion. In this analysis, the higher score was obtained by the Jiul Defile, the differentiation from the other geomorphosites coming from the larger dimensions, historical importance, scientific

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concerns, but also its uniqueness in the territory. The next position in hierarchy is occupied by the two karst areas, in which the Olteț and Galben Gorges were formed, followed by the Muieri Cave, situated in the same karst area.

Păpușa Peak and the Urdele Pass have scores that classify them on intermediate places, their main characteristic being higher altitude (the Urdele Pass is the highest point attained by the Transalpina – the highest road from Romania). The last two positions are granted to the Frunți Plateau, especially used for off road competitions and the Blahnița Valley, disadvantaged by distance to public roads, but also by lack of cultural and artistic events.

Table 2: The results of assessment

CRITERIA	Blahnița Valley	Olteț Gorges	Frunți Plateau	Galben Gorges	Jiul Defile	Muieri Cave	Păpușa Peak	Urdele Pass
Sce1	1	1	0.5	1	1	0.75	1	0.5
Sce2	0.25	0.75	0.5	1	0.5	0.5	1	0.5
Sce3	0.75	0.75	0.5	0.75	1	0.75	0.75	0.5
Sce4	0.25	0.75	0.5	0.75	0.75	0.25	1	1
Sce5	0.5	0.5	0	0	0	0	0.5	0
Vsce	0.55	0.75	0.40	0.70	0.65	0.45	0.85	0.50
Sci1	0	0.5	0	1	1	1	0	0.25
Sci2	0.25	1	0	0.5	1	1	0.75	0.75
Sci3	0.75	0.75	0.25	0.75	1	1	0.5	0.25
Sci4	0.5	0.75	0.25	0.75	1	1	1	1
Sci5	0.75	0.75	0.5	0.5	0.5	0.75	0.75	0.25
Sci6	0.5	1	0.5	1	0.75	1	0.5	0.25
Vsci	0.43	0.80	0.25	0.75	0.85	0.95	0.55	0.43
Cult1	0	0.75	0.25	1	0.75	1	0	0.75
Cult2	0	1	0.25	1	1	1	1	1
Cult3	0	1	0	0.5	1	1	0	0.75
Cult4	0	1	0	0.5	1	0.25	0	0
Cult5	0	0	0	0.5	0.5	0	0	0
Vcult	0.00	0.79	0.13	0.75	0.88	0.71	0.33	0.58
Eco1	0.25	0.5	0.5	0.75	1	0.75	1	1
Eco2	0.25	0.5	0.5	0.5	0.5	0.5	1	0.25
Eco3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Eco4	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Eco5	0.25	1	0.25	1	1	1	0.25	1
Veco	0.30	0.55	0.40	0.60	0.65	0.60	0.60	0.60
Vtour	**0.32**	**0.72**	**0.29**	**0.70**	**0.76**	**0.68**	**0.58**	**0.53**

In scoring the scenic value, difficulties appear due to the variety of geomorphosites in this area. The assessment criterion Sce1 (number of viewpoints) has to be applied differently for punctual geomorphosites (e.g. Muieri Cave) and linear type (e.g. Jiul Defile). Also, the criterion Sce4 scores the contrast of colour between geomorphosite and its surroundings. In Muieri Cave's case, the outside difference of colour is absent, but the inside of the cave strongly contrasts with the outside environment (e.g. Gory Stone has a rusty colour, due to the leakage of iron oxides).

The ecological interest is scoring according to the rarity and the diversity of species, as well as the natural dynamic of them. All assessed geomorphosites are integrated in the natural protected areas, which aiming the protection of biodiversity and the preservation of habitats and species (fauna and flora). Some of studied geomorphosites are covered by two categories of natural protected areas (SCI & IUCN). In scoring for this criterion, attention was also paid to the numbers of categories of natural protected areas which cover the geomorphosite.

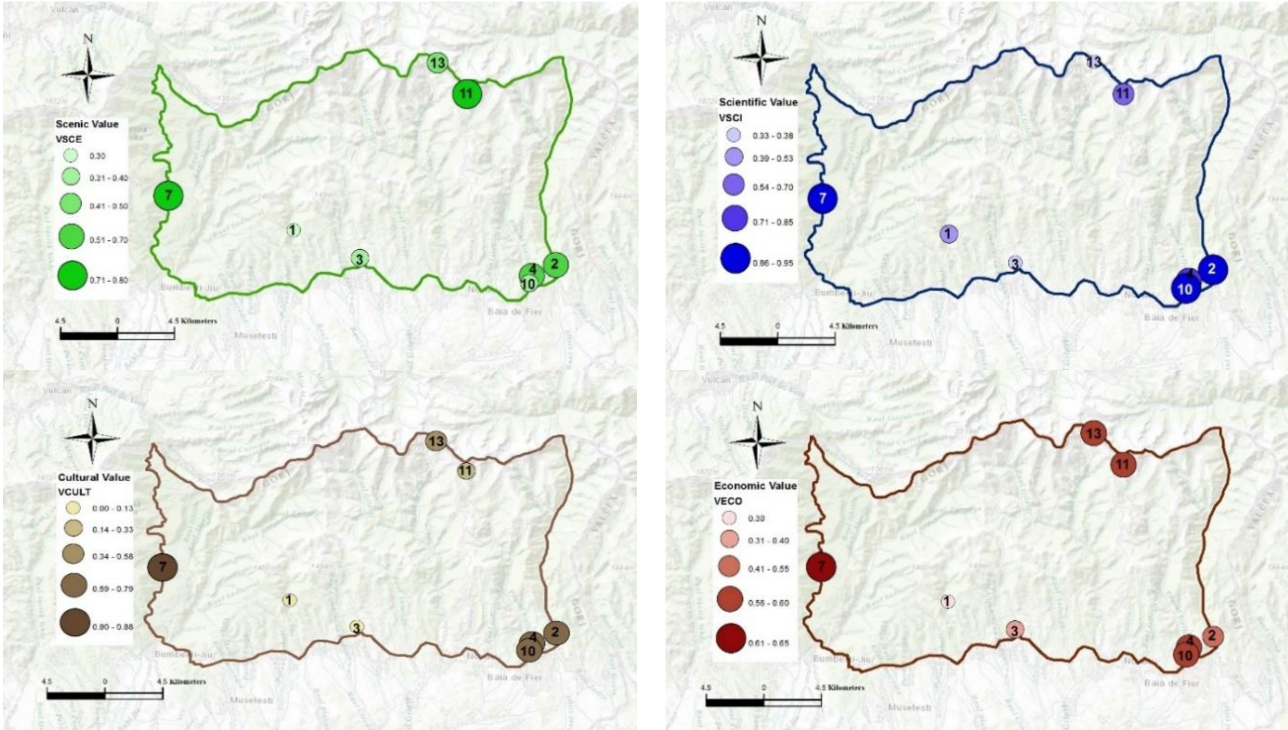

Fig. 4: Graphical representation of the four values (scenic/aesthetic, scientific, cultural/historical and economic/social) of analysed geomorphosites

1 –Blahnița Valley; 2 - Oltețului Gorges; 3 - Frunți Plateau; 4 - Galbenului Gorges; 7 - Jiului Defile; 10 - Muierilor Cave; 11 - Păpușa Peak; 13 - Urdele Pass

For less known geomorphosites, the Cultural value has a low score or even zero (the Blahnita Valley). Also, low scores were obtained by geomorphosites that are more difficult to reach or which are not suitable for cultural events (the Frunți Plateau).

For the economic value scoring, the criterium Eco4 regarding the level protection of gemorphosite, there are low values for all analysed elements, the scoring being inversed in comparison to Sci6 criterion; their economic exploitation is limited. Also, the location and the accessibility of geomorphosites are relevant for the EcoValue. Maximum score was obtained by the geomorphosites with direct access to the national road.

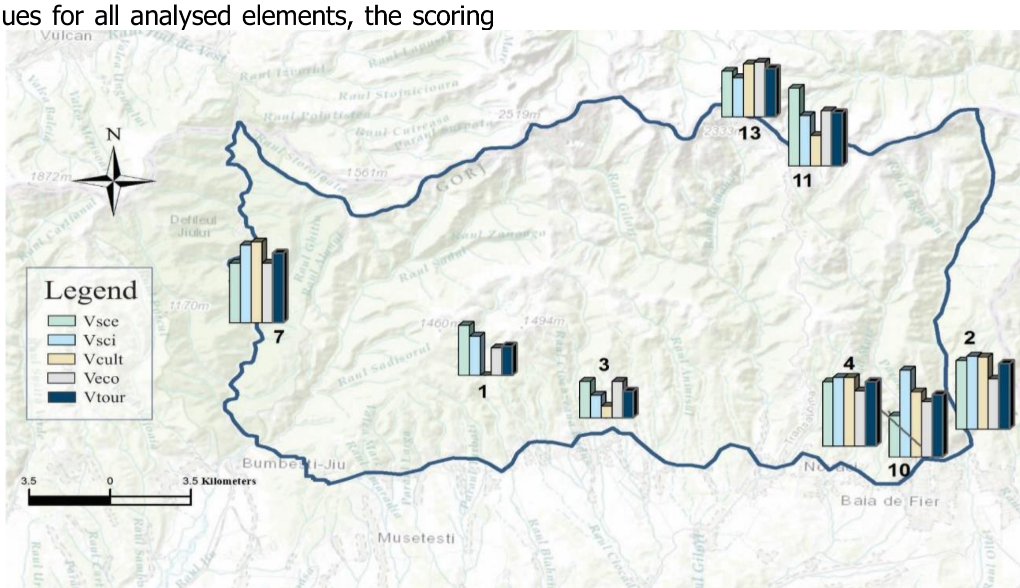

Fig. 5: The results of the assessment

1-Blahnita Valley; 2 - Oltețului Gorges; 3 - Frunți Plateau; 4 - Galbenului Gorges; 7 - Jiului Defile; 10 - Muierilor Cave; 11 - Păpușa Peak; 13 - Urdele Pass

Conclusions

The economic development strategy for the north-eastern part of Gorj county is centered on touristic component of it. In this context, a starting point in attracting the tourism flow is represented by the identification and the assessment of geomorphosites.

The assessment method, initially applied to the geomorphosites from the highest area of the Alps was also applied to the central – southern part of the Parâng Mountains, having as result the accomplishment of a touristic hierarchy, but also the highlighting of the geomorphosites not yet included in touristic circuit. It is recommended that the analysed geomorphosites to be included in the regional maps and to be promoted through the Tourist Information Centers of the area.

The method created by Pralong could be succesfully applied in any mountain area, with small adjustements, according to the encountered particularities. In order to avoid the assessor's subjectivity, the scorecard must be completed by more assessors. The final values (scenic, scientific, cultural, economic and touristic) of the geomorphosites will be the arithmetical mean of values established by all assessors.

References

Bruschi, V. M. & Cendrero, A. (2005). Geosite evaluation; can we measure intangible values? *Il Quaternario - Italian Journal of Quaternary Sciences, 18 (1)*, 293-306

Comânescu, L., Nedelea, A. & Dobre, R. (2011). Evaluation of geomorphosites in Vistea Valley (Fagaras Mountains-Carpathians, Romania). *International Journal of the Physical Sciences*, 1161 -1168. doi: 10.5897/IJPS10.384

Comănescu, L., Nedelea, A. & Dobre, R. (2009). Inventoring and Evaluation of Geomorphosites in the Bucegi Mountains. *Forum geografic*, VIII*(8)*, 38-43

Comănescu, L., Nedelea, A. & Dobre, R. (2012). The Evaluation of Geomorphosites from the Ponoare Protected Area. *Forum geografic*, XI*(1)*, 54-61. doi:10.5775/fg.2067-4635.2012.037.i

Coratza, P. & De Waele, J. (2012). Geomorphosites and Natural Hazards: Teaching the Importance of Geomorphology in Society. *Geoheritage*. doi:10.1007/s12371-012-0058-0

Coratza, P. & Giusti, C. (2005). Methodological proposal for the assessment of the scientific quality of geomorphosites. *Il Quaternario*, 307-313

Diaconu, G., Lascu, C. & Ponta, C. (1980). *Peștera Muierilor.* Editura Sport – Turism, București, 115 p

Erhartič, B. (2010). Geomorphosite assessment. *Acta Geographica Slovenica*, 295–319. doi:10.3986/AGS50206

Kubalíková, L. (2013). Geomorphosite assessment for geotourism purposes. *Czech Journal of Tourism*, 80–104. doi:10.2478/cjot-2013-0005

Pereira, P. & Pereira, D. (2010). Methodological guidelines for geomorphosite assessment. 215-222. Retrieved from http://geomorphologie.revues.org/

Pereira, P., Pereira, D. & Caetano Alves, M. I. (2007). Geomorphosite assessment in Montesinho Natural Park (Portugal). *Geographica helvetica*, 159-168

Pralong, J.-P. (2005). A method for assessing tourist potential and use of geomorphological sites. *Géomorphologie: relief, processus, environnement*, 189-196

Reynard, E. & Panizza, M. (2005). Geomorphosites: definition, assessment and mapping, Géomorphologie: relief, processus, environnement. *Géomorphologie: relief, processus, environnement*, 177-180

Reynard, E., Fontana, G., Kozlik, L. & Lausanne, C. S. (2007). A method for assessing «scientific» and «additional values» of geomorphosites. *Geographica Helvetica*, 148-158

Serrano, E. & González-Trueba, J. J. (2005). Assessment of geomorphosites in natural protected areas: the Picos de Europa National Park (Spain). *Géomorphologie: relief, processus , environnement*, 197-208

Zouros, N. (2005). Assessment, protection, and promotion of geomorphological and geological sites in the Aegean area, Greece. *Geomorphologie*, 227-234

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