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Considerations on Desertification Phenomenon in Oltenia

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Abstract

The paper analyses the desertification phenomena in Oltenia, which have been more intense after 1990. Significant references are also made to the overall aspect for the entire country. The droughty periods have different meteorological characteristics compared to the last century such as: their association with intense heat waves, intensity and important areas of extension. These were caused by stable and persistent anticyclonic regimes which affected most part of the European continent. The paper is a part of series of extended studies on climate variability in Oltenia (Bogdan and Niculescu, 1999, Bogdan and Marinică, 2007, Marinică and Marinică, 2010; Marinică, 2006, 2009). The paper is useful to students, master graduates and to all specialists in climatology.

Keywords: *draughty periods, heat waves, desertification, anthropic impact*

Rezumat. Considerații privind fenomenul de deșertificare în Oltenia

În lucrare sunt analizate fenomenele de deşertificare în Oltenia, mai intense după anul 1990. Importante referiri sunt făcute şi la aspectele de ansamblu pentru întreaga ţară. Perioadele secetoase au avut caracteristici meteorologice distincte faţă secolul trecut printre care cităm asocierea acestora cu valuri intense de căldură, intensitatea şi arealele de extindere deosebite. Acestea au fost produse de regimuri anticiclonice stabile şi persistente care au afectat cea mai mare parte a continentului Europa. Lucrarea face parte dintr-o serie extinsă de studii privind variabilitatea climatului în Oltenia (Bogdan şi Niculescu, 1999, Bogdan şi Marinică, 2007, Marinică şi Marinică, 2010; Marinică, 2006, 2009). Lucrarea este utilă studenţilor, masteanzilor şi tuturor specialiştilor în climatologie.

Cuvinte-cheie: *perioade secetoase, valuri de căldură, deşertificare, impact antropic*

Introduction

The anthropogenic impact on clime, especially in the last century, was extremely high so that it can with no doubt be considered a modifying factor on a global, regional and local scale.

Climatic data in the last century showed, apart from a progressive general warming of the atmosphere (highlighted at global level), also a reduction of the quantities of precipitations, which became limitative factors for the growing, development and productivity of crops in certain geographic areas of the country and, in the same time, very restrictive factors for the allocation and use of water resources.

In 1997, Romania signed (through Law 629/1997) the Convention to combat desertification (CCD), adopted in Paris on June 17, 1994 and entered into force on December 26, 1994, elaborated pursuant to the resolution of the United Nations General Assembly 47/188 from December 22, 1992, as a consequence of the Rio de Janeiro United Nations Conference on Environment and Development (1991). The Convention aims to combat desertification and to reduce drought effects in the countries with serious problems of drought and/or desertification through efficient measures at all levels, in order to contribute to the fulfilment of sustainable development in damaged areas. In Romania, there has been elaborated a synthesis of studies carried out by the following specialty institutes: Forest Research and Management Institute (ICAS), Institute of Research for Pedology and Agrochemistry (ICPA), National Company – National Institute of Meteorology, Hydrology and Water Management (CN-INMHGA), Institute of Studies and Projections for Institute of Studies and Design for Land Reclamation Projects (SC ISPIF SA), National Institute for Research and Development in Environmental Protection (ICIM), Institute of Research and Technological Engineering for Irrigations and Drainages (ICITID), Research Institute for the Quality of Life (ICCV), Research Institute for Cereals and Industrial Crops (ICCPT-Fundulea) and Pasture Research Institute (ICPCP Măgurele – Braşov). This synthesis presents the problem of desertification, land degradation and drought in a national context and the action strategy in order to combat it (National Strategy and Action Programme to Combat Desertification, Land Degradation and Drought, elaborated within the Ministry of Water, Forests and Environmental Protection and hereinafter referred to as SNPAPCDDTS).

At a global level

The appearance and extension of conditions similar to deserts also in other areas of Terra was characterised in different ways.

The United Nations Conference on Environment and Development – UNCED) defined desertification as land degradation in arid, semi-arid and dry sub-moist areas, resulted following the action of several factors among which the most important are climate variations and human activity.

Desertification manifests in territory through:

- reduction of soil surface covered by vegetation;
- a consistent soil poverty and erosion;
- increase of albedo of adjacent surface;
- increase of solar radiation.

Desertification is therefore a severe phenomenon of climate risk whose multiple causes are related to a complex of factors.

Droughts are risk complex climate phenomena with a slow manifestation, which affects and implies (depending on their duration and intensity), a varied number of components of geographic environment. These are mainly caused by meteorological factors and manifest through effects not only on both atmospheric, hydrologic, pedological, vegetal, animal environment, etc. Consequently, in their classification it speaks of: meteorological, hydrological, edaphic (from a pedological point of view, something related to soil nature) and agricultural drought. This is due, in the first place, to the lack of precipitations or their deficit, and the negative effects caused on different components of the geographic environment are visible on vegetation, soil and hydrological resources. Drought is a time-based phenomenon, and aridity is a characteristic of a certain region on which two factors acted simultaneously, namely: clime and anthropogenic impact.

Land degradation

It is a broad term referring to both semiarid, dry sub-moist and moist areas; it is caused by different natural and anthropogenic processes, and includes: erosion due to water or wind, degradation of physical, chemical, biological or economic soil characteristics and the loss of the natural vegetation on long term. The processes of desertification contribute also to these as a consequence of climate changes.

At global level, according to data provided by CCD a third of the Earth's land surface is covered by arid lands. 70% (that is 3.6 billion hectares) of arid lands with agricultural use are moderate to highly affected by degradation. Because of the erosion, 24 billion tones of arable land are lost every year. Desertification affects 110 countries on all the continents, including 5 Member States of the European Union, namely a population of more than a billion, and the annual cost desertification is about 42 billion dollars (Marinică, 2006). Series of international projects for the assessment of current stage of land degradation were coordinated by the International Soil Reference and Information Centre (ISRIC), and these include GLASOD project, concluded in 1991 through the publication of a book (at the scale 1:10 000 000) of degraded land at a global level; AASOD project intended for this estimation (at the scale of 1:1 500 000) for Southern and South-Eastern and SOVEUR project intended for a similar description (at the scale 1: 2 500 000) for the countries of Central and Eastern Europe (including Romania).

SOVEUR project takes into account the following types of soil degradation:

- soil pollution under the following aspects: acidification, pollution with heavy metals, pollution with pesticides, eutrophication, radioactive pollution;
- erosion due to water: surface erosion, depth erosion, landslips, erosion secondary effects; - erosion caused by wind: losses of arable soil, formation of dunes and other land irregularities, erosion secondary effects;
- physical degradation with the following aspects: aridity, formation of crust, subsidence, removal from production through urbanisation or other economic activities, excess inducted by humidity.

In Romania, drought phenomena, which are extremely powerful in some periods, have increased in intensity and frequency, and dryness processes have extended not only due to climate changes at global level, but also as a consequence of some deep and major local transformations, which occurred at the level of most land heritage (agricultural and forest), superposed on a unbalanced climate background, among which: destruction of moist areas years ago as a consequence of some draining aimed to create lands for agriculture, deforestations, destruction of protection forest curtains etc., which all at their turn induce climate effects.

The processes of land degradation expand and intensify rapidly manifesting not only in moist sectors, but also in semiarid and dry sub-moist sectors. The processes of soil degradation affects at different degrees more than 1/3 of the country surface. The most notable of all these, through extension and social-economic impact is the erosion caused by water, which together with landslips cover more than 7 million hectares. In Romania, the highest percentage of eroded soils is located in: Moldova Plateau, Subcarpathians between the Trotuş and the Olt, Transylvania Plateau and Getic Plateau among which there are included the Subcarpathian hills and plateaus in Oltenia. At the level of the entire country, the annual quantity of soil lost through erosion is about 123 million tonnes (Marinică, 2006).

Meteorological data in the last one hundred years in Dobrogea, Eastern Wallachia and Southern Moldavia (we took into account 17 meteorological stations from these regions), show a potential affectation of desertification of about 3 million hectares, of which 2.8 million ha are agricultural lands, representing 20% of agricultural surface.

Drought practically affects the whole agricultural surface of the country. Because of the increase of the risk of desertification, drought phenomena and land degradation, Romania's accession to CCD was a natural need.

Data and methods

Land desertification and degradation phenomena are closely connected with drought and dryness phenomena. For the study of dryness and drought phenomena the following criteria and methods can be successfully used:
- the analyse of non-regular variation of precipitations and the deviations of the quantities of precipitations (monthly, seasonal, biannual and annual);
- the frequency of pluviometric time type (Tables 1 and 2), according to hellman criterion applied to monthly and annual quantities of precipitations (the criterion has also established deviation percentage intervals of the biannual and seasonal from the normal).
- the use of Walter Lieth climate diagrams,
- the use of standardized precipitation index (SPI).

In this paper, we have broadly used Hellman criterion and as database the recordings from the meteorological stations in Oltenia with long series of meteorological observation (some of them of more than 120 years). We drafted series of charts necessary to the comparative analysis in the study of these complex phenomena and we used the statistical data published in order to predict the effects of droughty periods.

Table 1: Pluviometric time type in 1992 according to Hellmann criterion

														No of months		
Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An	TS	TP	TN
Craiova	ED	R	ED	N	ED	N	ED	N	ED	ED	ED	ED	ED	8	1	3
Băileşti	ED	ED	ED	VR	ED	LR	ED	ED	ED	ED	ED	ED	ED	10	2	0
Bechet	ED	VD	ED	VR	VD	ER	ER	ED	ED	VD	ED	ED	ED	9	3	0
Calafat	ED	ED	ED	ER	D	LR	ED	ED	ED	ED	ED	VD	ED	10	2	0
Tg. Jiu	ED	ED	ED	LD	ED	LR	D	ED	ED	N	D	VD	ED	10	1	1
Apa Neagră	ED	ED	ED	VD	ED	ER	VD	ED	VD	R	VD	N	ED	9	2	1
Polovragi	ED	ED	ED	D	VD	VR	D	VD	ED	N	VD	VD	ED	10	1	1
Tg. Logreşti	ED	VD	ED	LD	VD	VR	LD	ED	VD	D	VD	VD	ED	11	1	0
Dr. Tr. Severin	ED	ED	ED	LD	ED	ER	D	ED	ED	LD	ED	R	ED	10	2	0
Bâcleş	ED	ED	ED	N	ED	ER	ED	ED	ED	ED	ED	VD	ED	10	1	1
Slatina	ED	VD	VD	LD	ED	N	ED	ED	ED	ED	ED	ED	ED	11	0	1
Caracal	ED	D	ED	LD	ED	ER	ED	VR	ED	ED	ED	ED	ED	10	2	0
Rm. Vâlcea	ED	ED	ED	VD	ED	ER	ED	VD	VD	N	ED	ED	ED	10	1	1
Drăgăşani	ED	VD	ED	LD	ED	D	VD	N	ED	VD	ED	ED	ED	11	0	1
Petroşani	ED	LD	ED	LD	ED	ER	ED	D	VD	N	VD	VD	ED	10	1	1
Parâng	VD	ER	ED	VD	VD	VR	ED	N	LD	LR	D	ED	VD	8	3	1
Dry time (TS)	17	15	17	13	17	1	16	14	17	11	17	15	170	83.3%		
Rainy time (TP)	0	2	0	3	0	14	1	1	0	2	0	1	24	11.8%		
Normal time (TN)	0	0	0	1	0	2	0	2	0	4	0	1	10	4.9%		

(Source: processed data)

(ED=excessively droughty, VD=very droughty, D= droughty, LD= little droughty, N=normal, LR= little rainy, R= rainy, VR=very rainy, ER=excessively rainy, TS expressed in number of months / time dry weather station (TS), analog mention during rainy (TP) expressed in number of months / rainy weather station and time that normal (TN). For example, if the station X weather we had in Y, we say that we have a long dry month if / etc. stayed dry, this size has significant space-time useful in addressing drought and excess rainfall. lately sizes were defined which have significant space-time such as the average amount of rainfall for the entire country, monthly, annual, etc.. was noted that this size correlates well with flooding phenomena (on an average monthly rainfall of 80 litres/m^2 country - floods occur) and the drought etc.'s especially useful in climate weather problems within a month, quarter, semester, year, etc.).

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Table 2: Pluviometric time type in 1993 according to Hellmann criterion.

	Months													No of months		
Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An	TS	TP	TN
Craiova	FD	LR	ER	ED	FD	ED	ED	FD	D	ED	ER	FD	ED	9	3	0
Băileşti	FD	FD	R	ED	N	ED	ED	FD	D	ED	ER	D	ED	9	2	1
Bechet	FD	N	LR	ED	N	ED	ED	FD	FD	ED	ER	FD	ED	8	2	2
Calafat	ED	ED	LR	ED	VR	ED	ED	N	LD	ED	ER	D	ED	8	3	1
Tg. Jiu	ED	ED	ER	FD	FD	ED	FD	D	N	ED	ER	D	ED	9	2	1
Apa Neagră	ED	ED	ER	D	D	ED	ED	N	N	FD	VR	FD	ED	8	2	2
Polovragi	ED	ED	ER	FD	D	ED	FD	D	N	FD	LR	R	ED	8	3	1
Tg. Logreşti	ED	LD	ER	FD	FD	ED	ED	VR	ER	FD	VR	LD	FD	8	4	0
Dr. Tr. Severin	ED	ED	ER	ED	N	ED	ED	N	D	ED	ER	D	ED	8	2	2
Bâcleş	ED	ED	ER	ED	LD	FD	ED	LD	D	ED	ER	FD	ED	10	2	0
Slatina	ED	N	ER	ED	D		ED	VR	ER	FD	LR	ED	ED	8	4	0
Caracal	ED	D	LR	ED	ED	ED	ED	ED	ED	D	LR	ED	ED	10	2	0
Rm. Vâlcea	ED	ED	ER	LD	FD	ED	FD	N	LD	FD	R	N	ED	8	2	2
Drăgăşani	ED	N	ER	FD	D	N	ED	FD	FD	D	N	ED	ED	8	1	3
Petroşani	FD	ED	ER	ED	FD	D	FD	D	D	ED	D	N	ED	10	1	1
Parâng	ED	N	VR	FD	D	FD	FD	N	LR	ED	LD	N	ED	7	2	3
Dry time (TS)	17	12	0	17	13	16	17	10	11	17	2	13	145	71.1%		
Rainy time (TP)	0	1	17	0	1	0	0	2	3	0	14	1	39	19.1%		
Normal time (TN)	0	4	0	0	3	1	0	5	3	0	1	3	20	9.8%		

(Source: processed data)

Discussions

1. Desertification in Oltenia

1.1. Regionalization of Romanian territory according to aridity index (R)

The aridity index R is defined as the ratio of the annual precipitation sum P and potential evapotranspiration ETP (P/ETP).

According to the values of this index there are five areas:

- hyper-arid areas, in which R · 0.05;
- arid areas, in which R ≥ 0.05 and · 0.2;
- semiarid areas, in which R≥ 0.2 and · 0.5;
- dry sub-moist areas, in which R ≥ 0.5 and · 0.65;
- moist areas, in which R · 0.65;

In Romania, R · 0.2, according to this index, the climate falls within the semiarid, dry sub-moist and moist areas, (figure no. 1). In hilly and mountainous areas, the aridity index R exceeds 0.65, in steppe areas (steppe "islands") R is comprised between 0.2 and 0.50, and for forest steppe, between 0.5 and 0.65.

1.2. Climatic characteristics of the areas with desertification risk

– In the areas with a high risk of desertification and drought, climate is warm and dry;

- the annual average values of air temperature exceed 10·C;
- the sum of average temperatures · 0·C is comprised between 4000 and 4300·C;
- the sum of average temperatures · 10·C is comprised between 1600 and 1800·C;
- the sum of annual average precipitation sum is comprised between 350 and 550 l/m^2;
- the sum of monthly average precipitations in the period April – October is comprised between 200 and 350 l/m^2;
- soil water reserves on a depth from 0 to 100 cm on March 31 are comprised between 950 and 1500 m^3/ha, and the equivalent of precipitation values is comprised between 95 and 150 l/m^2.

In Oltenia

- in Oltenia Plain R ≥ 0.5 and · 0.65;
- in the hilly areas R≥ 0.65 and · 1.0;
- in Subcarpathians and mountainous area R ≥ 1.0 and · 2.70 (Fig. 1).

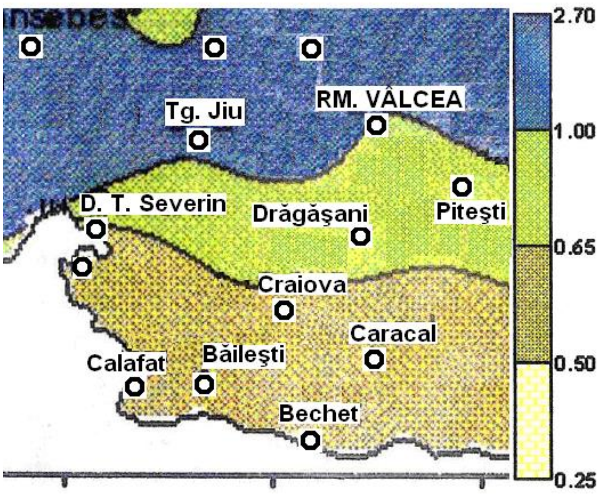

Fig. 1: Repartition of aridity index (R = P/ETP) in Oltenia *(according* to the National Strategy and Action Programme to Combat Desertification, Land Degradation and Drought*, 2000).*

Agroclimatic resources.

According to agroclimatic zoning (Fig. 2), in Romania there are three big agroclimatic areas with specific characteristics: warm-drought, moderate sub-moist and cool moist. The first one is subjected to imminent process of aridity.

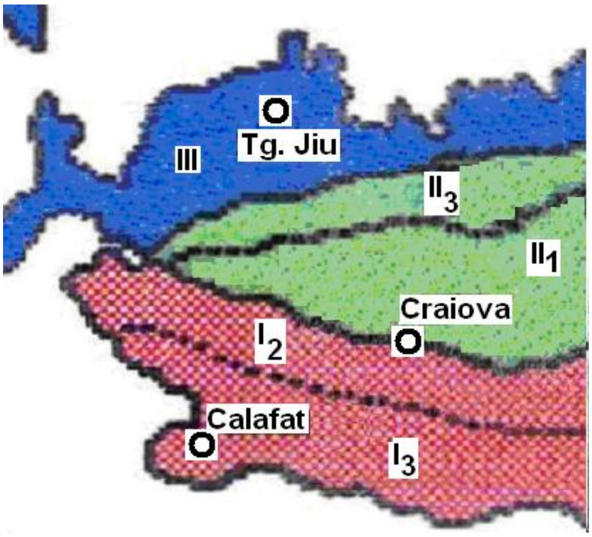

Fig. 2: Agroclimatic zoning in Oltenia *(according to the* National Strategy and Action Programme to Combat Desertification, Land Degradation and Drought, 2000). The zone I: hot dry, Σdaily average T > 4300-4000°C, annual rainfall 350-550 mm;). The zone II: moderate subhumid, Σdaily average T > 4000-3400°C, annual rainfall 550-650 mm; The zone III: cool wet, Σdaily average T> 3400-3000°C, annual rainfall 600-750 mm)*.*

The annual energetic flow is comprised between 110 and 140 Kcal/cm^2, namely by the level of the large cereal area in Europe, North America and East Asia.

The thermal potential is between 3000 and 4300·C, and the total value of temperatures in the vegetation period is comprised between 1200 and 1800·C.

In the area comprised between the annual isotherms of 6 and 8·C from the hilly-plateau, depressions and average mountains areas, people can cultivate micro and mesothermal (potato, rye, two-row barley, rape, flax), between annual isothermals of 8·C and 11·C (hilly areas) most of the agricultural plants can be cultivated, and in the area with annual average temperatures exceeding 11·C (plain) megathermal plants (cotton, rice, castor-oil plant).

The liquid resources vary as follow:

- on plain between 370 and 750 l/m^2, but have a non-uniform spatial-temporal distribution, which leads to significant annual fluctuations of crops;
- periods of time in which hydric resources provides an efficient capitalization of thermal resources representing 30% of the vegetation season, and in the rest of the time droughts or excesses of precipitation occur;
- most of the fluctuations are registered in the plain area in the south of the country in which Oltenia Plain is included with monthly values of precipitations comprised between 1 l/m^2 and 300 l/m^2 (and even 0 l/m^2 in some months);
- ***droughty periods are generally grouped in 2-4 years and returns cyclically, a fact proved by the grouping of droughty and rainy months.***

Non-regular variations of the quantities of precipitations and their negative deviations.

The regime of precipitations and temperatures, directly connected to the phenomena of dryness and drought registered great non regular variations in the last century.

The analyse of the negative deviations of the annual and monthly quantities of precipitations from the multiannual mean considered to be *normal* carried out for the southern half of Romania located at the shelter of Carpathian-Balkan orographic barrage from the western circulation, but exposed to the eastern circulation and to pontic influences, emphasized several climatic sectors: western – with oceanic and sub Mediterranean influences; central – interference of western and south-western with the eastern circulations; eastern – with continental influences, seaside with pontic influences and the sector adjacent to Carpathian Curvature with foehn effects reveal some significant results (Bogdan, Niculescu, 1999). They represented the base for the calculation of negative deviations of precipitations from the multiannual mean, considered to be normal.

2. The drought in the interval 1991-1993

The analysis of the pluviometric time type shows that this drought actually began in 1987, when in the south of Oltenia and in general in the Romanian Plain, especially in the warm season droughty and excessively droughty months registered. In the extreme south of Oltenia, droughty and excessively droughty months registered also in 1983, 1985, 1986, drought had therefore a slow evolution in time with short periods in which precipitations came back to normal, but the deficit of precipitations in soil and the phreatic layers has accumulated in time and has increased, although the annual quantities of precipitations were closed to normal.

The phase of drought maximum intensity occurred in the summer of 1993 when, seven counties in the south of the country were damaged and, the Romanian Government had to pass the Law 70/1993 on the cover of expenses made in order to set up crops (Tables 1 and 2). In these two years, drought became violent due to dryness phenomena of plants, pastures and even of some areas with

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forest vegetation. In these two years, the lack of precipitation occurred during a long period of time, for example a droughty time has been registered for 19 months of 24 in Băileşti in Oltenia Plain of which 15 were excessively droughty, as well as in Tg. Jiu and Slatina, 20 months in Caracal in the south-east of Oltenia, in Bâcleş in Mehedinţi hills, in Petroşani depression, etc. (Tables 3 and 4).

Table 3: Pluviometric time type in 2000 according to Hellmann criterion

	Months													No of months		
Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An	TS	TP	TN
Craiova	N	N	ED	VR	ED	ED	R	ED	ER	ED	VD	ED	ED	7	3	2
Băileşti	VD	ED	ED	LD	ED	ED	VR	ED	ER	ED	ED	ED	ED	7	3	2
Bechet	LR	VD	ED	N	ED	ED	D	ED	ER	ED	VD	ED	ED	9	2	1
Calafat	VD	ED	ED	LR	ED	ED	LR	ED	N	ED	ED	ED	ED	9	2	1
Tg. Jiu	ED	ED	LD	D	VD	ED	D	ED	R	ED	ED	VD	ED	11	1	1
Apa Neagră	ED	ED	VD	D	ED	ED	VD	ED	VD	ED	ED	ED	ED	12	0	0
Polovragi	VD	ED	D	LD	ED	ED	VD	VD	N	ED	ED	VD	ED	11	0	1
Tg. Logreşti	VD	VD	VD	N	ED	ED	LR	VR	ER	ED	ED	ED	ED	8	3	1
Dr. Tr. Severin	ED	ED	ED	VD	ED	ED	N	ED	N	ED	ED	ED	ED	10	0	2
Bâcleş	ED	ED	ED	ER	ED	ED	ER	ED	ER	ED	ED	ED	ED	9	3	0
Slatina	LR	VD	ED	ED	ED	ED	LD	ED	ER	ED	ED	ED	ED	10	2	0
Caracal	D	D	ED	N	ED	ED	ED	ED	ER	ED	ED	ED	ED	10	1	1
Rm. Vâlcea	VD	ED	VD	VD	ED	ED	LD	ED	R	ED	ED	VD	ED	11	1	0
Drăgăşani	LR	D	ED	N	ED	ED	N	ED	VR	ED	ED	ED	ED	9	1	2
Voineasa	ED	ED	N	D	ED	ED	VD	LD	D	ED	ED	LD	ED	11	0	1
Petroşani	N	ED	ER	LD	VD	ED	D	ED	VD	ED	ED	N	ED	9	1	2
Parâng	R	D	ER	VD	ED	ED	ED	ED	VD	ED	ED	N	ED	10	1	1
Dry time (TS)	9	15	13	10	16	17	10	16	4	16	16	14	156	80.4%		
Rainy time (TP)	4	0	2	3	0	0	5	1	9	0	0	0	24	12.4%		
Normal time (TN)	2	1	1	3	0	0	2	0	3	0	0	2	14	7.2%		

(Source: processed data)

Table 4: Pluviometric time type in 2007 according to Hellmann criterion

	Months													No of months		
Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An	TS	TP	TN
Craiova	ED	ER	ER	VD	ER	VD	ED	ER	ER	ER	ER	D	ER	5	7	0
Băileşti	ED	ER	N	VD	R	ED	ED	ER	ER	ER	ER	D	VR	5	6	1
Bechet	ED	ER	D	VD	N	ED	ED	ER	LD	ER	R	N	LD	6	4	2
Calafat	ED	VR	N	VD	VR	VD	ED	ER	N	ER	VR	VD	LR	5	5	2
Tg. Jiu	LD	ER	ER	VD	ER	VD	VD	ER	ER	ER	ER	D	ER	5	7	0
Apa Neagră	LD	ER	ER	VD	R	LD	ED	ER	VR	ER	ER	VD	ER	5	7	0
Polovragi	LD	ER	ER	VD	VR	ED	VD	ER	ER	ER	ER	D	ER	5	7	0
Tg. Logreşti	VD	VR	ER	VD	ER	LR	ED	ER	ER	ER	ER	VD	ER	4	8	0
Dr. Tr. Severin	ED	ER	VR	VD	VR	VD	VD	ER	D	ER	ER	VD	LR	6	6	0
Bâcleş	VD	ER	LR	VD	N	N	ED	ER	VD	ER	ER	ED	N	5	5	2
Slatina	VD	R	R	VD	VR	ED	ED	ER	R	ER	ER	LD	ER	5	7	0
Caracal	VD	ER	LR	VD	N	VD	ED	ER	N	ER	ER	VR	ER	4	6	2
Rm. Vâlcea	R	VR	ER	VD	N	VD	ED	ER	ER	ER	ER	VD	R	4	7	1
Drăgăşani	VD	N	VR	VD	N	ED	ED	ER	ER	ER	LR	VD	VR	5	5	2
Voineasa	ER	R	ER	VD	VR	VD	VR	ER	ER	ER	ER	ED	ER	3	9	0
Petroşani	ER	ER	ER	VD	VR	ED	VD	ER	VR	ER	VR	ED	ER	4	8	0
Parâng	ER	ER	ER	VD	VR	VD	LD	ER	ER	ER	ER	ED	ER	4	8	0
Dry time (TS)	13	0	1	17	0	15	16	0	3	0	0	15	80	39.2%		
Rainy time (TP)	4	16	14	0	12	1	1	17	12	17	17	2	113	55.4%		
Normal time (TN)	0	1	2	0	5	1	0	0	2	0	0	0	11	5.4%		

(Source: processed data)

Among the major negative deficits of precipitation we mention:

- *in 1992:* 259.7 l/m^2 (46.48% of the normal value) in Calafat, 275.2 l/m^2 in Dr. Tr. Severin (36.69% of the normal value), 286.0 l/m^2 in Bâcleş (46.24% of the normal value), 289.5 l/m^2 (33.5% of the normal value) in Polovragi, 296.6 l/m^2 (32.43% of the normal value) in Apa Neagră, 304.9 l/m^2 (53.72% of the normal value) in Băileşti, 308.0 l/m^2

(40.40% of the normal value) in Tg Jiu, 321.3 l/m^2 (55.02% of the normal value) in Slatina etc. ***The percentage deficits were comprised between 17.83% in Parâng in the high mountainous area and 55.02% in Slatina in Getic Plateau at the northern limit of Oltenia Plain.*** In this year, the droughty year had a percentage of 83.33% months-meteorological station.

-*in 1993:* 141.9 l/m^2 (25.40% of the normal value) in Calafat, 165.7 l/m^2 (29.19% of the normal value) in Băileşti, 181.8 l/m^2 (26.22% of the normal value) in Dr. Tr. Severin, 186.0 l/m^2 (25.69% of the normal value) in Rm. Vâlcea, 196.0 l/m^2 (34.53% of the normal value) in Bechet, 205.3 l/m^2 (22.44% of the normal value) in Apa Neagră, 222.8 l/m^2 (25.75% of the normal value) in Polovragi, 218.3 l/m^2 (28.03% of the normal value) in Petroşani, 235.4 l/m^2 (24.32% of the normal value) in Parâng, 236.1 l/m^2 (43.59% of the normal value) in Caracal etc.

The percentage deficits were comprised between 18.84% in Tg. Logreşti in Oltenia hills and 43.59% in Caracal in the south-east of Oltenia Plain.

In this year, droughty time had a percentage of 71.08% months/meteorological station.

Although in 1993 the deficits of precipitations were lower than in 1992 the effects on crops and, in general, on the vegetal cover were much more serious, thus the drought climax was reached.

In figure 3, we present the evolution of this drought in number of months/meteorological station of droughty time.

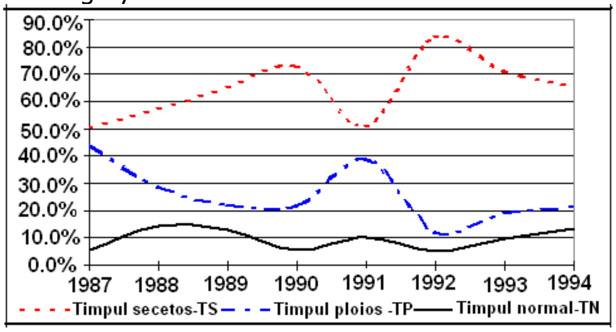

Fig. 3: Drought evolution in the interval 1987-1994 in percentages of number of cases of time type (months/meteorological station)
(Source: processed data)

In the period 1987-1993 the percentage of droughty time in Oltenia was comprised between 50.49% in 1987 and 83.33% in 1992, with an average of 64.62%.

Mehedinţi, Dolj, Olt and Teleorman were among the worst affected counties.

Some of the disasters were:

– on extended areas, corn crops were damaged in a percentage of 95–98%;

– all crops have been damaged.

For example, in Dolj county there have been damaged:

– 260 000 ha corn crop, in a percentage of 100%. At the county level the average production was of 200 kg cobs per hectare;

– 4 500 ha soy crop, damaged in a percentage of 100%;

– 3 000 ha bean crop, damaged in a percentage of 100%;

- orchards, vineyards and hay-fields were highly damaged (Marinică, 2006).

In Dolj County, 10 282 billion lei were paid (at the value of 1993), as indemnities representing only the costs of setting up crops. Drought also caused the fountains' drain and drastic decrease of underground water reserves in many localities, rivers and lakes' drain.

In many cities in the south of the country and even in Bucharest, the rationing of drinkable water was implemented. It was affected the production of electricity of the hydroelectric power stations on the Danube.

On the Danube and in Delta, special measures were taken for navigation. The analysis of flowing on the rivers in the south of the country showed that it has been the most severe drought after the drought in 1946 (Marinică, 2006).

Its duration in Oltenia was about 8 years, and in 1991, precipitations returned and a short period of interruption occurred, a typical situation since drought are interrupted by short rainy periods.

For the area of the 7 counties to which the Law 70/1993 refers, this was a catastrophic drought. The specificity of the Romanian territory is that drought does not manifest with the same intensity on the whole country and seldom affects the entire territory, an aspect due to the interaction of the Carpathian chain with the general circulation at the level of the entire European continent.

It should be noted that, from a thermal point of view, no record of maximum temperatures were broken although there were registered some hot periods during summer.

3. Drought and canicula in Oltenia in 2000

The droughty period which started in January 2000 lasted until July 17, 2002. It was interrupted by three short rainy periods in 2001 in which rains were followed by sunny days with wind gusts, which contributed essentially to the evaporation of soil water and the reappearance of water deficit in arable layer.

The summer of 2000 marked for Romania (Oltenia) the occurrence of canicula on extended periods of time. This was also accompanied by drought.

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The drought evolved slowly in the first months of the year, January, February and March, being marked by precipitations well below the norm.

The spring arrival was early during February, and afterwards, in the end of April, late hoarfrosts appeared, which were followed by spring months, April and May, with very few precipitations. In the end of June, canicular days started to appear. In July and August, the periods of prolonged canicula succeeded with short intervals of time, in which weather "cooled" slightly compared to the previous canicular days.

From a synoptic point of view, there has been an evolution of synoptic situation similar with those described in the characteristic drought types. The difference consisted in the fact that the periods of canicula, temperature maintained high even during nights.

In our country, a thermal record for July registered, on July 5, 2000, in Giurgiu 43.5° C, being the absolute maximum temperature of July.

The analysis of the pluviometric time types revealed the following aspects:

After the rainy summer of 1999, when in July there were registered 135.4 l/m^2 in Parâng, 136.4 l/m^2 in Voineasa, 136.6 l/m^2 in Slatina, 149.2 l/m^2 in Tg Jiu, 190.3 l/m^2 in Petroşani, 331.4 l/m^2 in Dr. Tr. Severin, 386.3 l/m^2 in Apa Neagră (Marinică, 2006), drought arrived gradually in Oltenia (August 1999 was droughty in most part of Oltenia, then the pluviometric poor time maintained in September, October and November, and in December the excess of precipitations returned).

The characteristics of drought in 2000 are:

The maximum intensity was registered in 2000 when 12 droughty months were registered in Apa Neagră Subcarpathian Depression and 11 months in Polovragi and Rm. Vâlcea, 10 months in Dr. Tr. Severin and Caracal, 9 months in Bechet, Calafat, Bâcleş, Drăgăşani and Petroşani, etc. (table no. 3).

In 2000, the percentage of droughty time was of 80.41%, compared to that in 1992. Among the most important annual deficits are: 294.9 l/m^2 (52.8% of the normal value) in Calafat, 296.1 l/m^2 (52.17% of the normal value) in Băileşti in Oltenia Plain, 300.00 l/m^2 (38.5% of the normal value) in Petroşani, 313.6 l/m^2 (53.7% of the normal value) in Slatina, 352.9 l/m^2 (45.5% of the normal value) in Voineasa (Vâlcea County), 373.6 l/m^2 (51.6% of the normal value) in Rm. Vâlcea, 407.7 l/m^2 (58.81% of the normal value) in Dr. Tr. Severin, 428.9 l/m^2 (56.3% of the normal value) in Tg. Jiu, 443.7 l/m^2 (45.8% of the normal value) in Parâng, 495.0 l/m^2 (57.2% of the normal value) in Polovragi and 576.6 l/m^2 (63.0% of the normal value) in Apa Neagră. The percentage annual deficits of precipitations were comprised between 36.2% in Craiova and 63.0% in Apa Neagră.

The drought of 2000 in Oltenia was in general extremely intense and associated with extended periods of canicular weather and heat waves in the intervals: June 6-10, 21-25, July 2-12, 22-27, August 3-7, 17-24. It affected the entire social life, causing the increase of food price and implicitly of other products.

According to the values of these deficits of precipitations, the entire year 2000 was excessively droughty (Table 3). The aridity processes were intense in all the southern half of Oltenia and especially in the area called "Oltenia Sahara". (*The surface of sandy soil of* ***over 100.000 hectares on the left of the Danube, between Calafat and Dăbuleni – known as Oltenia Sahara*** *(fig. no. 5)* ***represent an arid area, with tendencies of desertification.*** *The only country in Europe which owes a* ***Museum of Sand*** *is Romania. The Museum is located in the locality of Dăbuleni in the south of Oltenia. It is a surface of 12 hectares with white sand, which was left undeveloped in the communist regime in order to make the comparison between crops obtained on developed and undeveloped surfaces of land. It was declared a Museum. Nowadays, a significant percentage of the former agricultural arrangements are destroyed, and aridity processes are in progress in Oltenia Sahara (Craiova Regional Agency for Environment Protection, quoted by http://www.realitatea.net/sahara-olteniei-are-peste-100-000-de-hectare-de-teren-arid_480337.html).*

In 2001: March, April, June and July were rainy, and January, May and August were droughty, and then the excessive drought came back in the interval September, 2001 – July 17, 2002. The interruption of drought occurred in the second part of July 2002 when a rainy period began, which reached the climax in 2005.

In figure 4 we present the evolution of drought in the interval January 1, 2000-July 17, 2002.

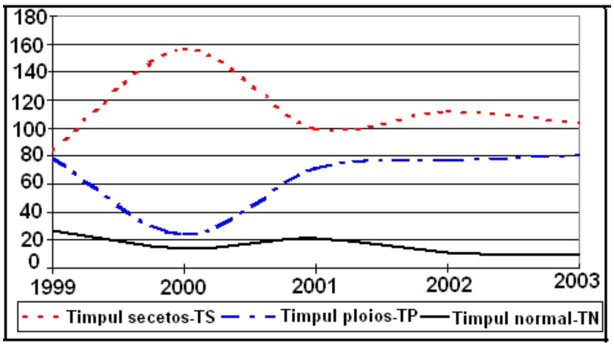

Fig. 4: Drought evolution in the interval 2000-2002 in number of cases of time type (months/meteorological station)
(*Source: processed data*)

The drought in the summer of 2000 affected 2.6 million hectares (of the entire country) and led to damages evaluated to about 6500 milliard lei (at the value of 2000) (Marinică, 2006).

4. Drought of 2007

In the summer of 2007, in Oltenia, weather was extremely changeable. Among the most important weather aspects we can enumerate six heat waves in the intervals: **June 19-26**; July 2-4; 8-10; **15-24**; 27-30; August 22-25;

Two of these had a great intensity, the one in the interval June 19-26 and that in the interval 15-24 July. Twice during this summer, in June and July, the vegetation on pastures dried, many forest fires affected Oltenia and the country, fires occurred in almost all countries on the continent, and all crops were considerably damaged, phreatic layers dried, many localities remaining without water supply. Consequently, domestic animals died because of the lack of food and water.

People have suffered and the price of vegetables and fruits has been high during all summer. The Danube level highly decreased causing problems to navigation. The violent drought in the most important months of summers forced the governmental bodies to consider that it was worse than the worst drought in the last century, that from 1945-1946. The Romanian Government proposed the elaboration of a plan of anti-drought measures, within which in some localities deep drillings were executed for the water supply, the water tank supply being an improper solution.

The last two days of July and August brought significant quantitative rainfalls, thus 5 rainy periods registered, which for crops did not bring any improvement of the situation. Yet, these were beneficent for the straightening of water supply of many localities and led to the rehabilitation of the vegetation on pastures and redressed food conditions for animals. Consequently, the programme of anti-drought measures was "abandoned" and either by October 15, 2007 was not discussed in the Romanian Parliament. The price of bread-making wheat highly rose, and on October 16, 2007, its price was of 260 €/t, and on the same date it was provided that it would be of 300 €/t, and in 2006 on the same date was of 110 €/t (Bogdan and Marinică, 2007). The summer of 2007, which followed after the Mediterranean winter in the south of the country, 2006-2007, was very warm in the entire country.

The summer of 2007 began with June, an excessively warmish month in the last decade in which a strong heat wave affected the entire country and severely the south. Warmish weather was accompanied by a severe drought of complex time (atmospheric and pedospheric), which highly damaged firstly wheat crops in a percentage of 60% at the level of the entire country and then beginning with the second half of June also weedinger crops, vegetal carpet on pastures, causing fountains' drain and serious economic effects. Afterwards, the drought and canicula in July 2007 worsened a lot the destructive effects.

The heat wave in the period July 15-24, 2007 was the most intense for this month of all the period since meteorological observations are carried out and marked the exceeding of the monthly absolute maximum thermal value of July with 0.8°C (in Calafat registered on July 24, 2007, 44.3°C which now is the absolute maximum thermal value of July in Romania – the old absolute maximum thermal value of July in Romania was 43.5°C registered in Giurgiu on July 5, 2000). The maximum air thermal value, monthly absolute thermal value of July, registered in the last century on July 5, 1916 was 42.9°C in Alexandria and was exceeded with 0.6°C after 84 years on July 5, 2000. Until this date we observe a slow evolution of the absolute maximum thermal values of July, and then in an interval of 7 years one more spectacular exceeding with 0.8°C.

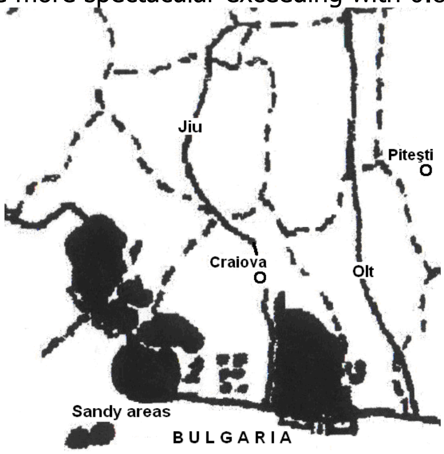

Fig. 5: Sandy areas in Oltenia (*processed according to Gh. Marinică and colab. 1999*)

We notice in July 2007 for the first time air temperature reached and exceeded the climatological threshold of 44°C. Values of 44°C and higher were registered in Romania one time in all the history of meteorological observations, only in August, more precisely in the last century on August 10, 1951 when at four meteorological stations the value of 44°C was reached and exceeded (in Bărăgan, in Râmnicelu commune at Ion Sion farm 44.5°C, which is the absolute maximum air temperature value in Romania and 44.0°C in Amara-Slobozia and Valea Argovei). In July 2007, values higher or equal to 44°C also registered at the meteorological stations: Băileşti and Moldova Veche 44.0°C, Bechet 44.2°C and Calafat 44.3°C, which means a more extended area of hot air than in the last century. At soil surface, the maximum thermal value registered in Calafat was 69.0°C, and in Băileşti 71.0°C, the diurnal thermal amplitude being of about 45°C. (This intense and persistent heat wave affected Hungary, Italy, Greece, Romania, R. Moldova, Turkey and Ukraine, and on July 27, 2007 forest fires

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caused by canicula (*The term of **canicula** characterises weather condition in which air temperature, measured in standard conditions at meteorological stations reaches or exceeds the threshold of 35°C (it is also said that **weather is canicular**) manifested on extended areas and mass-media announced that the south and east of Europe were "burning" (news from July 27, 2007*).

The drought in 2007 manifested for about 90 days, and the intervals of occurrence coincided with the periods in which crops had maximum needs of water. In table no. 7 we present the main characteristics of the time type in 2007.

On the whole, according to the annual values of precipitations, 2007 was exceedingly rainy in the

northern and eastern half of Oltenia, rainy in south-east, normal in Bâcleş area, little rainy only on a restricted area in the extreme south and west of the region (Calafat and Dr. Tr. Severin) and little droughty in Bechet area, which shows that for the agricultural year 2007, the annual values of precipitations are less significant, and the exceedingly drought in the optimum vegetation period, coupled with canicula and intense heat wave had extremely destructive effects. The percentage deviations of the normal precipitation values had values from 6.05% in Calafat up to 51.87% in Voineasa, and in the normal and little droughty area from -9.99% in Bechet up to -0.95% in Bâcleş, which shows the great variability of the quantities of precipitations in Oltenia in 2007.

– The two periods of exceedingly droughty in April-May and June-July in 2007 amounted about 97 days. According to the National Institute of Statistics, drought affected 4 million hectares of the agricultural surface of our country. Of all these, one million cultivated hectares were completely compromised (Source: Ziare.com September 8, 2007).

– August 2007 was extremely rainy, and the quantities of precipitations often exceeded 200 l/m^2, causing excedentary precipitations on the whole of summer.

– The excessively rainy period in August-November 2007.

– The main maximum pluviometric had lower precipitations than the secondary maximum pluviometric.

– In the last 8 years, in what precipitations are concerned, it can be observed this tendency, that the secondary maximum pluviometric is higher than the main one, the year thus splitting into two periods a warm and dry period (spring and summer) and the second rainy and cold period (autumn and winter, precipitations decreasing during winter).

The evaluation of damages produced by this drought accompanied by canicula in the summer of 2007 brought losses of tenth million euros. The most affected domains were agriculture, where the crop of thousands of hectares was compromised, as well as the production of energy from hydro sources.

In June, the average debits of the Danube are of 6,400 – 6,500 m/s. In 2007, in the first 20 days of June, the Danube flows were on average of 4,100 m/s, which meant a drop with 35 - 40% of the monthly average flow and of the electricity production. The production in June 2006 was of 17,000 MWh per day, and in 2007 only of 11,000 MWh per day. Even lower flows were registered at Iron Gate Hydroelectric Power Station in 1996, of 2,600 m/s (Teodor Pavelescu, manager of Navigation and Hydroelectric System Iron Gate, quoted by Mediafax, 1996).

By June 20, drought affected 1.2 million hectares of crops at national level, which represents 61% of agricultural surface, 34 counties being declared damaged areas.

Romania imported in the period 2007-2008 over one million tons of wheat, which led to the increase of bread price.

In our country, as a consequence of the severe drought in the summer of 2007, the rise of basic food was made with percentage values comprised between 40% and 100% and even much more at certain food.

During droughts, aridity and desertification phenomena highly develop in sandy areas. Almost 2/3 of the total surface occupied with sands and sandy soils is located in Romanian Plain, with a significant percentage in its western side, described in the literature called "sands in the south of Oltenia" (Marinică, Gh. and colab., 1999). In these areas, the relief is represented by dunes and interdunes with variable forms and dimensions, orientated from west to east. These are the most arid regions in the country, a fact proved by aridity index Emm. De Martonne, which is of 22.5 (Ifrim and colab. 2003). For the entire country the surface occupied with sands and sandy soils is of 439.0 thousand ha, of which the total of agricultural surface is of 381.0 thousands ha. The most important surfaces are: in the steppe and forest steppe, on low plains, in meadows, in the Danube Delta, on Black Sea seaside.

The draining of the Danube Puddles and the creation of great agricultural complexes equipped with modern irrigation systems maintained the albedo of these surfaces at values close to the previous ones as well as the microclimate, but subsequently after the decommissioning of these irrigation systems accompanied by the deforestation of protection belts (after 1990), the albedo of these sandy surfaces highly changed causing the strong air warming in those areas and favoured through local specific processes the penetration of warm air and heat waves from the south of the continent. Consequently, in the conditions of global climate warming, the frequency and intensity of heat waves increased, favoured by tropical circulation in the warm season, and the local conditions highly amplified their effects, the frequency of dust and sand storms increased, being close in some periods to the specific desert climate.

The coefficient of thermal conductivity (*The coefficient of soil thermal conductivity indicates the degree of heat transmission from the warm soil layers to the layers with a lower temperature.*) of the sandy soils is 0.0028 cal/cm.s.degree, namely the smallest of all types of soil which hinders heat propagation in the soil depth, but contributes essentially to the strong air warming in the concerned area. Thermal and hydric qualities of these soils makes them ~~to~~ be valuable for agriculture in the normal years from a pluviometric point of view or rich in precipitations, but these qualities makes them also extremely vulnerable to aridity and desertification phenomena during drought, and this is why on these soils arrangements for irrigations are necessary. The albedo of these land surfaces is about 35%, namely with only 4% lower than the general albedo of Earth as a planet, and as all the other qualities of which he have already spoken contribute to the strong increase of air temperature in these areas especially during heat waves.

Conclusions

The desertification phenomenon is obvious during the long periods of droughts within the southern and south-western part of Oltenia on the sandy soils with weak structure, the deflation leading to the movement of sand dunes.

In the studied interval, droughts manifested intensively and highly damaged the entire social life. Their frequency has grown, and during the warm season has been associated with increasingly intense heat waves, which increased their effects. Fires of forest vegetation occurred on pastures and fields. The agricultural production highly decreased, and the financial efforts necessary to the economic recovery became higher and higher. The intense droughts in the period when plants had maximum needs of water were extremely destructive, and the damages have been substantial. Their effects are felt even nowadays. From a meteorological point of view, they are caused by the predominance of atmospheric regimes of antycilonic type, and the appearance and installation of atmospheric circulations of tropical continental type lead to the occurrence of heat waves which worsen the effects of droughts causing the dryness of vegetal cover and the severe damage of biosphere. Monitoring data of drought phenomenon show that at the level of the entire country, about 14.7 million hectares of agricultural land, of which 9.4 million hectares arable land (64% of arable surface), are affected, to a greater or lesser degree, by frequent drought, on long periods of time and in consecutive years. Analysing the statistics, it was established that the warmest years were 1998, 2001, 2002, 2003 and 2004. Because of the lack of precipitations, Romania confronted with the phenomenon of prolonged drought in intervals such as: 1894-1907, 1945-1951, 1983-1994, 2000-2003. Due to its duration, intensity and effects, the drought of 2000 was considered one of the most severe droughty manifested on the territory of our country in the 20th century. Although it was registered only in the vegetation period of one single year, the drought of 2007 is one of the most severe, its effects being amplified by the intense heat waves. These phenomena are strictly connected with global climate warming and North-Atlantic Oscillation. During warm summer the extension towards north of the tropical climate in the Mediterranean Sea area occurs.

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Analysis of precipitation characteristics and trends for the Getic Piedmont and Subcarpathians, Oltenia region, Romania

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Abstract

Changes in precipitation characteristics of the hilly area of Oltenia, covering the western parts of the Getic Piedmont and SubCarpathians, were analysed, based on monthly rainfall data, for the timeframe 1961 to 2010. The precipitation trend analysis for the period 1961-2010 shows different results–increasing precipitation in winter half part of the year for most of the Subcarpathian area and a rainfall decrease in summer half of the year for the entire region. The piedmont part of the study area, with dominant agricultural land use, shows the highest spring precipitation decrease, whereas in the Subcarpathian area, summer and autumn precipitation increase is more pronounced. The positive trends are spatially the most homogenous in August, September and October, while the most uniform negative trends were recorded in February, May and November. At annual level, the most significant decrease corresponds to the piedmont, while the rest of the region displays an insignificant positive trend. The SPA emphasized that normal years (deviations oscillating between -1.00 and +1.00) predominate; however, in the eastern part of the region there are lower percentages compared to the western part (70-74% compared to 64-66%). At the same time, in the east, the share of dry weather is double compared to the western part, where rainy weather predominates.

Keywords: *precipitation, trends, SPA, Oltenia, Romania*

Rezumat. Analiza caracteristicilor şi tendinţelor regimului pluviometric din Piemontul şi Subcarpaţii Getici, Regiunea Oltenia, România

Au fost analizate modificările survenite în regimul pluviometric din regiunea deluroasă a Olteniei, care acoperă partea vestică a Podişului Getic şi a Subcarpaţilor Getici, plecând de la cantităţile lunare de precipitaţii înregistrate în perioada 1961 – 2010. Analiza tendinţei de evoluţie a precipitaţiilor pentru perioada menţionată a evidenţiat rezultate diferite – creşterea cantităţilor pentru semestrul rece în cea mai mare parte a zonei subcarpatice şi o scădere a cantităţilor pentru semestrul cald la nivelul întregii regiuni analizate. Zona piemontană, unde terenul este în mare parte utilizat agricol, prezintă cea mai evidentă scădere a cantităţilor înregistrate primăvara, în timp ce la nivelul zonei subcarpatice, cele mai însemnate creşteri se remarcă vara şi toamna. Tendinţele pozitive sunt omogene în lunile august, septembrie şi octombrie, în timp ce cele mai omogene tendinţe negative se înregistrează în lunile februarie, mai şi noiembrie. La nivel annual, cea mai semnificativă scădere a cantităţilor corespunde zonei piemontane, în timp ce în restul regiunii se remarcă o tendiţă pozitivă nesemnificativă din punct de vedere statistic. Valorile ASP au evidenţiat predominarea anilor normali (abateri cuprinse între -1,00 şi +1,00); totuşi, în partea estică a regiunii, ponderile sunt mai reduse decât în cea vestică (64-66%, respectiv 70-74%). În acelaşi timp, în partea estică, ponderea timpului secetos este dublă comparativ cu cel înregistrat în partea vestică, unde predomină timpul ploios.

Cuvinte-cheie: precipitaţii, tendinţe, ASP, Oltenia, Romania

Introduction

Precipitations represent the most variable climatic parameter, because global temperature increase usually triggers changes and variability of rainfall amounts, as well as of their spatial and temporal distribution (IPCC, 2007). In Europe, precipitation variability and trends have been thoroughly studied in the last decades. The results are sometimes contradictory, as they depend on the considered time scale and regions. Thus, Klein Tank and Können (2003) underlines an increasing trend of precipitation amounts, while Mudelsee et al. (2003), on the contrary, emphasized a decreasing trend. Other researchers focused on precipitation variability and trends at a global scale (Diaz et al., 1989; Hulme, 1995; New et al., 2001), regional scale (Norrant and Dougúedroit, 2006), or even local scale (Brunetti et al., 2001a, b, 2006; Rodrìguez-Puebla et al., 1998). In Romania, precipitation variability and trends have been analysed in the last decade, as well. Thus, it resulted that there was registered a significant decreasing trend for winter, especially within the extra-Carpathian region (Tomozeiu et al., 2005). A decreasing trend was also identified for summer and annual precipitation amounts in the central part of the Romanian Plain by Croitoru and Toma (2010), while Piticar and Ristoiu (2013) reached the conclusion that the increasing or decreasing seasonal or annual trends registered in the northeastern part of Romania are generally not statistically significant.

Research Methods

For the present study, there were used monthly precipitation amounts from six meteorological stations (Table 1, Fig. 1). The stations are uniformly distributed, namely two in the piedmont area, west and east of the Jiu River, and four in the

Subcarpathian area. The datasets cover a 50 years period (1961-2010) and they were provided by the Romanian National Meteorology Administration (ANM). There were no missing data.

To calculate trends of the precipitation amounts, there were used 19 data series for each station, namely 12 monthly series, 4 seasonal series, 2 half year series and one annual series.

In order to detect trends in the time series of precipitation amounts, it was used the Excel template MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), developed by the researchers of the Finnish Meteorological Institute (Salmi et al., 2002). Mann-Kendall test is a non-parametric test used for rendering the significance of a linear trend against the null hypothesis of "no trend". The test statistic Z enables the comparison between the absolute value of Z and the standard normal cumulative distribution to detect a certain trend at a certain level of significance α. Consequently, positive values of Z clearly indicate upward trends, while negative values of Z indicate downward trends. Sen's method enables the estimation of the magnitude of a trend. In the present study, the trends are considered to be statistically significant at α level of 0.05. The same method was successfully applied also in temperature data series by Micu and Micu (2006), Piticar and Ristoiu (2012), Croitoru et al. (2011a), Vladut and Ontel (2013), sunshine duration (Croitoru et al., 2011b), snow cover (Micu, 2009), etc.

Table 1 Geographical coordinates of the considered meteorological stations

Meteorological station	Latitude (N)	Longitude (E)	Height (m)
Bâcleș	44°29`	44°29`	313
Târgu Logrești	23°07`	23°07`	265
Apa Neagră	44°53`	44°53`	258
Târgu Jiu	23°42`	23°42`	203
Polovragi	45°00`	45°00`	531
Râmnicu Vâlcea	22°52`	22°52`	237

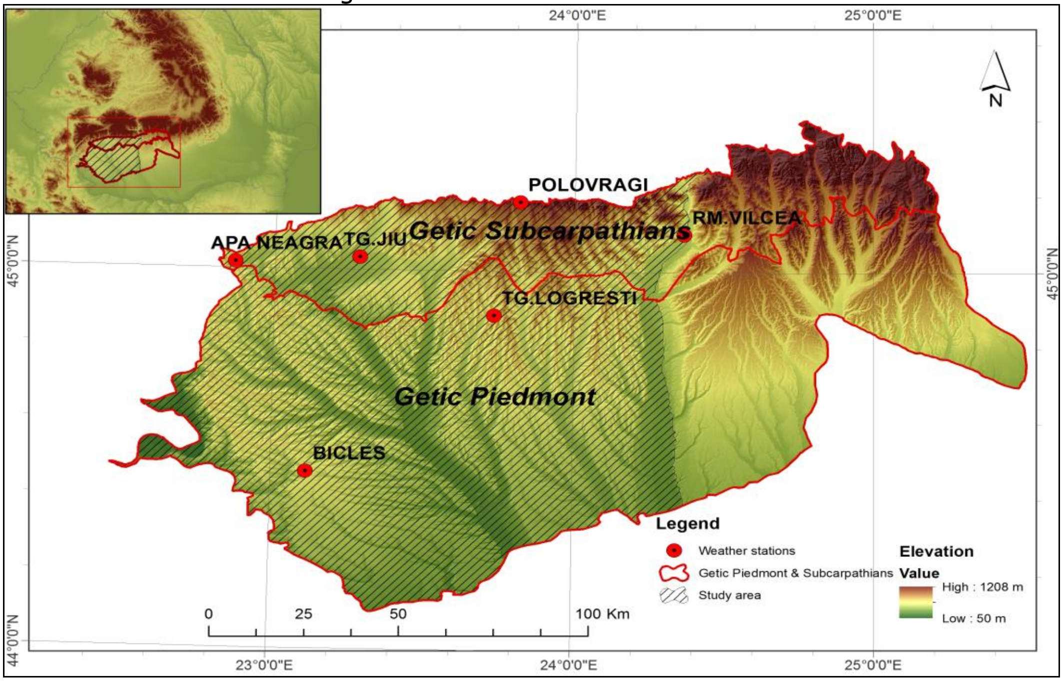

Fig. 1 Location of the meteorological stations within the Getic Piedmont and Subcarpathians

Standardized Precipitation Anomaly (SPA) represents a greatly used method in Romania (Dumitraşcu et al., 2001; Cheval et al., 2003; Croitoru and Toma, 2010). It is calculated as follows:

$$SPA = \frac{x_i - \bar{x}}{\sigma}, \text{ where}$$

SPA – Standardized Precipitation Anomaly;
xi – precipitation amount for *i* month/year;
$\bar{x}$ - multiannual average amount of precipitations;
σ - standard deviation

The standard deviation is computed by extracting the square root of the variance (σ^2). Dispersion is a synthetic indicator, respectively the square mean of the deviations of parameter individual values from the average of the entire string (Cheval et al., 2003). The formula for calculating the dispersion (σ^2) is:

$$\sigma^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n},$$

where *n* represents the number of years

Thus, standard deviation (σ) is calculated according to the formula:

$$\sigma = \sqrt{\sigma^2} = \sqrt{\frac{\sum_{i=n}^{n} (x_i - \bar{x})2}{n}}$$

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When the data string is longer than 30 years, *n* is replaced by *n-1*; however, the results does not substantially modify.

According to the obtained values, the years can be classified in nine categories, from exceptionally rainy to exceptionally dry (Table 2).

Table 2 Pluviometric characteristics of months and years according to the SPA values

Characteristic	SPA
Exceptionally rainy	> 2.5
Excessively rainy	2 … 2.5
Very rainy	1.5 … 2
Rainy	1 … 1.5
Normal	1 … -1
Dry	-1 … -1.5
Very dry	-1.5 … -2.0
Excessively dry	-2.0 … -2.5
Exceptionally dry	< -2.5

Source: Gaceu, 2002

Results

Spatial distribution and characteristics of precipitation amounts

The mean annual amount of precipitation in the analysed region undergoes certain patterns in terms of spatial distribution. Generally, it slowly decreases from west to east, at least in the Subcarpathians, and from north to south, due to altitude differences, distance from the mountains and frequency of either moist Atlantic or dry tropical air masses. Thus, the highest amount is registered in the northwestern part, at Apa Neagra (917.2 mm), while the lowest at Bacles, in the south-west (609.7 mm).

The seasonal precipitation amounts enable us to highlight a more detailed assessment of the precipitation patterns in the region. Thus, even if the highest amounts correspond to summer, in the western part, there are reduced differences between seasons, especially between summer and spring (less than 25 mm), each of the seasons representing between 25 and 29% of the annual amount. In the eastern part, due to the reduction of the frequency of humid tropical air masses and increased penetration of dry continental polar air masses, summer represents between 33 and 36% of the annual amount. The lowest amounts are registered in winter and they vary between 118.5 mm in the eastern piedmont area and 204.3 mm in the western Subcarpathians. Consequently, the eastern areas of the studied region are more exposed to dry conditions than the western ones.

Dry conditions are well emphasized by the values of the SPA. Thus, it resulted that normal years (deviations oscillating between -1.00 and +1.00) predominate within the entire analysed region; however, in the eastern part, there are lower percentages compared to the western part (70-74% compared to 64-66%). The second category in terms of highest percentage is that of dry years. There is registered a notable difference between the western and eastern parts of the region, namely in the west the share of dry years oscillate between 10% in the piedmont and 4% in the Subcarpathians, while in the east, 20%, respectively 18% (Fig. 2). However, there was registered only one case of exceptionally dry year (Targu Jiu, 2000), while excessively dry years hold only 2% at each station. In terms of rainy years, the categories rainy, very rainy and excessively rainy hold about 20% in the west and 12% in the east. Thus, the risk by deficit is higher in the east and the risk by excess is higher in the west.

The linear tendency as well as the polynomial tendency of the SPA values is clearly downward in the piedmont area, while in the SubCarpathians, the situation is far more complex (Fig. 2). Thus, the linear tendency is generally neutral, except for the north-western extremity (Apa Neagra), where it is upward, and the polynomial tendency is upward in three cases and downward in one case (Targu Jiu). Even if this station is located in the Subcarpathians, it is placed at the lowest altitude, in a depression largely opened southwards, which favours the penetration of drier tropical or polar air masses.

Changes in the precipitation amounts

According to Mann-Kendall test combined with Sen's slope (Table 3), precipitation trends are quite different. For 56% of the analysed data series, there are registered negative trends, but only four of these are statistically significant at 0.01-0.05 level of significance and seven at 0.1.

At annual level (Fig. 3), the piedmont presents a negative trend, while the rest of the region displays a positive trend, but neither of them is statistically significant.

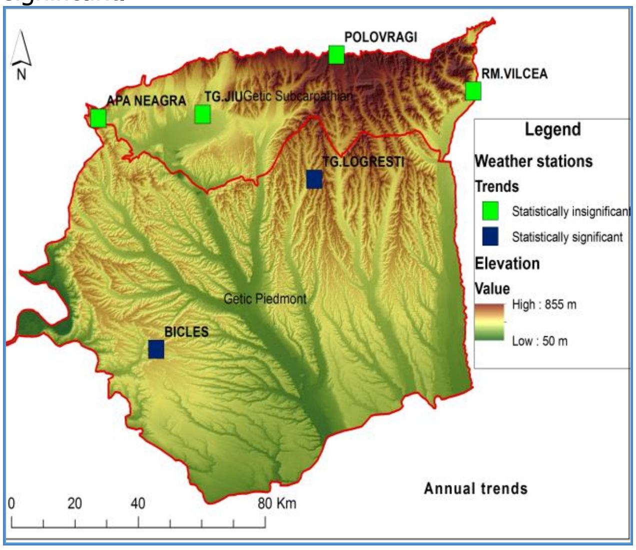
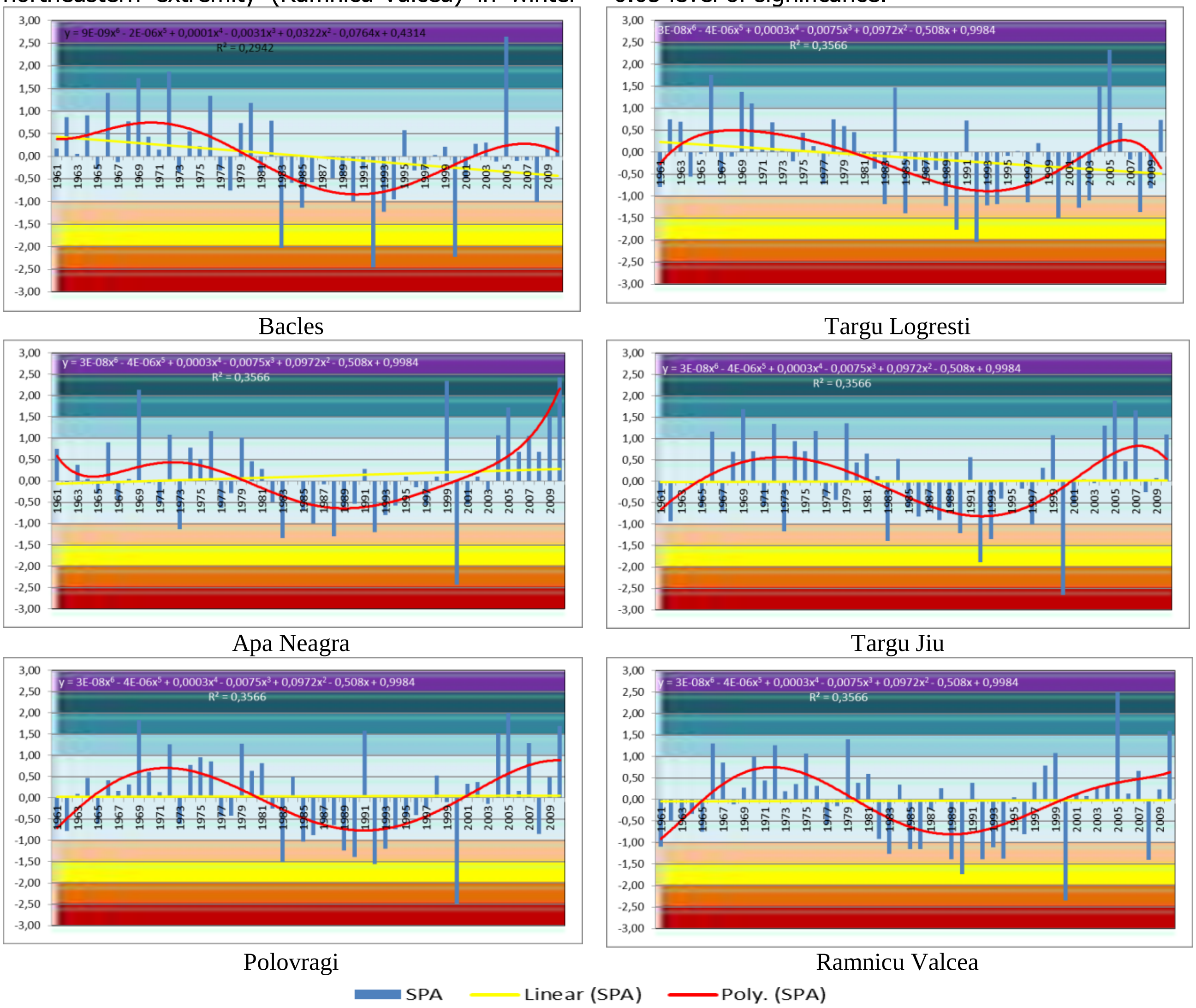


Fig. 3 Statistical significances (SS) for annual precipitation trends within the Getic Piedmont and Subcarpathians, Oltenia Region

In winter half part of the_year, the Subcarpathian area registered an upward trend, while the piedmont area a downward trend (0.1 level of significance). With regard to the summer half of the year, rainfall decrease and downward trends, even though not statistically significant, characterize the entire region.

At seasonal level (Fig. 4), winter and spring display different trends; in the piedmont area, there is a negative trend for both seasons, being more obvious in winter compared to spring, while in the Subcarpathians, trends are downward only in the northeastern extremity (Ramnicu-Valcea) in winter and in the central part for spring (Targu-Jiu). Summer is the season with the most uniform negative trend, which is also statistically significant for the piedmont area (0.01 level of significance), while autumn is the season with the most obvious upward trend, as only the southwestern part of the piedmont undergoes negative values of Sen's slope.

At monthly level, trends are different except for five months. Thus, uniform negative trends are registered in February, May and November, while positive trends in September and October. In the piedmont area, May registers a downward trend at 0.05 level of significance.



SPA values	Categories	Legend
> 2.5	exceptionally rainy	
2 ... 2.5	excessively rainy	
1.5 ... 2	very rainy	
1 ... 1.5	rainy	
1 ... -1	normal	
-1 … -1.5	dry	
-1.5 … -2	very dry	
-2 … -2.5	excessively dry	
< -2.5	exceptionally dry	

Fig. 2 SPA values, the linear and polynomial trend

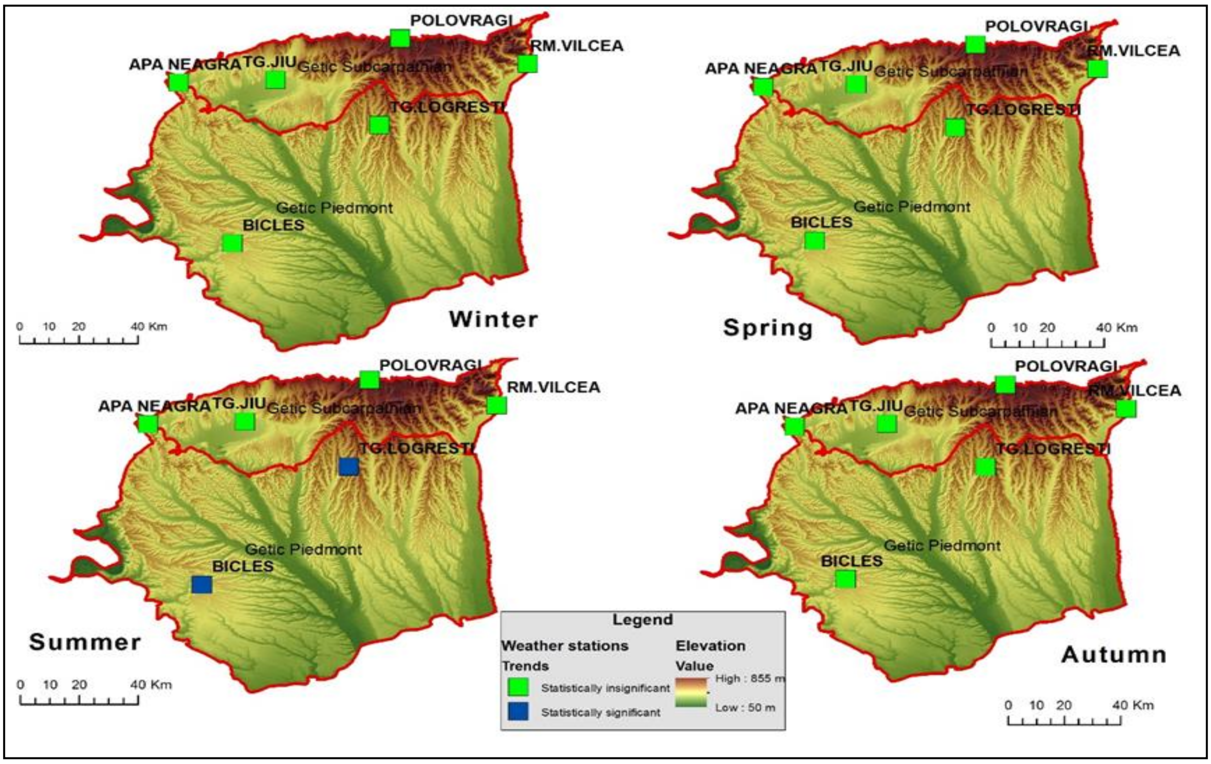


Fig. 4 Statistical significances (SS) for seasonal precipitation trends within Getic Piedmont and Subcarpathians, Oltenia Region

Table 3 Test Z, statistical significances (SS) and Sen's slope estimate (Q) for precipitation trends within the Getic Piedmont and Subcarpathians, for the 1961-2010 period

Period	Bacles			Tg. Logresti			Apa Neagra			Tg. Jiu			Polovragi			Rm. Vilcea		
	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q
J	-0.43		-0.100	0.14		0.052	-0.11		-0.037	-0.10		-0.033	-0.11		-0.037	0.36		0.064
F	-1.64		-0.393	-1.79	+	-0.504	-0.98		-0.435	-1.56		-0.491	-0.98		-0.435	-1.46		-0.304
M	-1.56		-0.373	-0.99		-0.227	0.01		0.010	-0.75		-0.237	0.01		0.010	-0.46		-0.092
A	-1.10		-0.288	-1.47		-0.317	0.42		0.205	-0.45		-0.136	0.42		0.205	0.02		0.003
M	-1.97	*	-0.650	-2.17	*	-0.720	-0.03		-0.018	-1.15		-0.441	-0.03		-0.018	-1.10		-0.469
J	-0.75		-0.288	-0.59		-0.333	0.70		0.380	0.18		0.082	0.70		0.380	0.42		0.237
J	-0.39		-0.222	0.43		0.205	-0.05		-0.024	1.09		0.431	-0.05		-0.024	-1.01		-0.443
A	-0.10		-0.045	1.30		0.497	0.69		0.227	0.54		0.283	0.69		0.227	1.05		0.528
S	1.53		0.483	1.49		0.450	1.48		0.767	1.79	+	0.812	1.48		0.767	1.42		0.591
O	1.25		0.394	0.14		0.052	0.40		0.229	0.87		0.342	0.40		0.229	1.22		0.490
N	-0.92		-0.285	-1.79	+	-0.504	-0.53		-0.247	-0.85		-0.285	-0.53		-0.247	-0.68		-0.260
D	-0.03		-0.010	-0.99		-0.227	0.44		0.311	0.28		0.121	0.44		0.311	0.85		0.322
WH	-1.82	+	-1.855	-1.81	+	-2.967	0.37		0.792	0.17		0.329	0.37		0.792	-0.05		-0.075
SH	-1.24		-1.350	-1.05		-1.123	-0.50		-0.747	-0.99		-1.057	-0.50		-0.747	-0.32		-0.250
W	-1.32		-1.256	-0.82		-0.978	1.01		1.564	0.67		0.830	1.01		1.564	-0.08		-0.125
S	-0.72		-0.450	-1.05		-0.562	0.39		0.414	-0.34		-0.298	0.39		0.414	-0.12		-0.082
S	-2.98	**	-1.533	-2.71	**	-1.489	-0.20		-0.164	-1.64		-0.933	-0.20		-0.164	-1.17		-0.700
A	-0.64		-0.468	0.31		0.333	1.04		1.400	1.05		1.244	1.04		1.400	0.42		0.353
Annual	-1.82	+	-1.855	-1.81	+	-2.967	0.37		0.792	0.17		0.329	0.37		0.792	-0.05		-0.075

*** if trend at α = 0.001 level of significance; ** if trend at α = 0.01 level of significance; * if trend at α = 0.05 level of significance; + if trend at α = 0.1 level of significance

Synthetizing the results, generalized downward trends characterize only four data series and upward trends only two data series. It should be noted that the piedmont area, with dominant agricultural land use, shows the highest summer precipitation decrease. Moreover, February-May interval, when the water reserve in the soil is highly important for plant germination and growing, also presents negative trends, stressing the water deficit characteristic to the summer period.

Conclusion

Climate signals, in this case precipitation signals, related to trends greatly depend on the considered time interval and the density of stations used for the analysis. Thus, the SPA values clearly indicate the predominance of normal years (deviations between -1.0 and + 1.0). However, the piedmont area, as well as the eastern part of the Subcarpathians, registered higher percentages of dry years and seemed to be more exposed to the risk by deficit. In the piedmont area, the linear tendency of both annual precipitation amounts and SPA values is downward, indicating a change of the precipitation regime.

According to Mann-Kendall test combined with Sen's slope, negative trends predominate, but their statistical significance is relevant in only 11 out of the total of 114 datasets, 10 of these in the southern piedmont area. Thus, at annual level, it was emphasized the downward trend for the piedmont area only. At seasonal level, summer underwent a generalized decrease and an obvious negative trend for the entire region; however, the results for the southern piedmont area are also statistically significant. At monthly level, the most significant and generalized negative trend is registered in May and February, while for positive trends we mention September and October.

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Assessment of the long-term wind energy resources in the Southern Bârlad Plateau. An applied climatology study

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Abstract

In order to evaluate the long-term wind conditions and energy resources in the Southern Bârlad Plateau, the WINDATLAS method has been applied, using the numerical software programs WindPRO 2.7 and WAsP 9. For this purpose, 2 years (2008 – 2010) of in-situ wind measurement data from two locations were used. These time series have been adjusted to a 30-year long-term period (1981-2010), using NCAR global weather analyses data, and validated with the monthly means of the wind speed recorded at Galați meteorological station (1981-2010). On the basis of the new generated long-term time series, local wind statistics have been obtained, which were used for wind conditions assessment and energy yield calculations within the study area. The average wind speed, the Weibull parameters for the vertical wind profile, as well as the expected wind energy resources have been determined. The Southern Bârlad Plateau is characterized by high wind energy potential demonstrated by long-term averaged wind speeds larger than 7 m/s (at 120 m a.g.l.), similar to Dobrogea region, and by corresponding wind energy values of more than 3000 kWh/m^2 at hill top positions. Another key issue is that the energy potential of this area is relatively constant at multi-annual scale, with prevailing winds from northern and southern directions, making it highly suitable for the development of Multi-Megawatt wind farms. The results obtained by applying this complex methodology can be practically valorized by being further integrated in energy production estimates and feasibility studies for wind farms.

Keywords: *WINDATLAS method, Weibull distribution, long-term wind statistics, energy yield.*

Rezumat. Evaluarea potențialului eolian din sudul Podișului Bârladului. Studiu de climatologie aplicată.
În vederea evaluării potențialului eolian în sudul Podișului Bârladului, am aplicat metoda WINDATLAS, cu ajutorul softurilor numerice WindPRO 2.7 și WasP 9. În acest sens, am utilizat 2 ani (2008 – 2010) de măsurători de vânt in-situ în două locații din acest areal. Aceste măsurători au fost ajustate, pentru a avea valabilitate multi-anuală, cu ajutorul setului de date NCAR, curpinzând 30 ani (1981 – 2010) de modelări climatice globale, și au fost validate cu ajutorul valorilor de viteză medie lunară a vântului măsurate la stația meteorologică Galați între 1981 și 2010. Pe baza noilor serii de date astfel generate, au fost obținute statistici locale ale vântului, care au fost apoi utilizate pentru evaluarea potențialului eolian și pentru calculațiile energetice în cadrul ariei de studiu. Au fost determinate astfel viteza medie a vântului, parametrii distribuției Weibull ai profilului vertical al vântului și resursele energetice potențiale. Sudul Podișului Bârladului se caracterizează printrun potențial energetic eolian ridicat, manifestat prin viteze medii multi-anuale ale vântului de peste 7 m/s (la înălțimea de 120 m), similare cu cele întâlnite în Dobrogea, și prin valori corespondente ale energiei vântului de peste 3000 kWh/m^2 la aceeași înălțime pe culmile dealurilor. O altă constatare foarte importantă este faptul că potențialul eolian în cadrul locației este relativ constant la scară multi-anuală, cu vânturi dominante din sectoarele nordic și sudic, ceea ce face ca această zonă să fie optimă pentru dezvoltarea parcurilor eoliene cu turbine multi-megawatt. Rezultatele obținute prin aplicarea acestei metodologii complexe pot fi valorificate în mod practic prin integrarea lor în estimări ale productibilului energetic electric și în studii de fezabilitate pentru parcurile eoliene.

Cuvinte-cheie: *metoda WINDATLAS, distribuția Weibull, statistică eoliană, calcul energetic.*

Introduction

Romania is considered to have the highest wind energy potential in the South-East Europe and the second one in Europe, with a predicted total installed capacity of 14000 MWh (Mihailescu, 2009). In the last decade, following the EU community regulations regarding the increase of renewable energy sources share in the total energy consumption (Colesca and Ciocoiu, 2013), there was a continuous demand for good quality in-situ high-frequency wind measurement data and wind energy potential studies for extensive areas, especially in Dobrogea and Southern Moldavia.

The use of wind speed and direction data measured at 10 m a.g.l. at meteorological stations across Romania was no longer sufficient as the wind energy assessment studies and energy production reports for wind farms required values measured and modelled for hub heights of the wind turbines, usually higher than 50 m a.g.l. Hence, the need for a re-evaluation of Romania's wind energy potential. In this context, there are some recent studies (Vespremeanu-Stroe and Tătui, 2011; Vespremeanu-Stroe et al., 2012) and maps (produced, among others, by the Romanian Administration of Meteorology and Wind Power Energy or MegaJoule private companies) which present the wind regime of Romania, its energetic potential or climate variability influences.

Long-term wind energy assessment methods and approaches (e.g. Carta et al., 2013; Weekes and Tomlin, 2014) were extensively discussed and wind energy potential studies (e.g. Bataineh and Dalalah, 2013; Nawri et al., 2014) were presented in the international literature. In Romania, the wind energy potential studies were performed especially by private company consultants and, therefore, we can observe a lack of scientific studies regarding the methodology, approaches and results of such wind energy assessment research. In this context, we aim at quantifying the wind energy resources in the Southern Bârlad Plateau through generation of detailed wind speed and energy maps in order to validate the implementation of wind farms in this area. Because of the complex computational resources needed and the lack of reliable data for such a large area, we are describing in this applied climatology study the methodological approach only for a study case representative for the wind conditions of the entire plateau.

Study area

The study site is located in the eastern part of Romania, within the Covurlui High Plain (the southernmost unit of Bârlad Plateau), 23 km N-NW of Galați city and about 40 km SE of the town of Tecuci (Figure 1). It covers the flat top areas of a monoclinal plateau which tilts down gently southward, at altitudes between 98 and 172 m a.s.l. The surrounding relief energy and density of fluvial fragmentation are very low due to both pluvial and hydrological regime and to the general morphology which is specific to high plains and low plateaus. The general aspect is plane or rounded and, with some exceptions located in the nearby valleys` versants, where inclinations could rise up to 20°, the slopes are between 0° and 8° for the majority of surfaces. The terrain conditions of the surrounding area are characterized by a wavy relief which is not very accentuated, with several well-rounded ridges running from North to South. The height difference between hill tops and the separating valley structures amounts to app. 60 m. With regard to the closer vicinity of the study area, the landscape gradually decreases gently towards eastern and southern directions and steeply northward and westward. Similar terrain appearance can be observed in the far field (15 km distance) towards the North, West and SW, while the altitudes are slightly decreasing to the South.

From the climatic point of view, the Southern Bârlad Plateau is located in a transitional area between the Eastern Europe continental climate and the Balkan Peninsula pre-Mediterranean temperate climate. These particular climatic characteristics are represented by an excessive continental climate, with high temperature amplitudes, low precipitation values (~500 mm in the study area), hot and dry summers and cold winters with strong winds (Climate of Romania, 2008).

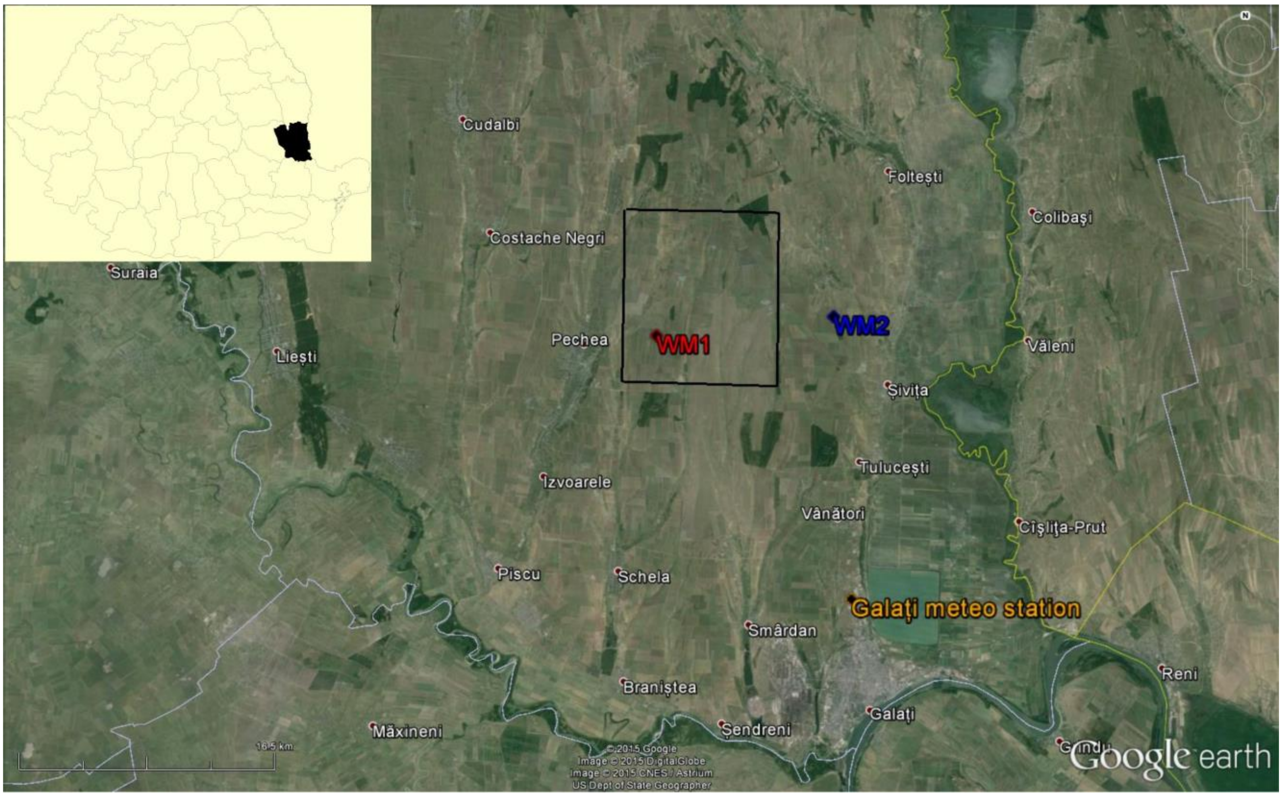

Fig. 1 Locations of the study site (*black rectangle*), of the wind measurement sites (WM1 and WM2) and of the meteorological station at Galați in the frame of the Galați County, Romania.

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The plateau is delimited by the 10°C annual isothermal line (10.5°C is the multi-annual average temperature measured at Galați meteo station between 1961 and 1990). The annual mean temperature in the study area is approximately 11°C (12.6°C were measured between November 2008 and November 2009). The annual mean air pressure in the study area oscillates between 980 and 1000 hPa (the multi-annual average at Galaţi is 1008.2 hPa). The annual average air humidity is 76-78%.

The multi-annual mean wind speed measured at Galați meteo station between 1961 and 2003, at 10 m height, is 4.26 m/s (Vespremeanu-Stroe and Tătui, 2011). The annual average number of days with wind speeds higher than 16 m/s is between 25 and 50 days (1961 – 2000). In terms of wind direction, the highest frequency is registered by the northern sector winds (23.8%).

Data & Methods

In order to evaluate the average wind conditions in the frame of the study site, we used in situ wind measurements during 24 months (November 2008 – November 2010) from WM1 mast and from a mast situated at 11.7 km E-NE of the study area (WM2), with total heights of 50 and 60 m respectively (Figure 1). Measured data have been registered with equipment provided by NRG Systems with a sampling rate of 1 Hz as 10 min. averages for wind speed and wind direction. The position and configuration of each mast is presented in Table 1. All sensors have been calibrated according to MEASNET standards in advance of operation and functioned in good conditions.

Table 1: Location and measurement equipment presentation for WM1 and WM2 masts.

Site			**WM1**	**WM2**
Height a.s.l. (m)			130	155
UTM WGS 84 [m], Zone 35			E: 567130 / N: 5054254	E: 578803 / N: 5055894
Measurement period			2008-11-30 until 2010-11-08	2008-11-30 until 2010-11-08
Parameter	**Height**	**Sensor**		
Wind speed	60 m	NRG #40	-	Boom length: 155 mm Orientation: 0° (N)
Wind speed	60 m	NRG #40	-	Boom length: 155 mm Orientation: 157°
Wind speed	50 m	NRG #40	Boom length: 250 cm Orientation: 90° (E)	Boom length: 157 mm Orientation: 0°
Wind speed	50 m	NRG #40	Boom length: 250 cm Orientation: 270° (W)	
Wind speed	40 m	NRG #40	Boom length: 250 cm Orientation: 90°	Boom length: 157 mm Orientation: 0°
Wind speed	30 m	NRG #40	-	Boom length: 157 mm Orientation: 0°
Wind speed	20 m	Vector W200P	Boom length: 250 mm Orientation: 90° (E)	Boom length: 157 mm Orientation: 0°
Wind direction	60 m	NRG #200	-	Boom length: 157 mm Orientation: 170°
Wind direction	48 m	NRG #200	Boom length: 200 mm Orientation: 90° (E)	-
Wind direction	40 m	NRG #200	-	Boom length: 157 mm Orientation: 170°
Wind direction	20 m	NRG #200	Boom length: 200 mm Orientation: 270°	-
Temperature	3 / 10 m	NRG #110S	Boom length: integrated Orientation: 180°	Boom length: integrated Orientation: 0°
Pressure	3 m	NRG BP20	Boom length: integrated Orientation: 180°	-
Humidity	3 m	NRG RH5	Boom length: integrated Orientation: 180°	-

Long-term wind data being taken in the past and model calculations according to the WINDATLAS method by using WAsP (Petersen et al., 1981; Nielsen and Chun, 1994) conclude the approach. The long-term datasets consist in weather reanalyses data, provided by the U.S. American National Centre for Atmospheric Research (NCAR), and long-term observations at the Galați meteo station, provided by the NOAA National Climatic Data Center (NCDC). NCAR data are large-scale wind analyses, which cover the time period 1981-2010 (6-hourly values) for the study area (the center of the grid is 45.0°N / 27.5°E); they are based on two fixed heights of 10 and 42 m a.g.l. and are distance-weighted derived from the four nearest grid points of the calculation grid. These data are based on global numerical weather analyses and are characterized by a high temporal consistency contrary to local measurements. This dataset describes the large-scale wind field (scales ~250 km) and can be transferred to localized wind energy questions only if the smaller scale topographical and meteorological conditions aren't too complex. Data of the Galați meteorological station are covering a long-term period (1-hourly time series) of 50 years (January 1961 - December 2010) but, unfortunately, the data set shows a large number of gaps.

The calculation of the wind conditions is based on the planning software WindPro, version 2.7 (Nielsen and Chun, 2000) and the numerically flow model WAsP (Wind Atlas Analysis and Application Program), version 9. The WAsP model considers the influences of the parameters roughness, obstacles and orography on the wind conditions at defined points of reference according to the method of WINDATLAS. By using these as input parameters and by choosing suitable wind statistics based on representative wind measurements (normally long-term data), frequency of occurrence distributions of wind speed can be expressed as Weibull distributions and as functions of wind direction and height at a chosen point of reference.

The orography was assessed on an area of app. 1.600 km^2 (40 x 40 km) around the study site, based on various data (Shuttle Radar Topography Mission – SRTM and 1: 25.000 scale topographic maps), which were integrated in the WAsP computational model. The terrain roughness was described based on the conventions of roughness classes presented in the European Windatlas (Troen and Petersen, 1988). The terrain conditions have been described by classifying roughness within 12 sectors of 30° each. A detailed subsequent classification of roughness parameters has been performed on the base of aerial photographs and digitized topographical maps (1:25.000). Up to five changes in roughness values have been considered within a radius of 20 km around the study site: open farm land sparsely interspersed with small trees, villages, forested areas and water areas. No considerable obstacles, which could obstruct the wind flow, have been observed within 1.000 m radius from the met mast locations.

Deterministic prognoses of the state of the atmosphere are limited to a few days in advance. The chaotic dynamics of the system imposes these narrow limits; for larger intervals statistical statements may be derived only. To get an estimate of the future average wind conditions being expected in a certain area, usually wind data taken in the past has been applied. Since wind conditions may vary considerably from year to year, it is necessary to consider periods of sufficient length (>10 years) both for the measurements and for the prediction time. For such longer periods, the assumption that the wind conditions do not vary any more is usually taken. The past is projected into the future. In climatological science such a procedure is called persistence forecast. At least for the areas outside the tropics it yields satisfying results. But even averages for longer periods are not constant in time, although the fluctuations become smaller for extended averaging periods. Due to that, a profound persistence forecast in a climatological sense is obtained only when the variability range of the expected wind conditions is determined also and included into the uncertainty considerations.

A scientist has two possibilities to evaluate the wind conditions at a physical site: either he can use a wind measurement taken directly at the site or he has to apply a mathematical process which is able to transfer long-term data from a reference station nearby into the characteristic conditions at the site by using the so called WINDATLAS Method (Petersen et al., 1981; Nielsen and Chun, 1994). The Danish National Research Centre in Risø, Denmark, has studied a variety of long-term wind data from several European countries with respect to their applicability for wind energy purposes (Troen and Petersen, 1988). A physical method has been worked out which allows for the transfer of measured wind speeds from a certain measuring point to another site or even a whole region. An overview sketch of the method is shown in Figure 2.

Wind data from a meteorological station with its characteristic terrain conditions (obstacles, roughness and orography) are transformed into regional wind climatology. This so called WINDATLAS represents regional wind climatology when all local topographic conditions are removed and may be understood as the geostrophic wind of the free atmosphere above the boundary layer. By using such a regional wind statistics as the physical wind supply – with regard to the Weibull parameters related to direction – the wind climate of the considered microsite can be determined by invoking the specific topographical conditions for that point and nearly each height of the site (see downward arrow in Figure 2). These transformations are performed by the simplified linear flow model WAsP which has been conceived for simple and moderate complex terrain such as low mountain ranges. The method has been developed over a long period and has been applied successfully in numerous cases. It may be viewed as the current state-of-the-art of technology.

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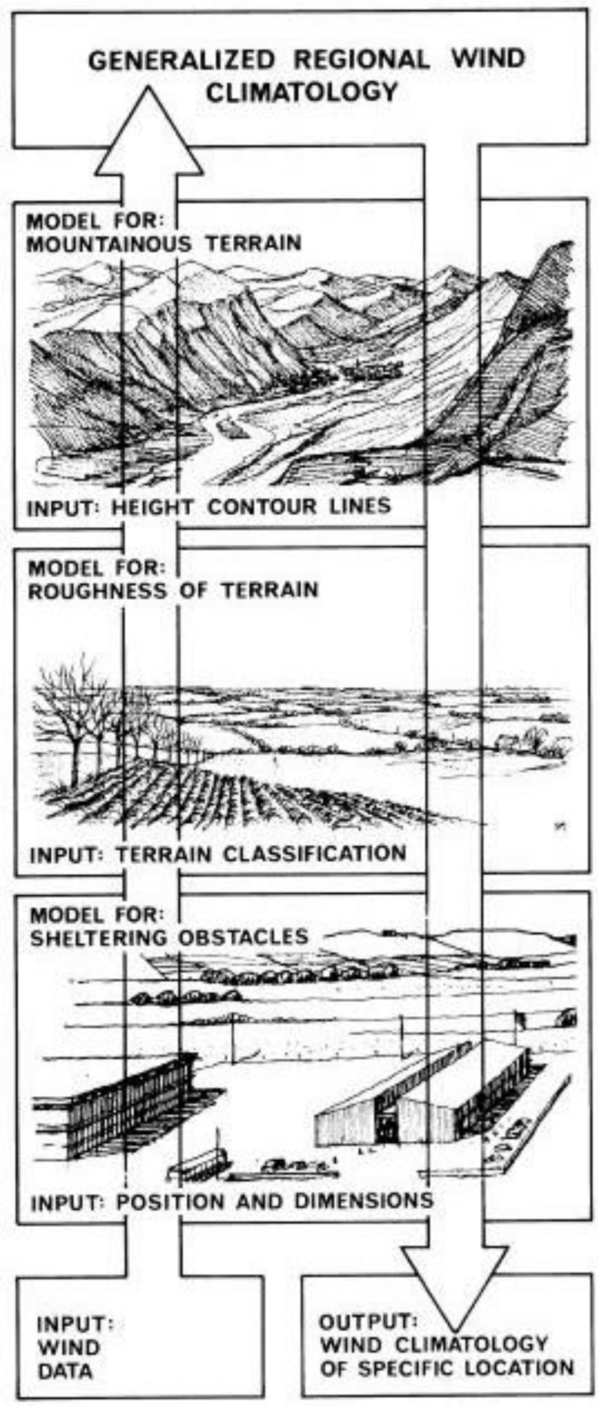

Fig. 2 The WINDATLAS method of WAsP for the evaluation of the wind potential of individual sites (*Source: Troen and Petersen, 1988*).

It has to be considered that every physical model is just an image of reality which is valid only under specific circumstances and might afflicted with uncertainties which have to be part of the analyses. On the one hand uncertainties exist within the method itself such as the representativeness of the chosen wind statistics or the accuracy of terrain description. The WAsP-Model is hardly applicable in extremely complex terrain as its linear assumption is not able to account several physical phenomena e.g. flow separations at steep edges. Furthermore, the effect of annual variation of the wind conditions is not covered by this analysis method. The WINDATLAS-method has been designed for the surface boundary layer, which is typically 50-80 m thick, but the obtained results given by the model for bigger heights were also fairly good. Thus, these calculations may be viewed to be conservative in general and the connected uncertainties may be tolerable.

Results & Discussion

The measurement masts are located on the highest and most exposed areas to dominant winds within the Southern Bârlad Plateau, in the close vicinity of the Prut river valley, which determines the acceleration of the wind fields with 5-10% in comparison with the neighboring areas. Towards all directions, the closer vicinity exhibits just moderate inclination of all adjoining slopes. The surroundings of the measurement sites are characterized by arable terrains which are intensively used for crops. No observable obstacle is found within a considerable radius of about 2 km around the two measurement sites. The wind measurements are similar regarding the measurement system and assembly.

Wind measurements quality assessment

Due to small gaps occurring in the winter months, as a result of freezing events and the corresponding icing of the sensors, the total data availability for all measurement levels during the analyzed period is at 98.7% for WM1 mast and 94.7% for WM2 mast.

In order to evaluate if the wind fields are relatively consistent within different locations of the Southern Bârlad Plateau, we performed a correlation study of wind speeds and directions measured at the two studied sites. To detect possible measuring errors and to check the quality of the wind measurement, the data of the wind sensors were also compared among each other. The 10 min. means of wind speed and wind direction at the different measuring heights and sites show a quite similar temporal evolution confirming the plausibility of the recorded sensor signals (Figure 3). Correlation between the wind speed measurements at 50 m at the two sites, WM1 and WM2, amounts to 0.89 (Figure 3A), which has to be rated as excellent regarding the comparatively short averaging interval of 10 minutes and the large distance of about 11.7 km between the two sites (Figure 1). Related to the particular measurement site WM1, the correlation between the recordings amounts 0.999 concerning the two sensors at identical height level (50 m a.g.l.) and 0.995 for 10 m height difference (50 m and 40 m; Figure 3B). These correlations indicate an excellent relationship between the different measurement levels at the two masts and, therefore, confirm the high quality of the wind measurements.

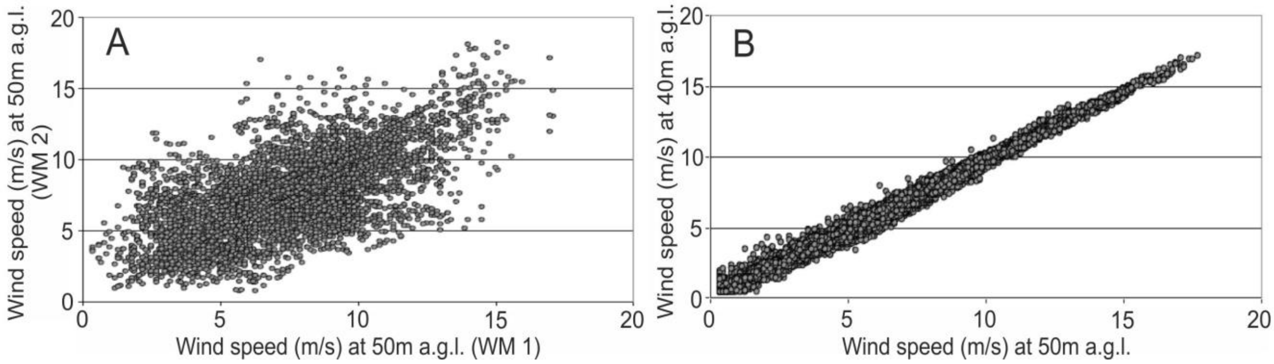

Fig. 3 Correlations of measured 10 min. means of wind speed for: A) WM1 vs. WM2 masts at 50 m a.g.l. and B) WM1 mast at 50 m vs. 40 m a.g.l.

The recorded time series at the different measurement heights at WM1 and WM2 locations have been compared with NCAR reference weather analyses data and to observations recorded at the Galați meteo station. All the reference data showed relatively good correlation with the measurement data on a 6-hourly basis. With regard to the total measuring period of app. 2 years, the NCAR Reanalysis data show a correlation of about 0.65, while the correlation of the recorded time series with the observations at the Galați meteo station is 0.70. In summary, all recorded time series at both measurement sites can be rated to be plausible as self-consistency checks and comparisons to reference data showed.

Wind measurements results

After verifying the measured data, the time series of the 10 min. average values have been classified according to wind speed (using the METEO module of WindPro 2.7). As a result, the measurements can be presented in the form of a two-dimensional frequency of occurrence distribution. For further mathematical processing, this distribution is approximated by a two-parametric distribution function, the so-called Weibull distribution with scale parameter A and form factor k (Figure 4). Parameter estimation is done energy-weighted, which means that the adaptation to the measured values is best for high wind speeds.

The average wind speed measured during the analyzed 23.3 months (November 2008 – November 2010) was estimated to be 6.1 m/s for WM1 and 6.4 m/s for WM2 at 50 m and 60 m a.g.l. respectively. The two sites show a considerable difference in the variety of wind speeds for the upper measurement levels. The results for the WM1 site, covering the measurement period, are presented in Table 2 and structured by the individual height levels.

The sector wise Weibull-adjusted average wind speed and average energy density for 50 m a.g.l. at WM1 mast are presented in Table 3. The highest average wind speeds of about 6.5 m/s are observed both in the northern directions (from NW to NE) and in the SW direction. The lowest average wind speeds of about 5.0 – 5.5 m/s come along with the eastern and western winds at both measurement sites.

Table 2: Average wind conditions at WM1 mast measured between November 2008 and November 2010 at 20, 40 and 50 m heights and estimated using the WAsP Interface module of WindPro 2.7 (WAsP long-term correlation) at 100 and 120 m heights. Calculation of the power density and energy density is based on an air density of 1.206 kg/m³, mean temperature of 10.9° C and a mean air pressure of 980 hPa at 120 m height level, based on the measurements at the wind measuring mast during the studied period of time.

Height (m)	Mean wind speed (m/s)	Weibull Parameters		Wind energy density (kWh/m²)
		A (m/s)	k	
20	5.06	5.7	2.07	1278
40	5.86	6.6	2.26	1827
50	6.04	6.9	2.32	2032
100	7.27	8.2	2.52	3188
120	7.71	8.7	2.48	3850

Table 3: Sector wise measurement results at WM1 site at 50 m a.g.l. (November 2008 – November 2010).

Sector	Frequency (%)	Wind speed (m/s)	Weibull k-parameter (m/s)
N	17.9	6.73	2.5
NNE	10.9	6.43	2.34
ENE	6.1	5.87	2.42
E	3.9	5.59	2.35
ESE	8.3	5.99	2.61
SSE	7.5	6.27	2.73
S	8.2	6.33	2.65
SSW	10.1	6.18	2.02
WSW	4.8	5.0	2.47
W	5.3	5.03	2.47
WNW	7.1	5.7	2.24
NNW	9.8	6.31	2.39
Total	100	6.13	2.33

The frequency of wind direction, as well as the sector-depending energy contribution at 50 m height

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level during the measurement period at WM1 site is given in Figure 4. At both sites, the prevalent winds are coming from northern directions, with total frequencies of about 45%. A second maximum occurs from the southern directions, with total frequencies of about 30% (Table 3). The highest mean wind speeds during the measurement period are observed in the sectors North to NNW and South to SSW. Associated with the high frequency of occurrence, these sectors share the highest proportion in the wind energy distribution. About 55% of the wind energy content at WM1 site is associated with the North to NNW sectors and about 30% with the south to SW sectors (Figure 4).

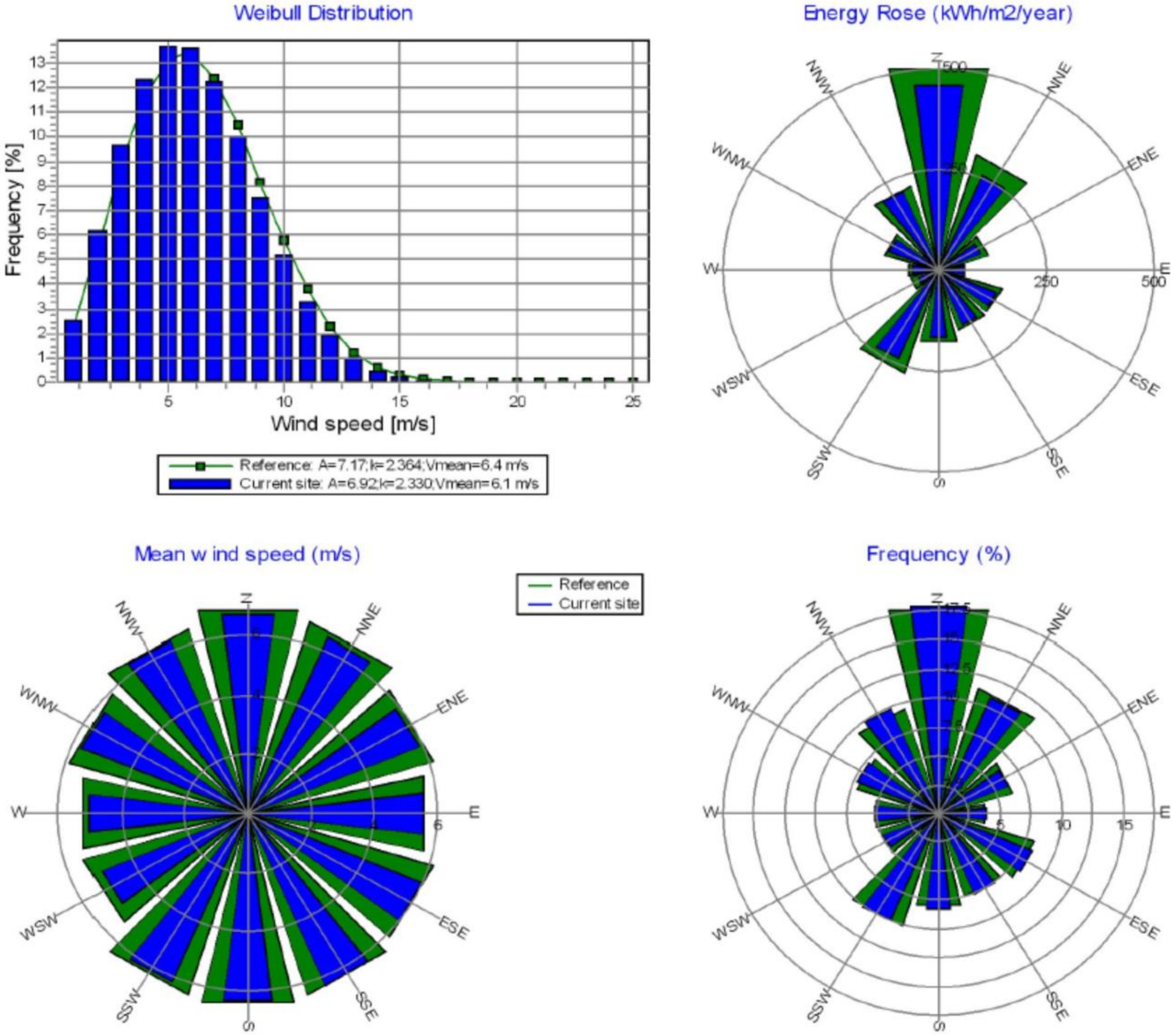

Fig. 4 WAsP Interface module results – Wind data analysis (50 m a.g.l.) for WM1 mast: sector wise frequency of occurrence, mean wind speed and energy distribution.

Long-term wind conditions and adjustments

Wind conditions may vary considerably from one year to another. Therefore, it is required to assess the long-term wind conditions at a site to get a reasonable base for wind energy planning considerations. Since a project related wind measurement is usually time-limited, an adjustment with respect to long-term climate data is required. The wind measurements cover 23.3 months of data, which represent fairly good the full seasonal cycle. However, the year to year variability can be significantly high. Thus, a long-term correction was performed. This was done by taking suitable reference data into account, which are representative for the same wind climate and cover a long-term period, including the short-term measurement. For that purpose, large-scale meteorological analyses data provided by NCAR (Figure 5A) and long-term observations at the Galați meteo station have been taken into account and analyzed individually (see Data & Methods section for a description of the datasets).

Considering that the complexity of the topographic conditions of the area under investigation is poor, NCAR Reanalysis data can be regarded to be suitable concerning the long-term adjustment of the measured time series. The correlation of the NCAR time series at 42 m height and the wind measurements at 50 m height at WM1 site (23.3 months) is 0.71, on the basis of 6-hourly means, and 0.8, on the basis of monthly means (Figure 5B,C). The observations from the Galați meteo station should be more appropriate for long-term correction purposes concerning WM1 site, indicated by the high correlation with the measurement data of about 0.72. However, due to the very poor data availability of only 63% over the long-term period, the observed time series at the meteo station were not appropriate to constitute a basis for a long-term approach. Moreover, this time series show a significant temporal trend which is local and human-induced. Since the observed wind speeds become significantly poorer since the beginning of 2002, it is strongly expected that the location of the station has been affected by new buildings erected nearby. Hence, in the following, the long-term time series deduced from the local NCAR data have been used for all calculations regarding the long-term wind and energy yield conditions at the study site.

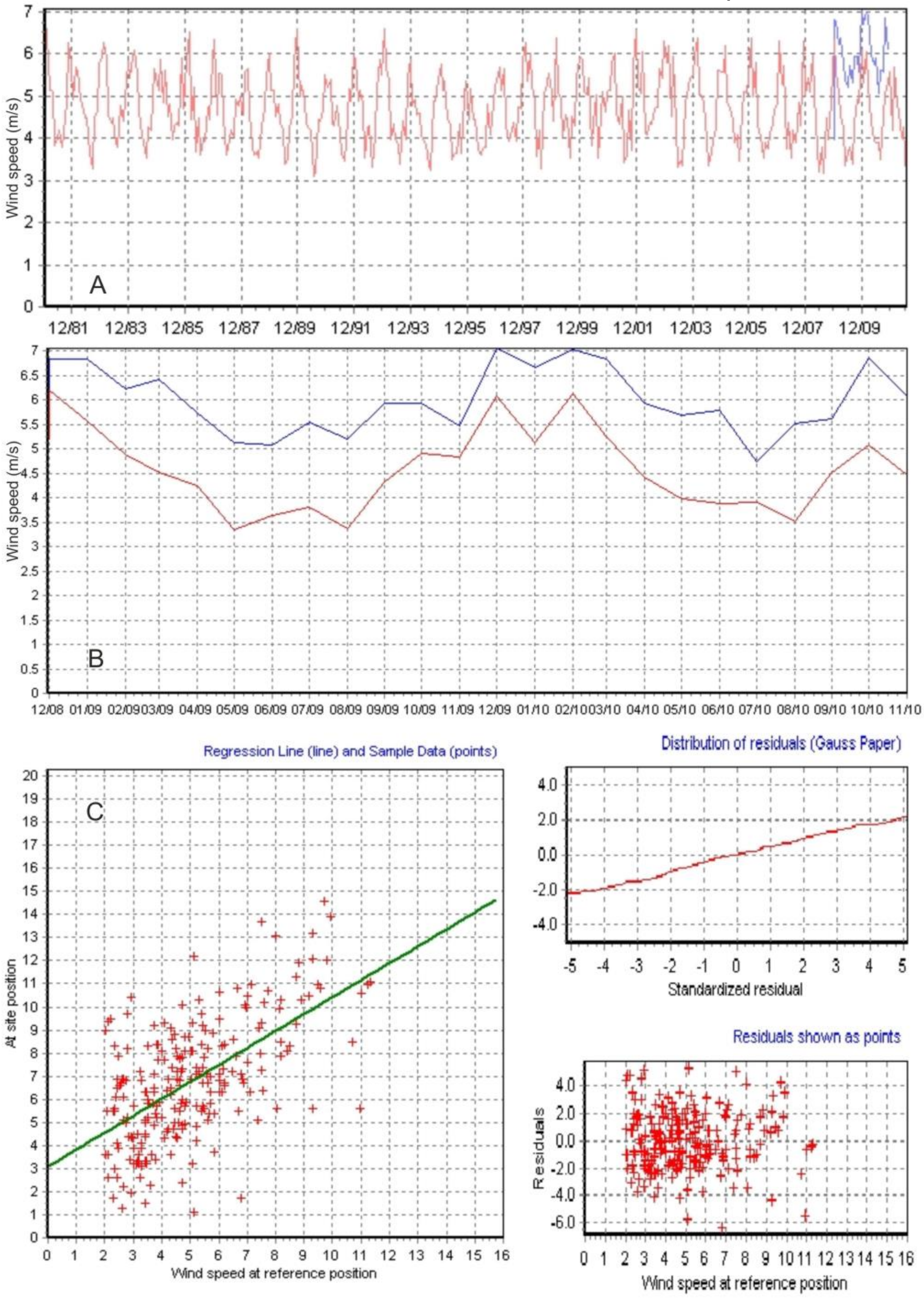

Fig. 5 MCP module results – Wind speed correlations between WM1 (*blue line*) and NCAR long-term (*red line*) data series for: A) 1981 – 2010 interval and B) 2008 – 2010 measurements period. C) Regression analysis of the NCAR and WM1 wind speed time series.

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To perform the transfer of the short-term measurements at WM1 site to the long-term representative period, a Measure-Correlate-Predict (MCP) method was performed using the MCP module of WindPro 2.7. For this study, a sector-dependent regression model, based on data of the measurement and the data of the reference index, was applied. A long-term time series representative for the measuring site $x^{long}(t)$ is reconstructed from the given long-term reference dataset $y^{long}(t)$:

$$x^{long}(t) = F(y^{long}(t))$$

The transfer function $F = F(x^{short}(t); y^{short}(t); a)$ is estimated from the concurrent short-term wind speed values and directions. Here, a sector depending scaling of mean and variance according to the standard deviation approach has been chosen. This model allows a sector-dependent and energy consistent conversion of wind speed and the reconstruction of a time series and frequency distribution that represents the long-term time frame. Deviations of the directional distribution between short-term and long-term period might be considered also. For reconstruction, we have used data on a 6-hours average basis, but included corrections for the variability lost due to this averaging to adapt the energy level to the quality of the 10 min. averages of the measurement. The 30 years period, covering 1981 - 2010 interval, had been chosen as long-term reference period (Figure 5A).

By following the described approach, a long-term adjustment has been carried out for the recorded time series over 23.3 months (2008-11-30 until 2010-11-08) for the 50 m at the WM1 site (Figure 5B). The resulting data reconstructions for the considered measuring levels give an acceptable correlation to the real recordings at WM1 site during the regarded measurement period of about 0.7 (Figure 5C). The measured average wind speed over the regarded measurement period is reproduced with accuracy better than 1 %. Almost the same accuracy has been obtained for the energy content of the wind. It could be reproduced by a small range of deviation from 98.0% up to 99%. The newly obtained 30 years long-term wind conditions at the WM1 site, deduced from the above described method, with respect to the considered measuring heights, are very close to the short-term (2008 – 2010) values. The calculated average long-term wind speed at the 50 m height level is slightly higher than for the short-time (6.13 m/s in comparison with 6.04 m/s). The short-time average wind speed over the regarded measurement period of 23.3 months from November 2008 until November 2010 corresponds with about 99% of the expected long-term level. This relation translates to energy conditions for the long-term, which are about 0.6% higher than for the regarded measurement period.

Vertical extrapolation of wind statistics. Wind energy potential assessment

The long-term adjusted wind data series of WM1 site has been transformed into a wind statistics (using STATGEN module of WindPro 2.7) derived for the 50 m measurement level. This wind statistics has been generated according to the WINDATLAS method by taking into account the local orography, roughness and obstacles (see Data & Methods section). It includes the vertical profile of Weibull parameters A and k and of the long-term mean wind speed at site location (Figure 6). The wind shear exponent of the vertical profile is 0.21 (power law profile), while the roughness length is 0.15, corresponding to a roughness class of approximately 2. These values are almost identical to the values obtained during the measurement period.

Furthermore, vertical extrapolations up to 150 m a.g.l., based on the individual wind statistics and vertical profile, were computed (Table 4). At both measurement sites, the calculated wind parameters and energy deviate by about ±1%, largely confirming the derived terrain model and the reliability of the vertical extrapolation with regard to the observed wind profile. The results of these extrapolations show almost the same wind and energy parameters as for the short-term measurements, demonstrating the relative consistency of wind flows within the Southern Bârlad Plateau at multi-decadal scale.

Table 4: Calculated vertical wind profile values for the long-term wind statistics at WM1 site.

Height (m)	Mean wind speed (m/s)	Weibull Parameters		Wind energy (kW/m^2)
		A (m/s)	k	
50	6.12	6.9	2.35	2023
60	6.38	7.2	2.42	2233
70	6.61	7.4	2.49	2425
80	6.81	7.7	2.56	2602
90	7.0	7.9	2.63	2768
100	7.17	8.1	2.7	2925
110	7.33	8.2	2.77	3074
120	7.49	8.4	2.84	3217
130	7.63	8.6	2.91	3354
140	7.77	8.7	2.98	3487
150	7.9	8.8	3.05	3617

After obtaining the vertical profile of wind statistics, we mapped the long-term wind resources within the study area (Figure 7) using the RESOURCE module of WindPro 2.7. This module extrapolates the wind statistics of each measurement point on large neighboring surfaces, function of the influence of orography and roughness on wind flows. Analyzing Figure 7, we can see that the study site has a very good wind energy potential, proved by high long-term averaged wind speeds: the values are comprised between 7 and 8 m/s at 120 m height level. These values can be easily transformed into wind energy values and mapped using the RESOURCE module, obtaining a map similar with the one presented in Figure 7.

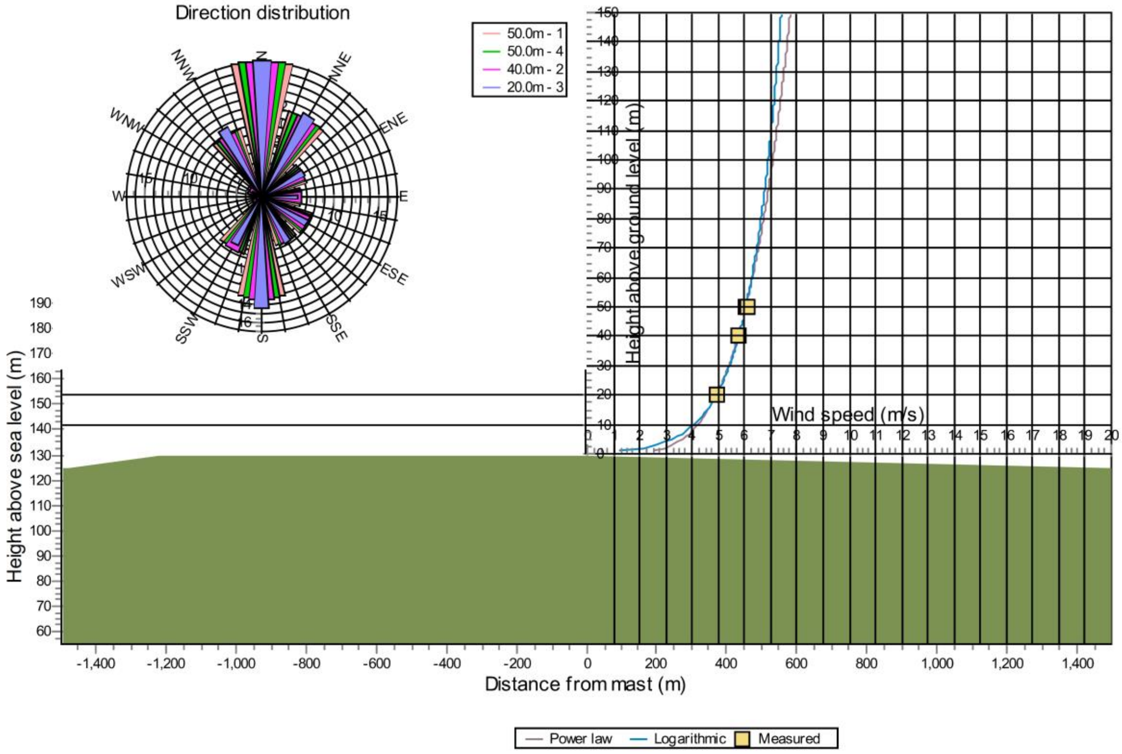

Fig. 6 Mean long-term vertical wind profile and terrain profile for the most frequent sector of height (50 m a.g.l. – North) for WM1 site.

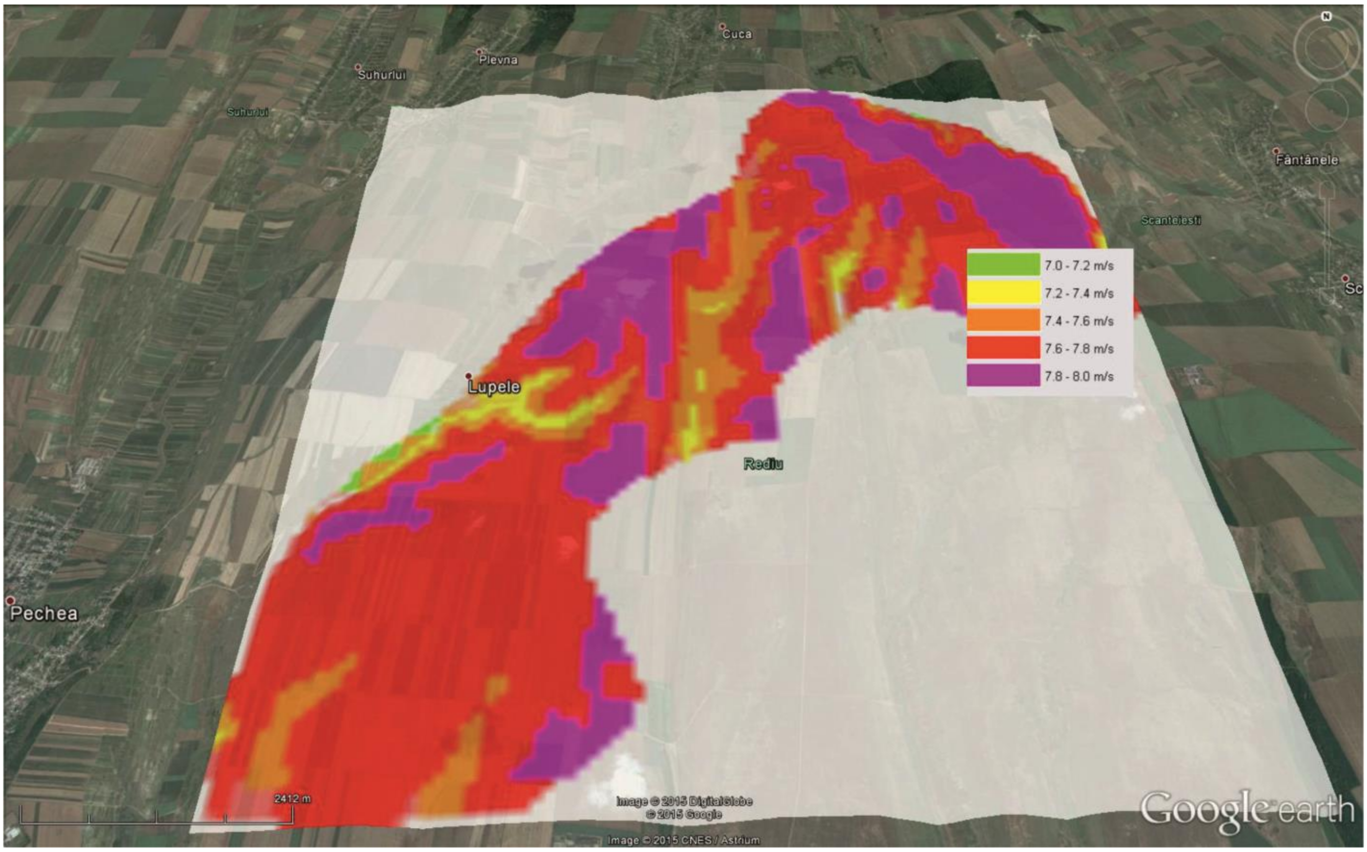

Fig. 7 Long-term wind resources at 120 m a.g.l. within the study area.

Furthermore, the power curve of the chosen Wind Turbine Generator (WTG) type, specified by the manufacturer or measured by independent consultants, has to be considered in energy yield calculations. By linking the statistics of the wind conditions with the power curve, the expected energy production may be determined. In conclusion, in order to determine the energy yield for a special WTG type according to the calculated wind resources, the Weibull distribution of the wind estimate has to be multiplied and integrated with the power curve of the WTG considering the whole spectrum of wind speeds (Petersen at al., 1998). This way, the estimated annual energy production of each WTG in a specific wind farm is representative for long-term wind conditions.

Conclusions

The present article describes a complex methodology for quantifying the wind conditions and energy potential of large areas based on several years of high resolution in-situ measurements (in multiple points), adjusted for long-term reliability using global climatic datasets or multi-decadal meteo station data.

After quality assessment, the in-situ measured data were analyzed and adjusted to long-term reference using a mathematical process (WINDATLAS Method) which is able to transfer long-term data from a reference station nearby into the characteristic conditions at the study site, taking into consideration the orography, roughness and obstacles which are influencing the wind flows in the area. The newly obtained long-term wind statistics, comprising sector wise Weibull distribution, mean wind speed, frequency of wind direction and wind energy distribution, were transformed into wind speed and energy maps, which were further used for the characterization of the wind energy potential within the location of interest.

Based on the wind characteristics evaluated within the representative study site, we can conclude that the Southern Bârlad Plateau has very good wind energy potential as the long-term averaged wind speeds range between 7 and 8 m/s at 120 m a.g.l. (similar to the values registered in Dobrogea region), with corresponding wind energy values higher than 3000 kWh/m^2 at the same height level. The prevailing winds are coming from northern and southern directions (relatively unidirectional on the same axes) and the long-term wind speeds are relatively constant at multi-annual scale, which means that this area is relative easily predictable for future wind conditions, being also highly suitable for the development of Multi-Megawatt wind farms.

Further on, the above presented local wind conditions and statistics can be integrated into energy yields for the WTG sites at the planned hub heights. This gives a strong applied character to the present climatic study, as its results can be further used in energy production estimates and feasibility studies for wind farms.

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Seasonal river flow variability of the Middle and Lower Danube and its tributaries

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Abstract

The seasonality of stream flow variability indicates special feature of local cycle of precipitations, evaporation and the timing of snow melt. This study presents seasonal occurrence of maximal and minimal annual flows and spatial variability of seasonal index (I_s) in the Middle and Lower Danube basin. The analysis is based on 47 time series of monthly runoff (12 for the Danube and 35 for its tributaries), which are collected from public database. The results show that the maximum annual stream flow appears during all months, but with highest frequency in April for 68% from watersheds. It varies between one and 60% (Danube – Baziaz). The monthly flow is concentrated in summer–autumn hydrological season, except for the Jalomita, Siret and Prut river basins, where it is in the winter. The highest frequency of minimum monthly runoff for the Danube and the Tisza is in October and November and for the Sava and Velika Morava – in August and September. The lowest and highest monthly discharge of the given month in the entire period were recorded in different years. Seasonal index (I_s) is between 0.98 and 3.18. It is about 1.00 for the Danube and more than 2.00 for the Tisza, Ialomita, Siret and Prut watersheds. I_s is stability – coefficient of variation is up to 0.30 with the exception of several river basins. Stream flow variability of the Middle and Lower Danube can provide valuable information for scientific studies and integrated management of water resources.

Keywords: *monthly discharges, seasonal runoff variability, the Lower Danube*

Rezumat. Variabilitatea scurgerii sezoniere a fluviului Dunărea și a afluenților săi în cursurile mijlociu și inferior

Variabilitatea sezonieră a scurgerii râurilor evidențiază aspecte importante ale ciclului precipitațiilor la nivel local, evaporare și timpul de topire a zăpezii. Cercetarea prezintă apariția sezonieră a debitelor anuale maxime și minime și variabilitatea spațială a indicelui sezonier (I_s) în cursurile mijlociu și inferior ale Dunării. Analiza de studiu se bazează pe 47 serii temporale ale valorilor de precipitații medii (12 pentru Dunăre și 35 pentru afluenții săi), care au fost colectate de la baze de date publice. Rezultatele evidențiază răspândirea debitelor maxime anuale la nivel de perioadă în fiecare lună a anului, dar cu o frecvență mai mare în luna aprilie pentru 68% din cazuri. Acestea variază între 1 și 60% (Dunăre-Baziaș). Scurgerea lunară/debitul lunar este concentrată în perioada hidrologică vară-toamnă, excepție făcând bazinele hidrografice Ialomița, Siret și Prut, cazuri în care concentrația acestora este vara. Frecvenșa cea mai mare a scurgerii minime lunare de precipitații pentru Dunăre și Tisa este prezentă în octombrie și noiembrie, iar pentru Sava și Velika Morava în august și septembrie. Valorile cele mai mari și cele mai mici ale debitelor lunare au fost înregostrate în zile diferite pentru o anumită lună. Indexul sezonier (I_s) are valori cuprinse între 0.98 și 3.18, mai exact 1.00 pentru Dunăre și mai mult de 2.00 pentru bazinele hidrografice Tisa, Ialomița, Siret și Prut. I_s este stabil pentru o variație mai mare de 0.30 cu excepția a câtorva bazine hidrografice. Variabilitatea scurgeri râurilor în bazinele mijlociu și inferior ale fluviului Dunărea poate oferi informații valoroase pentru studiile științifice și pentru managementul integrat al resurselor de aplociu și inferior

Cuvinte-cheie: *debite lunare, variabilitate sezonieră a precipitațiilor Dunărea inferioară*

Introduction

The stream flow patterns closely follow rainfall patterns and variability in runoff volume is significantly longer than the rainfall volume for the same period. The river basins in temperate climate region show mean maximum runoff during spring and minimum annual flow in summer and autumn. At the same time, every river basin and stream reacts differently to weather conditions, such as precipitation, seasonal differences, and evaporation. One way to reveal the specificity of stream flow is to study the monthly distribution, frequency of monthly maximum and minimum values and indices for seasonal variability for a long period. Purposeful research about monthly maxima and minima of stream flow in the river basin of the Danube is made by Kovács (2010) on characterization on the runoff regime and its stability. Data for the index of seasonal variability for catchment of the Danube gives Dobrovolski (2011). Other relevant research on the river flow of the Danube are those of Gastescu, 1998, Hristova 2011, 2014, Rambu et. al.2012.

This study investigates the frequency of monthly maximal and minimal streamflow as well as the temporal and spatial variability of seasonal index (I_s) in Middle and Lower reaches of the Danube and its tributaries in these two sub-regions.

Data and Methods

This study uses monthly discharge data, collected from Global Runoff Data Centre (GRDC): Long-Term

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Mean Monthly Discharges and Annual Characteristics of GRDC Station.

There are47 gauging stations (12 along the Danube and 35 along its tributaries: Drava – 3, Tisza/Tisa – 14, Sava – 6, Timiș – 1, Velika Morava – 2, Jiu – 1, Iskar – 1, Olt – 2, Ialomita – 1, Siret – 2, Prut – 2). The selection of the gauging station was based on the availability of data. Length of records varies between 13 years (Una – Novi Grad) and 151 years (the Danube – Orșova). The period with hydrometric observations for half of gauging stations is between 40 and 80 years (Fig. 1). The area, period of observations, latitude and longitude for river basins is mentioned in Appendix 1.

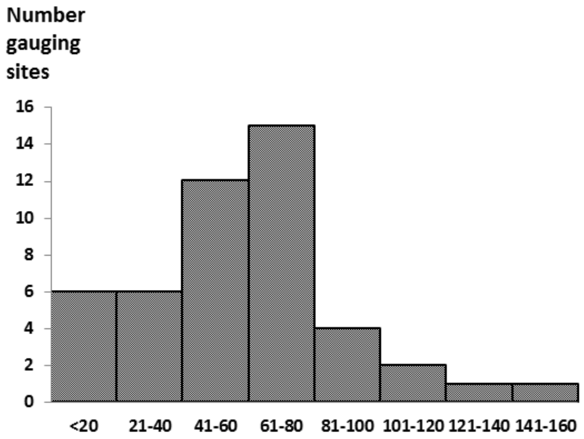

Fig. 1. Number of gauging sites with various lengths of record

For each single year we established the month with the lowest and highest discharge. Month frequency analysis is applied. The frequency of monthly maximum and monthly minimum for each month over the entire period is calculated as percentage. The lowest and highest monthly discharge of the given month for the entire period was analyzed.

The study calculates statistic characteristics of monthly minimum/maximum discharge time series: average, minimum, maximum, kurtosis, skewness, coefficient of variation. It searches combinations between monthly maximum and monthly minimum for isolation of regimes types.

Coefficient of seasonal variability – I_s, is calculated using the formula proposed by Dobrovolski (2011):

(1) $I_S = (Q_{MAX} - Q_{MIN})/Q$,

where Q_{MAX} is the highest monthly discharge of the given year, m^{3}s;

Q_{MIN} – the lowest monthly discharge of the given year, m^{3}s;

Q – mean discharge of all monthly discharges in the given year, m^{3}s.

Dobrovolski (2011) calculated the global value of I_s – 3.0 and established that seasonal variation of monthly discharge is three time higher than the annual one. The same author uncovered relationships between the index of seasonal changeability and catchment's area (in log10 and more than 100, 000 km), between I_s and stream flow (in mm/year).

Discussion

Mean monthly maximum varies between 3760.2 and 9976.5 m^3/s (Table 1). Values are generally stable for the entire period and do not register large fluctuations – coefficient of variation is 0.17–0.26. Mean monthly maximum increases along the Danube about three times, just like the mean annual discharge. It is similar to the average maximum discharge, as it was determined by Gâştescu at al. (2012) for the 1921–1930 period. The absolute monthly maximum was registered in June, 1965 for the Danube from Nagymaros till Bogojevo, in April, 1940 and 1942 respectively, for the Danube – Pancevo and the Danube – Veliko Gradiste, April, 2006 the Danube – Bazias, Danube – Zimnicea and Danube – Ceatal Izmail (Appendix 2). Orșova and Hârșova along the Danube make exception, the absolute monthly maximum being registered in June, 1897 and May 1970, respectively (Appendix 2).

The time series of monthly maximum features positive skewness, except for Danube – Harsova. Kurtosis of time series of monthly maximum is positive for the middle reaches of Danube and negative downstream of Bogojevo (Table 1).

The value of average monthly minimum along the Danube varies between 1274.9 and 3616.6 m^3/s (Table 1). It varies more than the monthly maximum – Cv is from 0.17 (Danube – Bazias) to 0.40 (Danube – Hârșova). The distribution of time series for monthly minimum is asymmetric, similar to the time series of monthly maximum (Table 1).

Table 1 Statistical parameters of monthly maximum and monthly minimum for the Danube

River – gauging station	Monthly maximum						Monthly minimum					
	Q (m^3/s)			C_v	Kurt.	Skew.	Q (m^3/s)			C_v	Kurt.	Skew
	Min.	Av.	Max.				Min.	Av.	Max.			
Danube – Nagymaros	2106	3760,2	7061	0,22	1,62	0,85	626	1274,9	2190	0,23	0,17	0,48
Danube – Mohács	2350	3690,5	7223	0,24	2,38	0,96	672	1367,8	2356	0,25	0,51	0,50

Danube – Bezdan	1700	3647,2	7570	0,26	2,59	1,04	749	1322,1	2052	0,22	-0,38	0,34
Danube – Bogojevo	2796	4522,6	8153	0,22	1,03	0,76	959	1653,9	2542	0,21	-0,20	0,35
Danube – Pančevo	5070	8492,8	12 173	0,19	-0,38	0,41	1454	2841,1	5136	0,25	1,20	0,72
Danube – V. Gradište	6155	9277,4	13 140	0,21	-0,70	0,40	1461	2986,7	5408	0,29	1,61	0,92
Danube – Bazias	6832	8690,8	14 093	0,22	2,60	1,59	1916	2911,9	3812	0,17	-0,23	-0,36
Danube – Orșova	4812	9009,6	13 324	0,21	-0,26	0,39	1645	2987,4	5734	0,25	0,89	0,90
Danube – Zimnicea	5739	9761,9	14 510	0,20	-0,36	0,37	1411	3258,7	6169	0,26	1,77	0,76
Danube – Hârșova	2839	9036,3	13 947	0,29	0,15	-0,64	358	2995,9	6679	0,40	0,57	-0,02
Danube – Silistra	6408	9785,6	13 408	0,17	-0,47	0,17	1785	3285,1	6586	0,32	2,15	1,23
Danube – C. Izmail	6100	9976,5	14 673	0,18	-0,20	0,27	1889	3616,6	7160	0,26	2,14	1,01

The absolute monthly minimum discharge of the given period for the Danube was recorded in October, 1947 between Nagymaros and Veliko Gradiste and in January, 1954 for lower course (Appendix 3) or during the longest dry period in Europe in the 20th century – from 1947 to 1954. The exception is Danube – Hârșova, where the lowest monthly discharge (358 m^3/s) was registered in September 2003. The frequency of monthly maxima of stream flow is highest in July and June for the middle reaches and in April from Pančevo till Ceatal Izmail (Table 2). It varies during these months between 23 and 61%. Monthly maximum is recorded very rarely during August–October period and rarely in winter.

The frequency of monthly minima is highest for the middle reaches of the Danube in November, September and October after Pančevo (Table 3). There was registered no monthly minimumstream flow in April and May. Single cases were recorded during May and June.

Table 2 Frequency (%) of monthly maximum for the Danube

River – station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Danube – Nagymaros	3	5	8	9	17	20	23	8	3	1	2	2
Danube – Mohács	3	4	10	12	7	25	23	9	1	–	3	3
Danube – Bezdan	4	1	9	15	13	24	21	6	3	–	3	3
Danube – Bogojevo	1	–	6	19	9	29	21	8	3	–	3	1
Danube – Pančevo	4	3	15	40	18	5	3	–	–	–	4	8
Danube – V. Gradište	3	3	20	40	18	10	3	–	–	–	–	5
Danube – Bazias	6	–	11	61	11	–	–	–	–	–	11	–
Danube – Orșova	3	3	12	35	25	8	4	1	–	–	3	6
Danube – Zimnicea	5	3	14	40	15	13	3	–	–	1	4	4
Danube – Hârșova	5	1	11	36	21	13	3	–	–	1	4	5
Danube – Silistra	5	3	19	35	16	14	3	–	–	–	3	3
Danube – Ceatal Izmail	4	–	8	26	25	20	6	1	–	1	3	6

Table 3 Frequency (%) of monthly minimum for the Danube

River – station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Danube – Nagymaros	19	11	3	–	–	–	1	1	3	18	24	21
Danube – Mohács	14	13	1	–	–	–	1	1	6	20	23	19
Danube – Bezdan	21	16	1				1	1	4	20	18	18
Danube – Bogojevo	21	17	1	–	–	–	1	3	5	17	21	14
Danube – Pančevo	12	4	–	–	–	1	4	12	30	26	7	3
Danube – V. Gradište	20	5	–	–	–	–	3	8	23	30	8	5
Danube – Bazias	–	–	–	–	–	6	6	33	33	17	6	–
Danube – Orșova	19	10	1	–	–	–	2	7	21	21	11	7
Danube – Zimnicea	8	1	–	–	–	–	5	11	29	24	19	4
Danube – Hârșova	6	4	–	–	–	–	5	11	21	29	20	4
Danube – Silistra	5	–	–	–	–	–	5	14	19	38	16	3
Danube – Ceatal Izmail	6	4	–	–	–	–	4	8	21	27	25	4

Results show five combinations between monthly maximum and monthly minimum for the Danube: *July–November* (for Danube – Mohács and Danube – Nagymaros); *June–January* (Danube – Bezdan and Danube – Bogojevo); *June–November* (Danube – Bogojevo); *April–September* (Danube – Panchevo, Danube – Bazias, Danube – Orșova, Danube – Zimnicea); *April–October* (Danube – Veliko Gradiste,

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Danube – Harsova, Danube – Silistra, Danube – Ceatal Izmail) (Table 2 and 3, Figure 2).

There are two types of regime according to the highest frequency of monthly maxima and monthly minima of the stream flow along the Danube between Nagymaros and Ceatal Izmail. The first type is distinguished for summer maximum (June/July) and winter minimum (January and November) and it is typical for the Danube from Nagymaros up to Bogojevo (Fig. 2). The frequency of monthly maxima and monthly minima is higher during these months (Table 2 and 3).

The second type is marked by spring maximum and autumn minimum of stream flow (Fig. 2). Monthly maxima of river runoff are in April and the frequency varies between 26 and 61% (Table 2). Monthly minimum discharge shows stable appearance during September and October (Table 3, Figure 2).

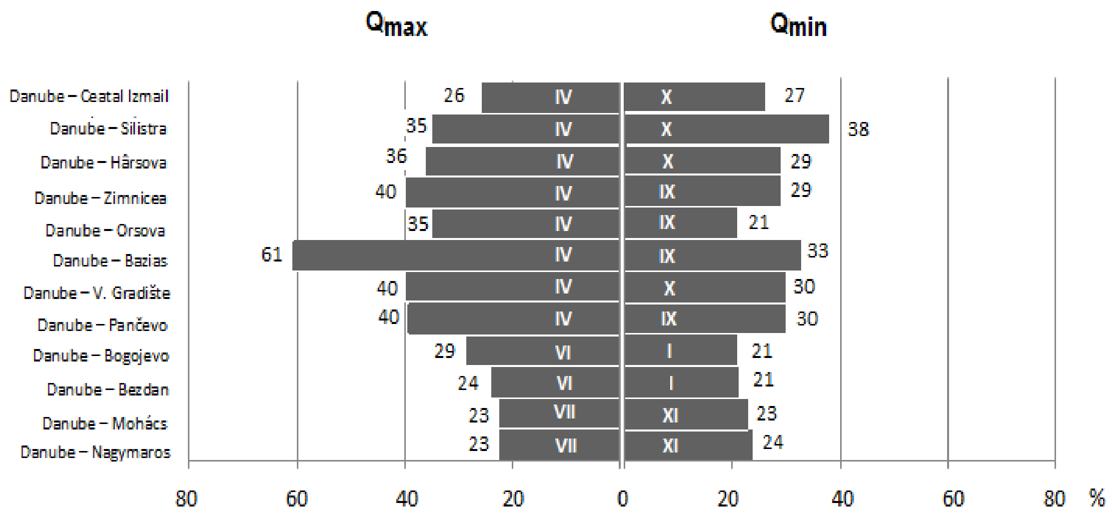

Fig. 2. Monthly maximum and monthly minimum for the Danube

Statistics of monthly maximum for tributaries of the Danube show large variations (C_v is 0,21–0,58) and positive skewness, (except for Drava – Borl and Tisza – Tiszapalkonya) (Table 4). The ratio between value of minimum and maximum for analyzed characteristic is large for all river basins. It is between three and five times and reaches to 14 times for rivers Sajo, Timiș and Ialomița (Table 4).

The picture of highest monthly discharges of given month in the entire period shows large differences for appearing of absolutely highest stream flow (Appendix 2). More of absolutely monthly maximum is during spring hydrological season (March–June), but in different years. The Sava River is an exception, as well asthe Tisza (Tisza – Szolnok and Tisza – Polgar), where the highest monthly maximum appears during November and February, respectively (Appendix 2). Data shows that 1970, 1979 and 1981 in the 20th century are the years with highest monthly maximum for a lot of river sub-basins of the Danube watershed. In other words, highest monthly flow peak shows regularity in time and space.

The values of monthly minimum discharge for the Danube tributaries varies quite a lot (Table 4). The ratio between the minimum and maximum value is between 1 and 12, except for several river basins (Körös – Gulja, Zagyva – Jasztelek, Timiș – Sag and Tisza –Tiszabecs). Results for lowest monthly discharges of given month in the entire period discloses the following: the absolutely monthly minimum of stream flow is typical for August–October, but in different years. It is registered during January for the Olt, Ialomita, Siret and Prut. A lot of the lowest monthly discharges occurred during the 1988–1992 and 2000–2003 period or during the dry periods in most Europe. Other dry years for the sub-basins of the Danube are 1934 (May, for the Tisza river basin), (1946 and 1947, September–October), 1950 (May–August) and 1962 (June–July) (Appendix 3). There are no geographical regularities in the study areas.

The frequency of the highest monthly discharges is normally higher during the spring months – April and May, except for the Sava River, where it is registered during November and December (Table 5). It is very rarely in August–October and during the winter months.

Frequency of monthly minima of stream flow typically is higher during August and September with the exception of the Olt, Siret and Prut rivers, where it is in January and December (Table 6). An isolated phenomenon is observed during spring hydrological season. The appearance of monthly minima of river runoff is very stable for a lot of river basins and it is the response to the dry summer and cold winter in temperate climate.

Table 4 Statistical parameters of monthly maxima and minima for the Danube tributaries

River – gauging station	Monthly maximum			C_v	Kurt.	Skew.	Monthly minimum			C_v	Kurt.	Skew.
	Min.	Av.	Max.				Min.	Av.	Max.			
Drava – D. Miholjac	487,0	939,7	1753,0	0,28	1,74	1,16	194,0	300,2	447,0	0,20	-0,04	0,62
Drava – Borl	70,3	543,0	879,7	0,32	1,09	-0,36	0,0	130,5	201,5	0,38	0,70	-1,02
Mur – G. Radnova	142,7	287,2	551,6	0,28	1,07	0,97	48,6	72,5	102,7	0,17	-0,39	0,28
Tisza –Tiszabecs	63,9	460,2	905,1	0,40	0,58	0,24	3,6	54,8	127,9	0,50	1,04	0,64
Tisza/Tisa – Szeged	674,3	1819,7	3489,6	0,34	0,17	0,52	108,8	275,6	820,2	0,48	2,72	1,39
Tisza/Tisa – Szolnok	513,0	1291,8	2216,0	0,30	1,31	0,41	83,1	191,8	320,0	0,37	-0,74	0,32
Tisza/Tisa – Polgar	489,0	1248,7	2270,0	0,38	-0,67	0,55	71,0	154,4	506,0	0,49	7,78	2,35
Tisza – Tiszapalkonya	710,1	1146,4	1456	0,20	0,03	-0,68	72,8	150,8	306,0	0,48	0,49	1,11
Tisza/Tisa–Senta	635,0	1743,6	3185,0	0,33	0,10	0,53	118,0	286,5	764,0	0,46	3,15	1,55
Szamos–Szenger	104,6	320,0	720,2	0,42	0,83	0,99	13,4	33,6	80,9	0,45	0,75	1,09
Szamos – Satu Mare	132,0	326,2	755,9	0,42	1,12	1,09	9,7	34,8	98,1	0,49	1,97	1,15
Sajo – Felsőzsolca	17,3	84,2	250,1	0,50	1,60	0,99	2,0	8,5	24,9	0,57	1,13	1,15
Zagyva – Jasztelek	4,2	12,3	26,8	0,59	-0,37	0,90	0,1	1,3	3,0	0,63	-0,37	0,46
Körös – Gulja	30,7	67,7	141,4	0,49	0,18	0,98	0,0	3,9	7,71	0,62	-1,22	0,19
Maros – Mako	156,7	404,6	1017,5	0,40	3,17	1,39	26,5	60,3	131,8	0,39	1,30	1,16
Maros – Alba Iulia	97,8	271,9	578,0	0,38	0,48	0,70	8,0	33,3	70,0	0,42	0,39	0,77
Maros –Arad	131,0	417,3	930,5	0,42	0,55	0,83	11,0	54,2	141,0	0,50	1,09	1,04
Sava – Hrastnik	326,1	551,2	1025,3	0,25	1,26	0,88	52,0	115,7	238,8	0,30	1,50	0,74
Sava – Radeče	239,4	445,5	749,0	0,24	-0,26	0,21	48,6	94,4	187,3	0,31	1,18	0,92
Sava – Čatež	198,1	332,2	692,6	0,36	4,22	1,83	35,7	65,3	96,5	0,26	-0,57	0,30
Sava – Sr. Mitrovica	1920,0	3115,6	4800,0	0,21	-0,27	0,51	229,0	509,9	1290,0	0,36	2,92	1,28
Una – Novi Grad	311,2	465,3	623,5	0,19	0,13	0,24	48,0	63,3	78,5	0,16	-1,25	-0,24
Lim – Prijepolje	109,4	175,2	306,0	0,26	0,84	0,94	10,2	17,1	36,5	0,31	5,15	1,97
Timiș – Sag	28,9	110,7	332,1	0,49	4,70	1,55	0,62	3,8	26,9	1,21	14,05	3,43
V. Morava – L.most	187,6	564,5	1056,0	0,33	-0,32	0,38	29,3	69,3	176	0,42	3,15	1,62
Ibar – Leposavić	30,3	62,2	120,6	0,42	0,08	0,92	4,1	8,8	13,4	0,25	0,17	0,12
Jiu – Rodari	89,1	208,5	521,0	0,38	3,56	1,28	6,3	26,9	65,9	0,43	1,37	0,94
Iskar – Orehovitsa	42,3	132,6	295,0	0,44	0,32	0,74	4,8	18,3	36,3	0,45	-0,24	0,60
Olt – Cornet	94,9	253,1	512,7	0,40	0,41	0,77	22,8	48,2	97,5	0,30	1,73	0,84
Olt – Stoeneşti	182,0	363,2	776,0	0,36	4,29	1,58	33,0	56,2	117	0,37	3,66	1,77
Ialomița – Coşereni	20,1	91,7	275,4	0,58	3,42	1,62	3,4	15,8	35,8	0,46	-0,26	0,70
Siret – Dragesti	51,0	240,2	468,3	0,50	-0,96	0,33	5,0	22,3	45,7	0,44	-0,29	0,61
Siret – Lungoci	132,6	504,3	1223,3	0,52	0,18	0,83	32,7	84,0	178,4	0,45	-0,03	0,75
Prut – Chernivsti	48,9	186,7	447,0	0,50	1,59	1,29	6,0	16,9	40,3	0,48	1,54	1,22
Prut – Rădăuţi	56,1	213,2	568,3	0,47	3,31	1,37	0,0	24,5	53,8	0,54	-0,31	0,26

The seasonal variability is driven by weather conditions and seasonal climatic patterns in the watershed. Mean value of I_S is between 0,99 (the Danube – Bogojevo) and 1,12 (the Danube – Harsova) (Table 7). The results are similar to those obtained by Dobrovolski (2011). The author calculates that the index I_S is 1,34 for river basins is West Europe and 0,2–2,4 for the Danube catchment.

The mean values of I_S for all gauging stations are similar. It relates for maximum and minimum values also (Table 7). C_v is less than 0.30 and proves stability of seasonal variation for the stream flow of the main river.

Seasonal changeability of the Danube for the analysed period fluctuates between 0.5 and 2.00 and it is similar for all gauging stations (Fig. 2). Results show little deviations around these values: less than 0.50 for four gauging stations – Mohács, Bezdan and Bogojevo during 1947 and Orșova in 1918 ; more than 2.00 for Danube – Hârșova and Danube – Zimnicea during 1947 again. Multiannual variability of Is confirms the stability of river regime

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for the Danube. It shows that influence of climate is higher than the anthropogenic impact.

Table 5 Frequency (%) of monthly maxima for the Danube tributaries

River – gauging station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drava – D. Miholjac			3	2	29	42	6	3	2	8	5	
Drava – Borl					21	46	7	4	4	14	4	
Mur – G. Radnova			3	2	38	20	14	11	2	9	2	
Tisza –Tiszabecs	10	3	8	38	23	3	5				5	5
Tisza/Tisa – Szeged	10	1	15	35	19	5	3	1			8	3
Tisza/Tisa – Szolnok	5	5	10	38	24	5					5	10
Tisza/Tisa – Polgar	11	5	24	27	16	2	2		2		5	5
Tisza – Tiszapalkonya	8		8	33	25	8	8				8	
Tisza/Tisa–Senta	10	4	13	36	20	6	1	1			5	4
Szamos–Szenger	11	12	23	23	14	8	3				5	2
Szamos – Satu Mare	10	8	25	27	10	7	4				6	4
Sajo – Felsőzsolca	7	8	28	21	10	5	2	3		2	7	9
Zagyva – Jasztelek	6	6	19	19	31	6	6					6
Körös – Gulja	13	13	25	19	19		6					6
Maros – Mako	5	3	9	38	26	11	5				2	2
Maros – Alba Iulia		5	9	55	14	9	5			2		2
Maros –Arad	2	2	11	37	23	14	6		1	1	1	2
Sava – Hrastnik	4	7	11	15	4	2	2		2	11	24	19
Sava – Radeče	4	5	8	16	7	6	2		1	12	24	15
Sava – Čatež	6	6	12	6					6	18	24	24
Sava – Sr. Mitrovica	9	9	12	26	13	1	1			2	8	18
Una – Novi Grad		8	38	15	15						8	15
Lim – Prijepolje	3	3	6	45	18					3	12	9
Timiș – Sag	4	8	8	38	15	19					4	4
V. Morava – L.most	4	18	26	26	13	6	1				3	4
Ibar – Leposavić	9	9	23	27	5	5	5				5	14
Jiu – Rodari	2	5	8	31	22	10	2	2		2	8	8
Iskar – Orehovitsa		8	16	24	29	3	8	5		5	3	
Olt – Cornet				36	23	14	14	5	5	5		
Olt – Stoeneşti				43	38	10	5			5		
Ialomiţa – Coşereni	2	3	10	25	16	20	7	3	2	2	7	5
Siret – Dragesti			2	32	15	17	11	15	6	2		
Siret – Lungoci	2	2	3	38	13	16	8	10	7	2		
Prut – Chernivsti			2	29	36	18	7	7			2	
Prut – Rădăuţi				27	32	19	5	14	3			

Seasonal variability for tributaries of the Danube is higher than that of the main river. Coefficient I_s in the sub-catchments varies between 1.14 (Drava – Donji Miholjac) and 3.01 (Timis – Sag) (Table 8). It is less than 2.00 for river basins of the Drava, Sava and Olt river, for Tisza/Tisa–Senta and Ibar – Leposavić. Results confirm conclusions by Kovács (2010) about stability of regime in sub-catchments areas of the Danube river basin.

I_s varies between 0.21 (Olt – Stoeneşti) and 0.43 (Drava – Borl). It is not much higher than C_v of the Danube and it indicates a comparatively constancy of seasonal changeability. This fact is quite interesting, because values of monthly maxima and minima vary in large interval during the observation period (Table 4).

The maximum and minimum of I_s varies in large interval (Table 8). The detailed analysis did not find any regularity about years, when the coefficient Is is the lowestor largest. The extreme values of seasonal variability are fixed for every river basin during the different years.

Table 6 Frequency (%) of monthly minima for the Danube River

River – gauging station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drava – D. Miholjac	29	19	8					2	6	11	8	16
Drava – Borl	25	36	4				4		4	7	4	18
Mur – G. Radnova	33	31	2					3	3	3	9	16

Tisza –Tiszabecs	13	8	5				3	13	10	18	18	13
Tisza/Tisa – Szeged	11	3			1	1	4	13	22	30	10	5
Tisza/Tisa – Szolnok	19						5	19	24	14	14	5
Tisza/Tisa – Polgar	11				2		7	15	24	33	5	4
Tisza – Tiszapalkonya	25						8	33	8		25	
Tisza/Tisa–Senta	16	3,8					8	11	19	29	11	3
Szamos–Szenger	9			2	2		5	11	22	34	12	5
Szamos – Satu Mare	14	6			1	1	5	12	20	29	10	2
Sajo – Felsőzsolca	13	2	1			2	4	22	28	15	7	7
Zagyva – Jasztelek								44	31	19		6
Körös – Gulja	6						6	13	25	13	38	
Maros – Mako	12	5	2				3	6	18	25	17	12
Maros – Alba Iulia	16	3					5	7	21	26	14	9
Maros –Arad	15	8				1	2	5	22	20	15	11
Sava – Hrastnik	11	9		2		4	9	31	15	11	6	2
Sava – Radeče	13	15	1	1		2	12	26	9	13	5	2
Sava – Čatež	6	12					6	47	18	12		
Sava – Sr. Mitrovica	4	1				1	5	41	35	11	1	1
Una – Novi Grad		8						46	31	8	8	
Lim – Prijepolje	3						3	36	39	12	3	3
Timiș – Sag	10	2	2			2	6	15	10	25	23	4
V. Morava – L.most	5	1			3	3	1	24	35	26	1	1
Ibar – Leposavić	5				5		14	32	27	9	5	5
Jiu – Rodari	15	3			2		2	27	20	22	3	5
Iskar – Orehovitsa	8	3			3		16	50	13	5	3	
Olt – Cornet	34	9				2	2		7	5	16	25
Olt – Stoeneşti	14	10					5		10	29	14	19
Ialomița – Coşereni	10	5	2			2	3	28	21	15	5	10
Siret – Dragesti	43	15						2		4	9	28
Siret – Lungoci	26	7		3		3	3	2	13	11	11	20
Prut – Chernivsti	43	21			2			2	4	2	9	18
Prut – Rădăuţi	38	19					3		8		11	22

Table 7 Statistics of Is for the Danube River

River – station	I_s			C_v	River – station	I_s			C_v
	min	av.	max			min	av.	max	
Danube – Nagymaros	0,49	1,06	2,08	0,28	Danube – Bazias	0,73	1,08	1,76	0,25
Danube – Mohács	0,46	0,99	1,72	0,29	Danube – Orșova	0,32	1,08	1,91	0,27
Danube – Bezdan	0,42	1,01	1,73	0,29	Danube – Zimnicea	0,55	1,09	2,11	0,25
Danube – Bogojevo	0,35	0,99	1,74	0,28	Danube – Hârșova	0,50	1,12	2,08	0,27
Danube – Pančevo	0,51	1,07	1,95	0,25	Danube – Ceatal Izmail	0,52	0,99	1,73	0,23
Danube – V. Gradište	0,54	1,10	1,95	0,28	Danube – Silistra	0,56	1,07	1,91	0,26

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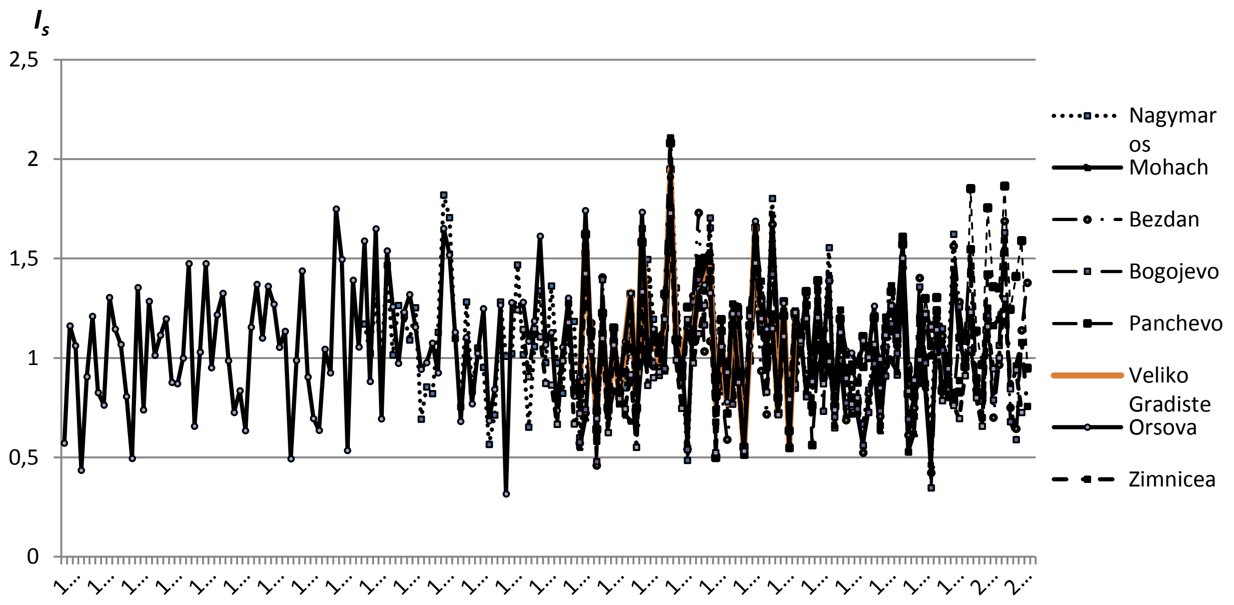

Fig. 3. Value of Is for observation period of the Danube

Table 8 Statistics of Is for the Danube tributaries

River – station	I_s min	I_s av.	I_s max	C_v	River – station	I_s min	I_s av.	I_s max	C_v
Drava – Donji Miholjac	0,65	1,14	1,90	0,28	Sava – Hrastnik	1,05	1,72	3,70	0,41
Drava – Borl	0,88	1,53	3,94	0,43	Sava – Radeče	0,87	1,55	3,10	0,28
Mur–Gornja Radnova	0,72	1,36	2,01	0,24	Sava – Čatež	0,96	1,58	3,68	0,32
Tisza/Tisa –Tiszabecs	1,22	2,23	3,88	0,26	Sava – Sr. Mitrovica	0,87	1,68	3,08	0,22
Tisza/Tisa – Szeged	1,06	1,88	3,41	0,28	Una – Novi Grad	1,29	1,95	2,52	0,18
Tisza/Tisa – Szolnok	1,14	1,94	2,73	0,26	Lim – Prijepolje	1,32	2,18	3,18	0,21
Tisza/Tisa – Polgar	1,15	2,11	3,77	0,29	Timiș – Sag	1,45	3,01	6,48	0,32
Tisza – Tiszapalkonya	1,37	2,01	2,69	0,23	V. Morava – Ljub. most	1,12	2,17	4,18	0,27
Tisza/Tisa–Senta	0,98	1,85	3,09	0,27	Ibar – Leposavić	1,13	1,97	3,05	0,23
Szamos–Szenger	1,12	2,23	3,65	0,26	Jiu – Rodari	1,09	2,15	4,02	0,36
Szamos – Satu Mare	0,07	2,25	4,45	0,33	Iskar – Orehovitsa	1,16	2,04	4,07	0,37
Sajo – Felsőzsolca	0,99	2,46	4,69	0,29	Olt – Cornet	0,98	1,77	3,14	0,29
Zagyva – Jasztelek	1,63	2,63	4,77	0,35	Olt – Stoeneşti	1,01	1,90	2,57	0,21
Körös – Gulja	1,66	2,78	4,84	0,30	Ialomița – Coşereni	0,89	1,85	4,17	0,34
Maros – Mako	0,94	1,98	3,83	0,28	Siret – Dragesti	0,97	2,60	4,77	0,33
Maros – Alba Iulia	1,03	2,26	4,10	0,30	Siret – Lungoci	0,72	2,02	3,32	0,34
Maros –Arad	1,03	2,12	4,23	0,28	Prut – Chernivsti	1,05	2,53	4,49	0,33
					Prut – Rădăuţi	1,07	2,33	4,79	0,36

Seasonal variability does not change along the Danube (Table 7). This result does not confirm the conclusion of Dobrovolski (2011), who affirmed that index I_S increases for the Middle Danube and decreases after the confluence with the Sava River. The study finds a weak relationship between seasonal variability and latitude for the Danube and its tributaries (Fig. 3 and Fig. 4). The drainage area (A) is not an appropriate indicator for spatial analysis of seasonal variability – there is no good relationship between A and seasonal index. The points on the graph show a tendency for I_s decreasing when the drainage area increases.

The seasonal changeability of the Danube and its tributaries depends on the Q_{MAX} and Q_{MIN}. The relationship between the index of seasonal variation and logarithms Q_{MAX} and Q_{MIN} is inversely proportional, with the coefficient of correlation of -0.74 and -0.75 respectively (Fig. 5). It shows that the influence of monthly maxima and monthly minima on seasonal changeability increases when the values of Q_{MAX} and Q_{MIN} are decreasing.

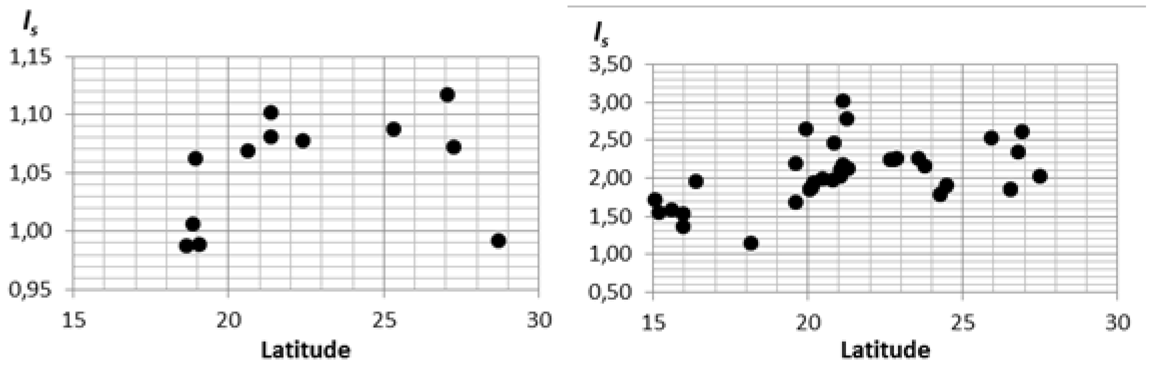

Fig. 4. Relationship between I_s and latitude for: a) Danube River; b) tributaries of Danube River

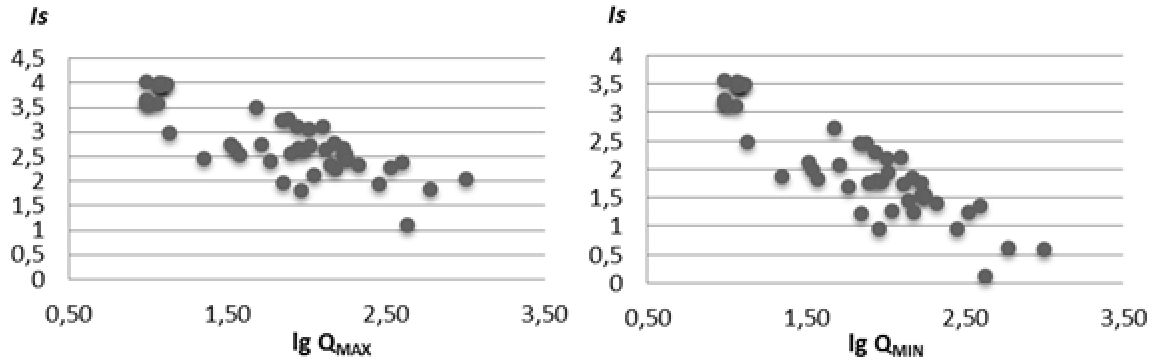

Fig. 5. Relationship between I_s and: a) Q_{MAX}; b) Q_{MIN}

Conclusion

The study shows that the anthropogenic activities (hydrotechnical infrastructure, irrigation systems etc.) do not induce any change to the months with maximum and minimum river flow. The climate imposes a marked seasonality on river flows with maximum flows normally in winter and minimum flows normally occurring in the summer or autumn except for the Sava river basin.

The appearance and frequency of monthly maxima and monthly minima of stream flow is changed along the Danube under the influence of its tributaries.

Seasonal changeability of the Danube and its tributaries is stable along the analysed years – the large deviations are isolated phenomena.

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Appendix 1. Data for gauging stations

River	Station	A (km²)	Period	n	Latitude	Longitude
Danube	Nagymaros	183 533	1893–1999	106	47.78	18,95
Danube	Mohács	209 064	1931–1999	69	46	18,67
Danube	Bezdan	210 245	1931–2010	80	45.85	18,87
Danube	Bogojevo	251 593	1931–2009	77	45.53	19,08
Danube	Pančevo	525 009	1931–2003	73	44.87	20,64
Danube	Veliko Gradište	570 375	1931–1970	40	44.80	21,4
Danube	Bazias	570 896	1991–2008	18	44.81	21,37
Danube	Orșova	576 232	1840–1990	151	44.70	22,42
Danube	Zimnicea	658 400	1931–2010	80	43.62	25,35
Danube	Hârșova	709 100	1931–2009	77	44.68	27,09
Danube	Silistra	689 700	1941–1999	59	44.13	27,26
Danube	Ceatal Izmail	807 000	1921–2010	89	45.21	28,71
Drava	Donji Miholjac	37 142	1921–1984	64	45.76	18,16
Drava	Borl	14 661	1954–1981	28	46.37	15,99
Mur	Gornja Radnova	10 197	1946–2009	64	46.68	15,99
Tisza/Tisa	Tiszabecs	9707	1937–1995	59	48.09	22,81
Tisza/Tisa	Szeged	138 408	1921–1999	79	46.25	20,16
Tisza/Tisa	Szolnok	75113	1973–1995	23	47.18	20,2
Tisza/Tisa	Polgar	62 723	1921–1979	59	47.86	21,08
Tisza/Tisa	Tiszapalkonya	62 723	1980–1995	16	47.88	21,06
Tisza/Tisa	Senta	140 130	1931–2010	80	45.93	20,08
Szamos (Someș)	Szenger	15 283	1931–1995	65	47.83	22,68
Szamos	Satu Mare	15 385	1925–2008	84	47.78	22,87
Sajo	Felsőzsolca	6440	1891–1995	105	48.11	20,84
Zagyva	Jasztelek	4207	1978–1995	18	47.48	19,97
Körös	Gulja	4251	1978–1995	18	46.65	21,28
Mureș (Maros)	Mako	30 149	1930–1995	66	46.21	20,48
Maros	Alba Iulia	18 055	1951–2008	58	46.03	23,58
Maros	Arad	27 280	1877–2008	132	46.16	21,32
Sava	Hrastnik	5177	1993–2009	17	46.12	15,09
Sava	Radeče	7084	1909–1994	86	46.07	15,18
Sava	Čatež	10 186	1956–2009	54	45.89	15,60
Sava	Sremska Mitrovica	87 966	1926–2010	85	44.98	19,61
Una	Novi Grad	8507	1978–1990	13	45.07	16,38
Lim	Prijepolje	3160	1978–2010	33	43.37	19,64
Timiș	Sag	4493	1961–2008	48	45.64	21,17
Velika Morava	Ljubicevski most	34 345	1931–2010	80	44.58	21,13
Ibar	Leposavić	4701	1978–2000	23	43.10	20,8
Jiu	Rodari	9334	1950–2008	59	44.25	23,78
Iskar	Orehovitsa		1953–2005	52		
Olt	Cornet	13 733	1967–2010	44	45.38	24,29
Olt	Stoeneşti	22 683	1950–1970	21	44.11	24,5
Ialomița	Coşereni	6265	1950–2010	61	44.69	26,57
Siret	Dragesti	11 899	1962–2008	47	46.72	26,94
Siret	Luongoci	36 030	1950–2010	61	45.55	27.ян
Prut	Chernivsti	6890	1931–1995	56	48.29	25,93
Prut	Rădăuţi	9074	1960–2008	49	48.24	26,81

Appendix 2. Highest monthly discharge of the given month in the entire period

River	Station	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
		Q	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year
Danube	Nagymaros	5008	1920	4408	1941	5907	1940	5083	1944	5556	1965	7061	1965	5669	1926	5114	1897	4206	1920	3447	1922	3766	1998	3920	1974
Danube	Mohács	3999	1948	4714	1945	4715	1940	4849	1988	5352	1965	7223	1965	5476	1965	5319	1966	3699	1938	3258	1937	4059	1998	4018	1939
Danube	Bezdan	4156	1948	4260	1966	4733	1937	5899	2006	5750	1965	7570	1965	6080	1965	5520	1966	3940	1966	3560	1937	3913	1998	4219	1944
Danube	Bogojevo	4545	1948	4725	1977	5586	1941	6844	2006	6621	1965	8153	1965	6954	1965	6393	1966	4988	1966	4823	1937	4694	1998	5067	1944
Danube	Pančevo	8690	1982	8850	1977	10943	1941	12173	1940	11965	1970	12015	1965	10349	1965	8013	1955	6985	1941	7360	1974	9750	1974	10591	1944
Danube	V. Gradište	8752	1948	9386	1963	11568	1942	13140	1942	12650	1970	12294	1965	10631	1965	8551	1955	7430	1941	7603	1937	9668	1941	10994	1944
Danube	Bazias	8001	1994	7476	2000	10101	1999	14093	2006	10530	2006	9527	2006	6736	1999	6564	1991	5721	2005	6587	1998	8962	1998	7468	1996
Danube	Orșova	10303	1926	10045	1977	11587	1941	13289	1888	12996	1853	13324	1897	12252	1926	10657	1926	8290	1851	8108	1912	9864	1974	10909	1944
Danube	Zimnicea	10186	1953	10501	1979	11643	1941	14510	2006	13 792	1970	13109	1970	12109	1965	8956	1955	7821	1966	7968	1937	10119	1974	10442	1944
Danube	Hârșova	11014	1982	9900	1979	11845	1977	13940	1942	13 947	1970	13570	1970	12252	1965	8963	1955	7781	1966	8289	1972	10435	1974	10268	1944
Danube	Silistra	10383	1953	9421	1948	11466	1941	13070	1942	12 607	1942	13408	1965	12691	1965	9192	1955	8055	1966	7026	1998	9544	1941	10468	1944
Danube	Ceatal Izmail	10880	1982	9771	1970	11902	1970	14673	2006	14 518	1970	14149	1970	12948	1940	11709	1926	9729	2005	9486	1972	10893	1974	10555	2010
Drava	D. Miholjac	762	1977	657	1977	997	1947	1092	1937	1321	1951	1753	1951	1700	1972	1202	1966	1161	1937	1101	1937	1314	1926	925	1923
Drava	Borl	279	1961	341	1977	384	1978	557	1975	717	1978	838	1965	724	1972	739	1966	880	1965	563	1960	558	1966	493	1960
Mura	G. Radnova	145	1983	190	1951	248	1947	321	2009	433	1951	552	1965	459	1972	456	1966	296	2009	325	1996	271	1958	205	2002
Tisza/Tisa	Tiszabecs	839	1948	609	1958	447	1947	905	1941	643	1941	456	1980	470	1980	489	1955	449	1941	549	1941	555	1992	434	1993
Tisza/Tisa	Szeged	2220	1926	2723	1979	2627	1941	3489	1932	3264	1941	3278	1970	2198	1974	2274	1980	1722	1941	1470	1922	2368	1974	1724	1952
Tisza/Tisa	Szolnok	1177	1979	2216	1979	1965	1977	1576	1976	1371	1978	1150	1974	1248	1980	1406	1980	668	1978	996	1974	1700	1974	1046	1981
Tisza/Tisa	Polgar	2000	1948	2270	1979	2240	1967	2080	1940	2080	1941	1580	1970	1350	1933	981	1955	1120	1941	1280	1922	1290	1931	1280	1952
Tisza/Tisa	Tiszapalkonya	1069	1982	931	1995	1456	1981	1343	1988	1295	1989	931	1980	1410	1980	1340	1980	455	1989	778	1980	1187	1992	1163	1981
Tisza/Tisa	Senta	1855	2010	2302	1979	2547	1941	3134	2006	3043	1941	3185	1970	2227	1974	1993	1980	1653	1941	1242	1974	2241	1974	1889	2010
Szamos	Szenger	647	1979	420	1979	671	1981	525	1932	720	1970	559	1974	411	1980	253	1980	305	1941	299	1941	311,7	1980	488	1981
Szamos	Satu Mare	555	1932	459	1958	756	1940	700	1932	725	1970	577	1974	382	1998	246	2005	338	1941	365	1941	314,0	1930	422	1925

River	**Station**	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**		**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
		Q	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**	***Q***	**year**
Sajo	Felsőzsolca	146	1953	198	1977	250	1937	185	1919	169	1978	150	1965	109	1891	131	1913	104	1913	156	1974	122,2	1952	137	1976
Zagyva	Jasztelek	21	1982	27	1979	16	1985	13	1979	26	1978	7	1978	9	1989	5	1991	3	1980	4	1980	9,9	1980	15	1980
Körös	Gulja	125	1979	113	1979	141	1981	72	1993	71	1978	74	1980	75	1980	51	1980	18	1989	33	1991	33,2	1980	109	1981
Maros	Mako	520	1982	556	1979	591	1981	931,2	1932	1017	1970	767	1970	684,5	1975	383	1980	426	1941	376	1972	384	1974	350	1981
Maros	Alba Iulia	187	1979	252	1970	450	1981	536,3	2006	578,0	1970	392	1998	386,6	1975	213	2005	166	1978	238	1972	216	1972	234	1981
Maros	Arad	405	1886	465	1979	671	1981	916,0	1932	930,5	1970	717	1970	924,0	1913	474	1913	867	1912	635	1912	460	1912	663	1925
Sava	Hrastnik	355	2001	260	2009	366	2001	315	2009	229,4	2004	195	1995	215	1996	175	2002	292	1995	443	1993	693	2000	447	2008
Sava	Radeče	579	1936	499	1951	624	1947	625	1919	476,5	1972	423	1939	491	1948	326	1926	556	1965	659	1964	749	1926	604	1960
Sava	Čatež	573	1962	596	1977	578	2001	698	1970	620,8	1972	507	1956	442	1975	430	1969	637	1965	826	1964	1025	2000	817	1960
Sava	S. Mitrovica	3850	1970	3790	1970	4310	1942	4800	1962	4110	1937	3122	2010	3500	1926	2390	1926	1880	1937	3660	1974	4120	1940	4340	1937
Una	Novi Grad	368	1979	487	1987	612	1981	503	1984	623,5	1980	286	1980	153	1989	163	1989	218	1989	326	1989	465	1979	587	1981
Lim	Prijepolje	166	2010	186	1979	212	1981	229	2000	255,4	1978	139	1978	68	1986	48	1979	67	1996	149	2002	306	1979	255	2010
Timis	Sag	156	1979	169	1966	160	1981	332	2005	156,6	2005	169	1970	117	1980	92	2005	98	1968	94	1997	110	1972	177	1981
V. Morava	Ljub.most	618	1955	823	1940	1046	2006	1056	1962	857,0	1965	705	1948	420	1999	427	1955	276	1955	553	1972	592	1955	758	1955
Ibar	Leposavić	88	1997	102	1999	121	1981	95	1984	115,4	1980	53	1980	53	1983	36	1983	24	1989	27	1989	83	1979	98	1981
Jiu	Rodari	301	1953	241	1977	413	1954	321	1970	354,5	1957	273	1953	237	1970	238	2005	153	1999	521	1972	246	1976	244	1952
Olt	Cornet	145	1998	204	1979	325	1981	345	2006	513	1970	379	1975	510	1975	268	2005	232	1978	476	1972	225	1972	205	1981
Olt	Stoeneşti	244	1955	263	1953	368	1970	518	1956	776	1970	504	1970	491	1969	345	1955	228	1955	232	1964	199	1964	217	1960
Ialomiţa	Coşereni	120	1970	126	2010	146	1955	156	1956	179	1971	125	1969	270	1975	171	2005	239	2005	275	1972	89	2004	96	1980
Siret	Dragoesti	112	1982	142	2002	239	1999	460	1996	468	1970	417	1975	455	2008	411	2005	232	1996	169	1972	134	1981	129	1981
Siret	Lungoci	296	1982	299	1998	486	1981	1008	1984	1223	1970	782	1975	1112	2010	1068	2005	455	1996	747	1972	296	1981	326	1981
Prut	Chernivsti	130	1948	104	1966	134	1981	268	1962	394	1970	432	1948	431	1933	447	1955	186	1978	102	1976	181	1947	102	1947
Prut	Rădăuţi	96	1982	129	2002	204	1999	403	1996	282	1965	333	2006	568	2008	303	2005	207	1978	134	2008	124	1981	104	1980

Appendix 3. Lowest monthly discharge of the given month in the entire period

River	Station	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
		Q	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year	*Q*	year
Danube	Nagymaros	758	1964	776	1963	1079	1972	1430	1991	1566	1934	1548	1934	1393	1976	1202	1947	763	1947	626	1947	766	1908	730,4	1953
Danube	Mohács	767	1964	837	1963	1077	1972	1401	1933	1558	1934	1441	1934	1342	1976	1233	1947	785	1947	672	1947	930	1969	787,1	1953
Danube	Bezdan	852	1947	1010	1952	1180	1972	1250	1950	1460	1954	1320	1950	1160	1950	1106	1992	888	1947	749	1947	900	1983	890	1953
Danube	Bogojevo	988	1954	1173	1963	1619	1972	1680	1991	2190	1998	2080	1993	1405	2003	1209	2003	1078	1947	959	1947	1193	1983	1162	1953
Danube	Pančevo	1454	1954	2137	1954	3206	1949	4380	1990	3820	1990	2680	1993	2170	2003	1820	2003	1780	2003	1460	1947	2170	1971	1750	1953
Danube	V. Gradište	1461	1954	2200	1954	3378	1943	4407	1943	4439	1946	3626	1950	2635	1950	2378	1952	1943	1947	1525	1947	2398	1947	1783	1953
Danube	Bazias	3801	1993	2919	1991	4022	1991	4495	1991	3897	2007	3122	1993	2340	2003	1946	2003	1916	2003	2701	1994	3085	2008	2921	2003
Danube	Orșova	1645	1954	1859	1858	3144	1858	3978	1894	4229	1990	3557	1947	2693	1950	2194	1990	2031	1947	1676	1947	2022	1971	1947	1953
Danube	Zimnicea	1411	1954	2383	1949	2963	1949	4429	1972	4355	2007	3477	1993	2658	1950	2315	1952	2082	1947	1620	1947	2062	1947	1977	1953
Danube	Hârșova	1195	2007	1530	2005	2080	2008	2182	2007	1335	2007	1274	2003	564	2003	441	2003	358	2003	682	2009	767	2008	862	2006
Danube	Silistra	1811	1954	2567	1949	3075	1949	4712	1943	5051	1949	3634	1993	2930	1950	2507	1952	2236	1992	1785	1947	2283	1947	2018	1953
Danube	Ceatal Izmail	1889	1954	2577	1925	3010	1949	3917	1921	4762	2007	3986	1993	2992	1950	2598	1990	2338	1990	2076	1921	2439	1947	2178	1953
Drava	D. Miholjac	227	1978	207	1949	194	1943	234	1943	356	1943	473	1971	374	1976	335	1983	243	1947	214	1947	198	1947	225	1942
Drava	Borl	40,9	1981	41,1	1981	43,5	1980	35,8	1981	47,9	1980	56,3	1980	0	1981	0	1981	0	1981	0	1981	0	1981	0	1981
Mura	G. Radnova	48,6	1947	53,2	1947	67,5	1949	96,4	2003	138,8	2007	118,9	1971	73,1	2003	55,1	2003	55,9	1947	49,7	1947	53,5	1947	55,8	2001
Tisza/Tisa	Tiszabecs	6,6	1952	8,6	1952	4,1	1953	26,1	1953	18,1	1952	15,0	1952	5,5	1952	3,6	1952	7,0	1953	4,9	1953	4,5	1951	5,9	1951
Tisza/Tisa	Szeged	142	1925	143,9	1954	320,3	1984	504,7	1974	278	1934	199,1	1950	141,9	1950	112,8	1990	112,1	1950	108,8	1946	159	1961	160	1924
Tisza/Tisa	Szolnok	177	1973	210,4	1993	290	1973	295	1974	304	1973	161,1	1993	134,2	1994	83,1	1992	121,3	1994	121	1986	140	1986	101	1986
Tisza/Tisa	Polgar	110	1964	118	1964	270	1943	215	1962	160	1934	135	1950	99,0	1961	82,0	1923	75,0	1946	71,0	1961	90,0	1961	103	1921
Tisza/Tisa	Tiszapalkonya	158	1984	196	1984	169	1984	367,0	1991	314,9	1992	138,5	1993	91,2	1992	72,8	1992	101,5	1994	107	1983	102	1983	112	1983
Tisza/Tisa	Senta	134	1947	166	1964	233,2	1984	452,2	1991	308	1934	223	1950	149	1950	127,4	1990	125	1946	118	1946	158	1961	180	1953
Szamos	Szenger	15,6	1954	23,0	1954	36,1	1984	44,6	1991	39,3	1934	28,5	1950	23,8	1950	17,7	1952	13,6	1961	13,4	1961	15,1	1961	22,0	1983
Szamos	Satu Mare	10,1	1954	9,7	1954	38,4	1984	52,7	1991	35,0	1934	27,1	1950	22,1	1950	14,0	1946	10,0	1946	12,0	1943	14,0	1943	17,0	1962

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Sajo	Felsőzsolca	3,71	1972	5,0	1909	8,81	1943	5,97	1974	6,58	1943	5,76	1993	4,42	1968	2,0	1894	2,0	1894	2,81	1943	3,0	1908	3,84	1973
Zagyva	Jasztelek	1,10	1984	0,79	1993	0,85	1993	1,7	1984	2,52	1992	1,4	1983	0,16	1983	0,07	1983	0,2	1986	1,0	1983	0,87	1986	1,03	1983
Körös	Gulja	4,52	1984	10,3	1991	9,10	1991	7,9	1991	7,81	1986	6,43	1983	0,95	1992	0,05	1992	2,03	1985	1,26	1995	1,87	1983	2,97	1986
Maros	Mako	41,0	1949	34,5	1954	73,2	1972	87,4	1991	70,2	1934	65,2	1950	42,0	1950	30,2	1946	26,5	1946	27,9	1946	37,4	1943	35,4	1953
Maros	Alba Iulia	7,96	1954	10,9	1954	51,1	1991	47,2	1991	52,7	1992	33,9	2003	26,5	1952	18,9	1952	13,3	1952	20,0	1961	16,0	1953	13,8	1953
Maros	Arad	14,0	1899	25,0	1899	49,0	1943	54,0	1894	63,0	1934	12,0	1931	38,0	1950	29,0	1877	14,0	1898	15,0	1943	15,0	1897	11,0	1898
Sava	Hrastnik	59,3	2002	57,8	2005	52,0	1993	68,6	1997	58,3	1993	46,7	2003	46,4	1993	35,7	2003	50,0	2003	52,5	1997	64,8	2006	59,0	2001
Sava	Radeče	55,6	1989	65,3	1909	57,8	1949	74,2	1949	65,5	1993	56,6	1993	59,7	1993	52,5	1992	51,7	1921	48,6	1947	66,0	1983	63,0	1921
Sava	Čatež	70,4	1989	90,4	1993	86,5	1993	131	1997	92,5	1993	68,9	2003	65,8	2003	52,0	2003	68,5	2003	68,3	1985	81,9	1983	103	2001
Sava	S. Mitrovica	498	1989	370	1989	595	1990	992	1946	735	2007	530	1946	368	2003	251	2003	229	1946	231	1946	376	1947	391	1953
Una	Novi Grad	76,5	1989	74,9	1989	101,2	1990	145,2	1989	119,7	1990	88,4	1979	58,3	1990	49,7	1990	50,3	1990	48,0	1985	50,5	1983	101	1989
Lim	Prijepolje	24,7	1983	21,3	1993	39,3	1993	73,9	1991	59,8	2002	26,6	1993	18,2	2003	11,5	2003	11,5	2007	10,2	1985	18,1	1986	15,7	1986
Timis	Sag	0,74	1964	1,29	1991	1,08	1972	1,70	1961	8,51	2002	1,20	1962	1,07	1962	0,75	1962	0,62	1962	0,67	1962	0,70	1963	1,30	1971
V. Morava	Ljub.most	30,0	1954	52,0	1932	84,0	1933	114,0	1972	76,0	1983	68,0	1950	43,0	1950	29,3	1993	32,5	1993	31,9	1993	49,0	1932	44,0	1953
Ibar	Leposavić	7,61	1983	13,15	1989	14,89	1990	13,2	1983	7,45	1983	9,66	1994	6,03	1998	6,55	1978	6,62	2000	4,67	2000	4,09	2000	4,85	2000
Jiu	Rodari	15,22	2001	16,66	1954	28,63	1961	33,4	2002	27,93	2002	20,5	1950	11,6	1950	9,67	1950	7,87	1950	6,26	1950	12,4	2000	15,0	2000
Olt	Cornet	28,8	2001	29,3	1993	47,2	1987	51,3	1974	59,6	1986	41,8	1968	42,0	1968	35,6	2000	31,6	1987	29,1	2000	31,7	2000	22,8	1986
Olt	Stoeneşti	33	1964	34	1954	88	1957	109	1961	119	1950	63,0	1968	50,0	1968	55	1963	44,0	1963	39,0	1963	35,0	1963	37,0	1953
Ialomița	Coşereni	8,06	1954	10,3	1954	11,9	2002	12,5	2002	10,9	2002	6,41	1950	5,50	1968	3,83	1950	3,42	1950	5,32	1950	9,31	1953	9,22	1953
Siret	Dragoesti	5,04	1964	7,19	1964	21,8	1991	21,0	1974	20,3	1986	16,1	1968	21,9	1987	14,4	1994	10,6	1987	9,68	1963	11,4	1963	9,40	1963
Siret	Lungoci	32,7	1987	37,8	1954	57,7	2001	60,7	1990	58,3	1986	67,7	1968	59,0	1950	43,4	1990	34,0	1994	43,1	1963	41,4	2000	40,6	1986
Prut	Chernivsti	6,0	1954	9,0	1945	23,0	1956	15,0	1934	7,0	1934	14,0	1934	21,0	1932	10,0	1946	8,0	1946	11,0	1935	8,0	1934	7,0	1961
Prut	Rădăuţi	0	1960	0	1960	0	1960	46,0	1990	56,1	1990	32,5	1964	25,0	1963	20,6	1990	12,3	1963	12,3	1961	12,6	1961	9,4	1962

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Analysis of River regime and Water balance of the Temštica River Basin (South-East Serbia) during the 1980-2012 Period

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Abstract

In this study we analyze river regime and water balance of the Temštica River on the base of thirty three year (1980 – 2012) data series. For this study period, the mean water level of the Temštica River was 41 cm. The average discharge of the Temštica River at Staničenje station for the investigated period is 5.63 m^3/s. Annual changes in average discharge is similar to the annual course of mean monthly low and high discharge values. It is concluded that the Temštica river has moderate - continental river regime. Although the precipitation quantity is not so low - 596 mm per year, of which 217.05 mm or 36.42 % of it runoffs, and 378.92 mm, or 63.58% evaporates. The ratio of the components of the water balance in the basin is not convenient, appropriate measures to improve the situation in this river basin should be taken.

Keywords: *Temštica river, water balance, water discharge, water level*

Rezumat. Analiza regimului și bilanțului hidrologic în bazinul râului Temstica (sud-estul Serbiei) în perioada 1980-2012

Articolul analizează regimul și bilanțul hidrologic al râului Temštica pe o perioadă de 33 de ani (1980-2012). Pentru această perioadă, nivelul mediu al râului Temštica a fost de 41 cm. Debitul mediu al râului la stația Staničenje pentru perioada analizată a fost de 5,63 mc/s. Schimbările anuale în debitul mediu urmează variațiile anuale ale debitelor minime și maxime lunare. În concluzie, regimul hidrologic al râului Temštica este unul continental moderat. Deși cantitatea de precipitații nu este foarte redusă – 596 mm/an, din care 217,05 mm sau 36,42% se infiltrează și 378,92 mm, adică 63,58% se evaporă, raportul dintre componentele bilanțului hidrologic al bazinului este deficitar, fiind necesare măsuri pentru îmbunătățirea situației în acest bazin hidrografic.

Cuvinte-cheie: *râul Temštica, bilanț hidrologic, debit de apă, nivelul apei.*

Introduction

Water balance is the flow of water determined as the surplus between input water and output water of watershed, region or waterbody within a period. Water balance is the basic principle of hydrology and water resource. Research on water balance has important theoretical significance and practical value (Xu, et al, 2009). The water balance equation is the basic hydrological model and it is widely applied to many fields (Darren et al., 2003; Yang et al, 2009). Precipitation, evaporation and runoff are the three main aspects in the water cycle process of river basin. For the river basin, water balance is the calculation basis of analyses of hydrology and water resources and effectiveness of water and soil conservation. However, water cycle process is affected by some complex factors such as climate, land surface conditions and human activities. Then we cannot collect enough information to get accurate values of the quantities of precipitation, evaporation and runoff. So the water cycle system of river basin is a grey one (Li et al, 2012). By using the correct investigation methods, we can get their number-covered sets (Yang et al, 2009; Li, 2009).

In the extensive international literature on trends in water levels, river flows and discharge changes in seasonal river flow regimes have been widely reported, for example in the USA (Novotny and Stefan, 2007; Hodgkins and Dudley, 2006), Canada (Khaliq et al., 2009; Burn et al., 2010), Switzerland (Birsan et al., 2005), the Nordic region (Wilson et al., 2010), and the Czech Republic (Fiala et al., 2010) and United Kingdom (Hannaford and Buys, 2012).

The aim of this study is to characterize the change in annual and seasonal water levels and discharge regimes of the Temštica River, throughout the full range of flows, including indicators of both high and low discharges as well as determining water balance characteristics of catchment area.

Study area

The Temštica River Valley in Pirot County on the southwestern slopes of the Stara Planina Mountain is a specific composition rich in natural habits of numerous plant and animal species (Stojsavljević et al., 2011).

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The Temštica is the largest tributary of the Nišava River. The mouth of the Temštica River is near the village Staničenje, 16 km upstream from Pirot, about 95 km from the mouth of the Nišava into the Južna Morava River (Mustafić, 2006). The Temštica River is made of the Toplodolska River that springs just below the highest peak of the Stara planina (Midžor, 2168m) and the Visočica River which originates in Bulgarian, part of Stara Planina Mountain. The confluence of these two rivers is near the place called Mrtvački most at the altitude of 483 m. The surface of Temštica River basin is 818 km^2 (Gavrilović & Dukić, 2002).

Surlica (883 m), Sokolovica and Boloslavica, are the hills that overlook the left bank of the Temštica River, while Gradiste (843 m), Tumba and Temac (523 m) can be seen on the right bank. There are also four meanders of the Temštica River which can be seen downstream from Mrtvački Bridge. The largest tributary is the river Klajča which flows into the Temstica near Temska village (Stojsavljević et al., 2011).

One of the main characteristics of the Temštica River basin is a large decline in longitudinal profile of riverbed, at its thirty kilometers of length, from the base of Midžor peak and the altitude of about 1300 meters to Temska village, river overcomes a height difference as much as 1000 meters. For this reason, the flow is composed of a multitude of small and large eddies, rapids and waterfalls (https://sites.google.com/site/stanicenjers/).

In Serbia there can be indentified three basic climatic areas. Within each climatic areas there are specific sub-areas which are marked with A, B and V. The area of the Temštica river belongs to A climate. This climatic area, for the most part, would have continental climate characteristics (Rakićević, 1980). The south border is connected to the Nišava River and West Morava river to the Drina River (north-west of Užice). Landscape of the Temštica River more specifically includes sub-areas labeled as A-2-v. This area includes Svrljiške Mountains and Stara Planina Mountain. In the "1200 – 1800m" zone, there is belt of cold and snowy boreal mountain climate with average annual temperatures of 4 to 7°C and 950-1100 mm of precipitation. In Pirot and Dimitrovgrad, at the foot of the mountain, autumn is warmer than spring (Ducić, Radovanović, 2005a).

The overview of the researches of climatic and hydrological characteristics of analyzed area includes works of J. Petrović (2000), N. Živković (1998), V. Ducić and associates (2003; 2005b), B. Milovanović (2010), S. Mustafić (2006; 2007). When climate of the area is concerned, the most reliable data can be found in climatic annuals published by the Republic Hydrometeorogical Service of Serbia (Stojsavljević et al., 2011).

Material and methods

In this paper database of the Republic Hydrometeorological Service of Serbia for the 1980 – 2012 period for Staničenje hydrological stations was used to present variations in water levels and average amount and seasonal distribution of discharge in the investigated river flow. Because there is no climatological station in the Temštica river basin the interpolation of data obtained from three representative stations (Dimitrovgrad, Pirot and Bela Palanka) were used. Precipitation quantities were obtained on a monthly level for a period of 33 years (1980 – 2012) so every station had 396 parameters. For the stations taken into consideration, less than 20% of the data needed were missing. For the calculation of monthly precipitation over the Temštica River basin, the interpolation method was used.

Brickners water balance equation was used (Kovačević-Majkić, 2008).

$$P = Y * \mathrm{E} \quad (1)$$

Where P – precipitation, Y - total runoff and E – evaporation.

For calculation of specific runoff the following formula was used:

$$q = \frac{\mathrm{Qx1000}}{\mathrm{P}} \quad (2)$$

Where q - specific runoff, Q - discharge (m3/s), P - surface of river basin

Total volume of runoff (W) was calculated:

$$W = Q * T$$

Q – average discharge in research period, T – research period in seconds.

Total height of runoff was calculated according to:

$$h = \frac{\mathrm{W}}{1000 * \mathrm{P}}$$

Where h - total height of runoff, W – total volume of runoff in research period, P – catchment area (Dukić & Gavrilović, 2008).

Assessments of change in hydrological datasets typically employ statistical significance testing to detect trends. Whilst significance testing is an important aspect of formal detection and attribution, there are many factors which must be considered in interpreting statistical significance, e.g. choice of testing method, impact of multi-decadal variability, serial and spatial correlation, long-term persistence. Trend testing is therefore a contentious area, and the literature abounds with discussions on the utility (or otherwise) of statistical tests for trend (see Svensson et al., 2006; Clarke, 2010) (Hannaford and Buys, 2012).

Seasonal river flow indicators were computed for the following widely-used monthly groupings: winter (December–February), spring (March – May), summer (June – August) and autumn (September – November).In addition, the seasonal mean flow was computed, as seasonal average flows are widely used in water research and management (Hannaford and Buys, 2012).

Results and discussions

Water level

As it can be seen in figure 1, the water level for the 1980 – 2012 period is variable. During the 1980 – 1990 period, we have the average high water level of 52 cm, while in the 1990 – 2005 period, we have a relatively uniform water level, an average of 40 cm. There is one exception, a sharp rise of 74 cm in water level in 2005, which represents the highest water level during the observed period. Our study shows that this peak is not due to precipitation because only 632.63 mm was recorded during that year in the Temštica river basin, this means that the rise in water levels is caused by other factor, most probably the higher water discharge from Zavoj lake which is situated on the Visočica river. Unfortunately we were not able to obtain data of water discharge from Zavoj lake for the observed period.

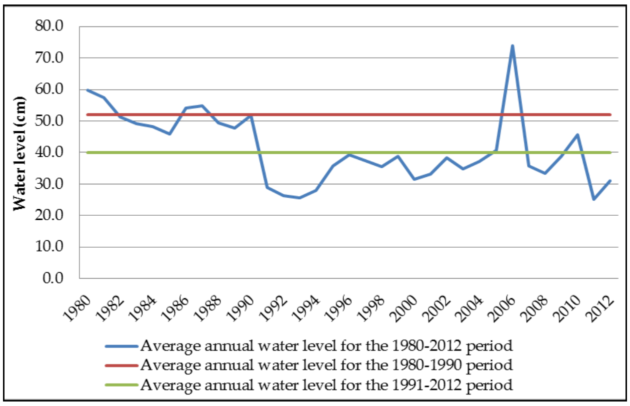

Fig. 1: The average annual water level for Temštica River during study period

The mean water level of the Temštica River was 41 cm and the lowest mean monthly water levels were recorded during September (26 cm), while the maximum mean monthly water levels were recorded during April (67 cm) for the 33 year period of observation.

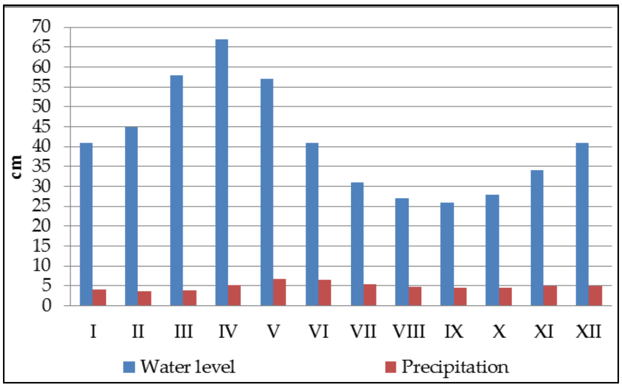

Fig. 2: Monthly values of the Temštica River water levels and precipitation for the 1980 – 2012 period

For the figure 2, precipitation values were recalculated into centimeters (cm). Comparing the mean monthly precipitation in the area of the basin and the mean monthly water levels (Fig. 2), we can conclude that they partially coincide and that the precipitation have significant influence on the water level.

Although the maximum mean monthly water level (April) and maximum mean monthly precipitation (May) does not coincide, they follow each other.

During the first half of the year data shows an increase in precipitation and consequently increase the water level, while during the second half of the year there is a decrease in water level due to the smaller amount of precipitation and higher evaporation.

Observing by seasons, the highest water level has been registered in spring and summer due to increase in the air temperature and partial snow melting. The water level decreases from April up to September even above the maximum precipitation in May and June when it was 67.82 mm and 65.81 mm. The lowest water level is at the end of summer and the beginning of autumn (Fig. 2).

Table 1: Average low and high monthly water levels of the Temštica river in cm (1980 – 2012)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average
ML WL	29	32	40	48	37	27	23	21	20	22	24	28	29
MH WL	69	79	100	119	119	80	57	52	43	52	71	81	77

As for annual value of the mean low and high water level, annual values were 29 cm (minimum) and 77 cm (maximum) and the average water level amplitude was 48 cm. The lowest value of the mean low water level throughout the year has been 20 cm recorded at the beginning of autumn (in September), whereas the highest values of the mean high water level were in April (48 cm).

River discharge

Average discharges are statistically derived mean values, which are often used in practice during the analysis and the making studies for the economy. However, these data will be processed in the work in order to obtain better picture of the regime Temštica River (Milanović, 2007). In hydrologycal research hydrographs of mean monthly flow values are often

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used because they are easiest to provide, process and to explain. In this study the mean monthly flow for the 1980-2012 period was used, average monthly data was used to create the hydrograph which represents the annual river discharge of the Temštica river for the observed 33 year period (Fig. 3).

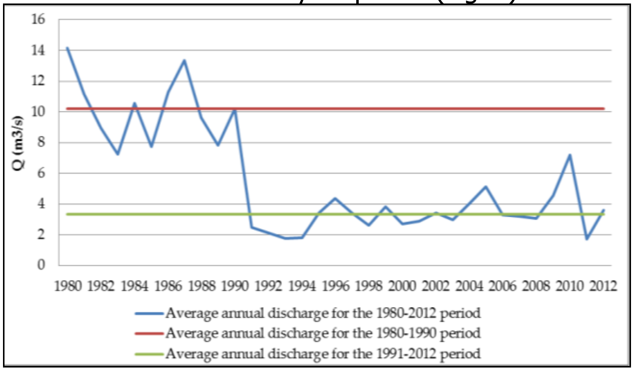

Fig. 3: Average annual discharge for the Temštica River during the study period

During the 1980 – 2012 period the average yearly discharge of the Temštica River clearly shows a disproportion between the first decade of the research period (1980 – 1990) and the rest of the period. During the first period, the average discharge value was 10.19 m^3/s, while the average precipitation for this period was 571.9 mm. During the rest of the period discharge values were lower, 3.34 m^3/s and the amount of precipitation was higher 608 mm. This observation is interesting because it indicates that some other factor, rather than precipitation has bigger influence to the river discharge. Most probably, the amount of water released from Zavoj lake that is located on Visočica River, one of tributaries of Temštica River. Monthly values of discharge for researched river are presented in figure 4.

In figure 4 we see that highest discharge on the Temštica River is during the spring months (March, April and May), on average 12.08 m^3/s, which represents 53.68 % of the total yearly discharge. Lowest discharge is observed during autumn (September, October and November), 2.16 m^3/s which represents 9.6% of the total yearly discharge. The highest discharge is measured during April (14.79 m^3/s). From this month the discharge starts to decline and reaches its minimal value during September, 1.38 m^3/s, after this minimum discharge starts to rise steadily till April. The average yearly discharge for the Temštica River during the investigated period is 5.63 m^3/s.

From this data we can conclude how much the discharge value is during "average" or normal years, with absence of extreme events like extreme precipitations or temperatures.

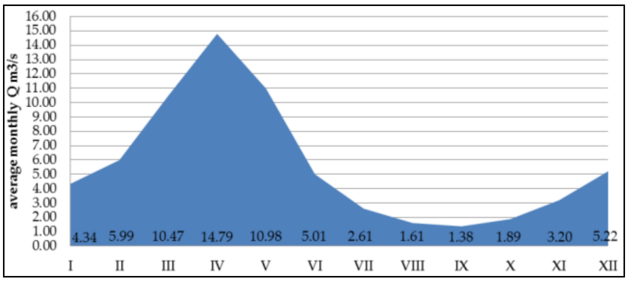

Fig. 4: Monthly variations with average monthly values of the Temštica River discharge for the 1980 – 2012 period

Maximum and minimum discharge

According to the data obtained from Staničenje hydrological station during the 1980 – 2012 period, the average annual minimum discharge was 2.18 m^3/s, while the average annual maximum discharge was 21.85 m^3/s. Amplitude between the average minimum and maximum discharge is 19.67 m^3/s. Minimum discharge had highest values in 1980, 5.82 m^3/s and the lowest in 1994 with 0.64 m^3/s. Higher discharge arise from precipitation and occur in waves and therefore more vary in relation to the small waters that depend on the groundwater flow (Milanović, 2007).

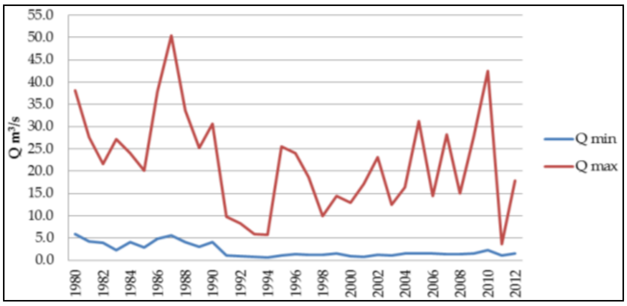

Fig. 5: Average annual values of minimum and maximum discharge of the Temštica River during the 1980 – 2012 period

In figure 5 it is noticeable that high waters had a lot of variations' during the observed period. The highest values of discharge were recorded in 1987 when it was 50.40 m^3/s, while the lowest values were recorded during 2011, 3.63 m^3/s.

Minimum discharge has higher values during the 1980 – 1990 interval (Q=4.01 m^3/s), while from 1991 to 2012 the minimum discharge was quite uniform, averaging less than 1.24 m^3/s

We can also notice is that in 1987, the minimum and maximum discharge values had their highest values for the observed period (Q_{min}=5.56 m^3/s, Q_{max}=50.40 m^3/s). The reason for that are the higher amount of precipitation recorded in the same year, 656.3 mm. The second peak is observed in 2010 when Q_{min} was 2.25 m^3/s and Q_{max} was 42.42 m^3/s, the reason for this peak is also the higher amount of precipitation during that year, 793.8 mm.

Precipitation

Average precipitation quantity in the Temštica River catchment for the 1980 – 2012 period, is 596 mm and it is well distributed throughout the year. The highest amount of precipitation falls during summer 55.65 mm (27.63%), slightly less in the spring, 53.37 mm (26.50%), in the autumn of 47.69 mm (23.68%), and during the winter, only 41.96 mm (20.83%) (Fig. 6).

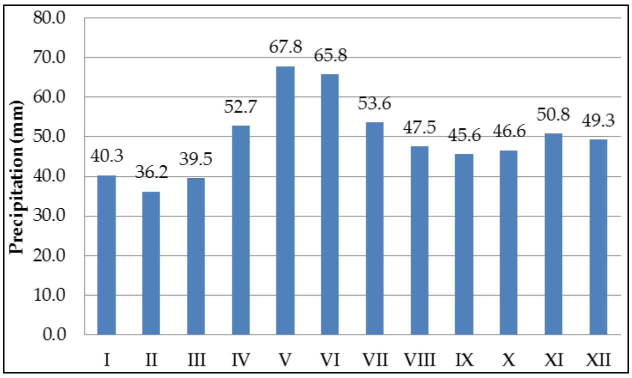

Fig. 6: Average monthly precipitation for the 1980 – 2012 period

High evapotranspiration caused by high air temperatures during time of maximum rainfall occurring in June, is the main reason for the divergence between rainfall and discharge peaks.

Specific runoff

Based on data from Table 2, it is noted that the values of specific runoff are small. Significantly increase values of the specific runoff are recorded from February till April, when the maximum of 18.07 l/s/km^2 is recorded, as a result of an increase in the amount of precipitation throughout the basin, while at the same time the air temperature is still low, and there is little evaporation. Decrease is measured during the warm period of the year (May – September), this is due to the minimal amount of rainfall and high air temperatures, which indicates extensive evaporation. From October till December increasing trend in specific runoff is observed (as a result of increased amounts of precipitation).

The general conclusion is that the low value of the specific runoff in the Temštica River basin is caused by climatic conditions (high evaporation), relief characteristics and anthropogenic influence (Milanović, 2007). In addition, the average and the absolute minimum and maximum values are important to be analysed. In the case of mean minimum and maximum specific runoff there was observed that the maximum runoff occurs in April, while minimum is observed during September (0.56 l/s/km^2) for the minimum value, and (7.74 l/s/km^2) for maximum value. Based on the calculated data of specific runoff, the height of runoff in the catchment area can be calculated, as well as runoff coefficient.

Table 2: Average, minimum and maximum monthly value of specific runoff (l/s/km²) of the Temštica River basin (1980 – 2012)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
q_{avg}	1.22	7.32	12.7	18.07	13.42	6.12	3.19	1.97	1.69	2.31	3.92	6.38
q_{min}	0.12	3.01	4.8	7.94	4.94	1.96	1.22	0.86	0.56	1.02	1.17	2.26
q_{max}	20.2	25.66	42.56	60.33	40.93	27.91	14.46	13.54	7.74	11.92	23.32	32.03

Water balance

Water balance of the Temštica River is shown based on the data obtained from Staničenje profile for the data relating to for the 1980 – 2012 period. Water balance is presented according to the relationship between rainfall at one hand and runoff and evaporation on the other (Table 3). Precipitation and runoff are based on the data measured and calculated, and the evaporation is calculated as a difference between rainfall and runoff (Milijašević and Milanović, 2010).

Water balance is the amount of available atmospheric, surface water and groundwater in a particular area, whether it is river or sea basin, a region or state territory. Knowing it is of great importance for water management and planning exploitation of water resources (Dukić, Gavrilović, 2012).

Table 3. Water balance of the Temštica River basin for the 1980 – 2012 period

Main elements of water balance						
Area (m2)	Discharge m3/s	Specific runoff (l/s/km2)	Precipitation (mm)	The amount of runoff (mm)	Evaporation (mm)	Runoff coefficient (%)
818	5.63	6.87	595.97	217.05	378.92	0.26

Water balance of Temštica River is presented as the relationship between rainfall on the one side and runoff and evaporation on the other side. Precipitation was determinate by interpolation of precipitation data obtained from three meteorological stations (Dimitrovgrad, Pirot and Bela

Palanka), and runoff data was obtained from measures taken at Staničenje hydrological station. Because there is no evaporation data measured in study area, the difference between precipitation and runoff was used to calculate evaporation.

Considering the Temštica River basin, with a catchment area of 818 km^2, it can be observed that the average amount of precipitation is 595.97 mm, of which 217.05 mm or 36.42 % runoffs, and 378.92 mm, or 63.58% evaporates. During the spring months the largest amount of precipitation flows as runoff, because air temperatures are still low, and evaporation reduced. Contrary to this, July, August and September represent the months with the lowest runoff of rainfall during the entire year because of higher evaporation.

Our research results have shown that within the basin of the Temštica River the average annual discharge is 5.63 m^3/s of water the richness of 6.87 l/s/km^2. Although precipitation is about 595.97 mm per year, lesser amount of it reaches the river, due to evaporation which exceeds 63%.

Conclusion

The analysis of the Temštica River discharge during the 1980 – 2012 period has shown that the maximum values are recorded during April, as a result of snowmelt, high soil moisture and frequent rains, and the minimum in September, due to high evapotranspiration and lower rainfall.

The water level analyses for the Temštica river in the 1980 – 2012 period have shown that the maximum values are registered in April (67 cm) as the result of snow melting and frequent rainfalls, and the minimum in September (26 cm) due to high evapotranspiration and less precipitation. The average water level amplitude is 48 cm for the 1980-2012 period.

Based on discharge data obtained at Staničenje station the existence of one maximum (April) and one minima(September) indicates a correlation between flow and precipitation in the basin. The amplitude of river discharge for the 1980 – 2012 is 13.31 m^3/s. According to the classification of river regime (Ilešič, 1947) it can be concluded that the Temštica River belongs to moderate - continental variant of hydrological regime. The amplitude between the average low and high water for the 1980 – 2012 period amounts to 20.61 m^3/s, and the amplitude of extreme flow are even more pronounced for the same period, from 3.63m^3/s in 2011 to 50.4 m^3/s in 1987 which represents an amplitude of 46.77 m^3/s.

The values of specific runoff for the Temštica River are low and are caused by climatic conditions (evaporation) and the low energy relief. Maximum values occur in March, as a result of an increase in the amount of rainfall throughout the basin, while at the same time the air temperature is still low, so evaporation values are also low. Minimum specific discharges are recorded in September, due to the low amount of precipitation and increased air temperatures, which indicate a larger evaporation.

In this paper, the components of the water balance of the Temštica River basin are calculated. Average annual precipitation for the entire basin is 595.97 mm, of which 36.52 % is the surface runoff, and 63.58 % is evaporated. The ratio of the components of the water balance in the basin is not convenient, and it should be taken appropriate measures to improve it (afforestation, hydrotehnical measure etc.

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Author contribution

This paper is the result of work done by Mirjana Radulović, she collected and analyzed the obtained data, Igor Leščešen helped with methodological part ad discussion, Dragoslav Pavić helped with expert advices and direction in which this paper should go.

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Research of water balance at hydrological micro-scale in the Aldeni Experimental Basin (Romania)

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Abstract

The paper presents a number of aspects regarding the Aldeni Experimental Basin (Romania). In order to experimentally investigate micro-scale (plot scale) hydrological impact of soil erosion, the National Institute of Hydrology and Water Management founded, in 1984, the Aldeni Experimental Basin (AEB). AEB is located in the Curvature Subcarpathians, a region characterized by a sharp erosion of soil.

Experimental investigations at a micro-scale are aimed towards: determining the parameters of the water balance equation, during natural and simulated rainfall; researching of runoff genetic and soil erosion processes on runoff plots; extrapolating relations involving runoff coefficients from a micro-scale to meso-scale.

Runoff plots have A = 80 sq m (20 x 4m), WNV-ESE aspect and an average slope of 5.6%; one runoff plot is maintained with grass, and the other "kept fallow" is devoid of grass by digging (processing) and the structure of the first horizon with a depth of 20 cm has been changed, which resulted in a greater development of infiltration than in the first runoff plot.

Complex measurements and sampling observations of the necessary elements for the quantitative estimation of the water balance equation are achieved with the help of specific equipment on standard climatologic and hydrological time (hourly and pentads) at hydrometric stations and meteorological platform, while at runoff plots scale per rainfall event.

Nowadays, the latest evolutions in data acquisition and transmission equipment are represented by sensors (such as sensors to measure the soil moisture). Exploitation and dissemination of hydrologic data is accomplished by: research themes/projects, yearbooks of basic data (Experimental Basins Yearbook) and scientific papers.

Keywords: *Aldeni Experimental Basin, runoff plots, water balance, micro-scale, experimental hydrology*

Rezumat. Cercetări hidrologice la microscară ale bilanţului apei în Bazinul Experimental Aldeni (România)

Articolul prezintă o serie de aspecte referitoare la Bazinul Experimental Aldeni (România). Pentru a cerceta experimental la microscară (scara parcelei) impacturile hidrologice ale eroziunii solului, Institutul Naţional de Hidrologie şi Gospodărire a Apelor a înfiinţat Bazinul Experimental Aldeni (BEA), în 1984. BEA este situat în Subcarpaţii de Curbură, regiune caracterizată printr-o accentuată eroziune a solului.

Cercetările experimentale la microscară sunt orientate către: determinarea parametrilor ecuaţiei bilanţului hidric, în condiţii naturale şi cu ploi artificiale; studiul factorilor genetici ai scurgerii lichide de suprafaţă şi a proceselor de eroziune a solului pe parcele de scurgere; extinderea relaţiilor privind coeficienţii de scurgere de la microscară la mezoscară.

Parcelele de scurgere au S=80mp (20x4m), orientare VNV-ESE şi o pantă medie de 5,6%; o parcelă este menţinută cu iarbă, iar cealaltă este lipsită de iarbă prin săpare (prelucrare) şi are modificată structura primului orizont de 20 cm, ceea ce a dus la o dezvoltare mai mare a infiltraţiei faţă de prima parcelă de scurgere.

Efectuarea complexului de observaţii, măsurători şi prelevări asupra elementelor necesare determinării cantitative a ecuaţiei bilanţului apei se face cu aparatura specifică la termene hidrologice şi climatologice standard (orare şi pentadale) la staţii hidrometrice şi platforma meteo, respectiv la evenimente ploioase la parcelele de scurgere.

In prezent, procesul de achiziţie şi transmisie a datelor se modernizează cu aparatură prevăzută cu senzori (de ex. senzori pentru măsurarea umidităţii solului). Exploatarea şi diseminarea datelor hidrologice se face prin: teme şi proiecte de cercetare, anuare (Anuarul Bazinelor Experimentale) şi articole ştiinţifice.

Cuvinte-cheie: *Bazinul Experimental Aldeni, parcele de scurgere, bilanţul apei, hidrologie experimentală*

Introduction

Experimentation and observations are central activities within the water sciences (Hopmans & Pasternack, 2006). From a hydrological point of view, experimental basins are typical natural laboratories, which play an important role in understanding the dynamics of genetic (natural or simulated rainfall) and conditional (soil, landuse, vegetation type, anthropogenic activities, etc.) factors that influence the overland flow and suspended sediment discharges. Also, plot-scale experimental studies are designed to help us better understand the relationships between processes involving hydrological, ecological and geomorphic factors (Linsley, 2009; Ferreira Moreira et al., 2011). Generally, water research investigations are based on the water balance equation (Eq. 1), (Lvovich, 1965):

$$P = S + U + N + T\,;\; W = P - S = U + E\,;$$
$$R = S + U\,;\; E = N + T\,;\; K_U = \frac{U}{W} \qquad (1)$$

where:

P - precipitation, S - surface runoff, U - underground flow, N - non-productive evaporation, T- Transpiration, W - gross moistening of territory (soil), E – evaporation of sweat, R - total runoff, K_u - coefficient of river feeding by underground waters.

According to Toebes & Ouryvaev (1970), the general equation for the water balance from an experimental basin (Eq. 2), is calculated as mean values and expressed in depths (mm):

$$P = Q + E \pm \Delta M_S \pm \Delta G \pm \Delta V + e \qquad (2)$$

where, over a specified period:
P = total precipitation; E = total evaporation of sweat; Q = total stream flow; ΔM_S = change in soil-moisture storage; ΔG = change in ground-water storage; ΔV = change in storage of liquid and solid precipitation in endoreic depressions; e = an error term which includes not only deep percolation (Qdp) but also errors associated with other elements of the water balance.

Regarding water balance investigations, experimental studies at hydrological micro-scale (1 sq cm → 1 sq km), allow simulations of elementary hydrological processes by means of runoff plots (Garcia et al., 1963; Toebes & Ouryvaev, 1970; Becker & Nemec, 1987). The sizes of runoff plots are: a) microplots "*one or two square meter*"; b) small-scale ~ 100 sq m and c) field plots ~ 1 ha (Hudson, 1993). The results thus obtained are representative for a region or a certain conditional factor, and, by means of extrapolation, these results can be used on the slopes of the catchment. Several types of studies can be used such as: modeling data; assessing socio-economic impact aspects of the water resource; detection of trends and changes in runoff regimes and ecosystem responses due to anthropogenic activities and climate variability (Schumann et al., 2010).

In 1986, UNESCO, through its International Hydrological Program - IHP, has created the Euro-Mediterranean Network of Experimental and Representative Basins (ERB), and Romania is affiliated with this organization since 1993, through the National Institute of Hydrology and Water Management (NIHWM). Within NIHWM, field experimental hydrological research at plot scale, in correlation with complex programs of observations and measurements, is conducted at 3 research units.

The content of its activity concerns the establishment of quantitatively defined relationships between discharge and genetic and conditional factors. These basins are situated in the Curvature Carpathians and Subcarpathians (Fig. 1).

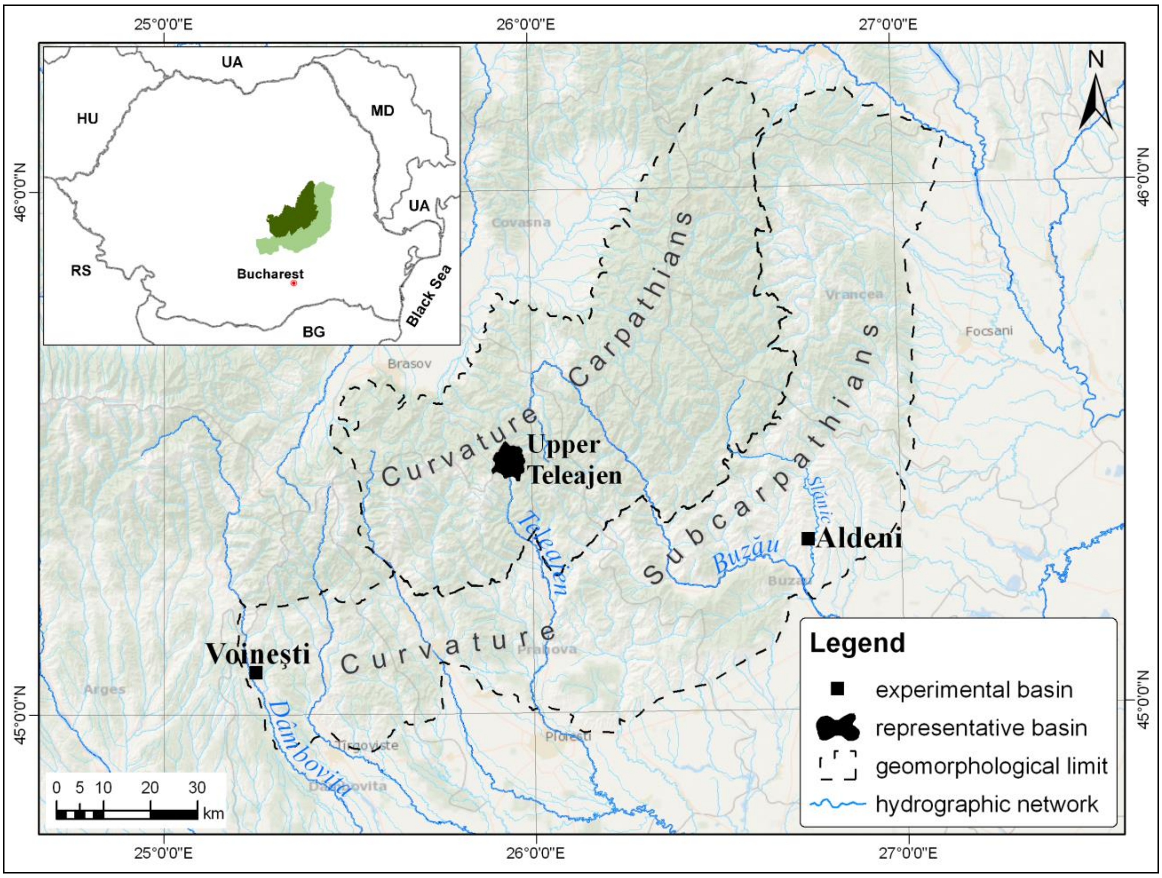

Fig. 1. Geographical location of ALDENI and VOINEŞTI Experimental Basin, respectively Upper Teleajen "CHEIA" Representative Basin (This figure was produced using ArcGIS 9.3)

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The research started around 1964, with the founding of the Station for Experimental Hydrology Voineşti, now called Voineşti Experimental Basin. Subsequently, in 1975, the research concerning the mechanism for the formation of slope discharge was extended to "Upper Teleajen" in the hydrographic basin of the Telejean River, and since 1984 to Aldeni (Mustaţă, 1980; Miţă, 1996). On the basis data obtained from these research units, especially those related to deterministic models numerous studies were published: Blidaru (1970); Diaconu & Crăciun (1973); Petrescu (1974); Blidaru et al. (1980); Mustaţă (1980), Stanciu & Zlate (1988); Zlate (2000), Stanciu (2002).

ALDENI EXPERIMENTAL BASIN

Within the Aldeni Experimental Basin, the micro-scale study of hydrological elements of the water balance is conducted with equipment of observation that allows an estimation of the physiographic influences in the region (geomorphic, climatic, soil and anthropic intervention: anti-erosion landscaping with terraces and orchard plantations).

Historical and Geographical background

In order to experimentally research at micro-scale the hydrological impacts of soil erosion, the National Institute of Hydrology and Water Management (NIHWM), has founded in 1984 the Aldeni Experimental Basin (AEB). Studies in the AEB are part of the hydrologic comprehensive research initiated since 1980.

In 1980, the first field explorations were conducted, and between 1981 and 1984, in collaboration with the present-day University of Agronomic Sciences and Veterinary Medicine of Bucharest, soil improvement activities were initiated (terracing, artificial rill and orchard planting), in order to assess, finalize and certify the basin. Anthropic interventions conducted by AEB in the area allowed the determination of the values of liquid and solid discharge in a modified anthropic regime.

In terms of geomorphology, AEB is situated within the Curvature Subcarpathians (45°19'30"N latitude and meridian 26°44'43"E longitude); a region characterized by accentuated erosion of the soil - especially in the eastern part (Mociorniţă & Birtu, 1987; Zaharia et al., 2011; Costache et al., 2014), and the catchment covers a surface of 0.6 sq km.

The altitude of the basin varies between 238 m a.s.l. and 411 m a.s.l., with an average of 331 m. Hydrographically, it is part of the Slănic River Catchment, a left-side tributary of the Buzău River. The landscape presents torrential formations of different stages: rills, ephemeral gullies, gullies. The main drained erosion formation created by rain water from the basin is the "Valea cu Drum" gully (partially channelized), which flows towards the Slănic River. The closure hydrometric station (hs) "Sondă" (Fig. 2; Tab. 1) is situated on this gully channel (up to 2 m deep).

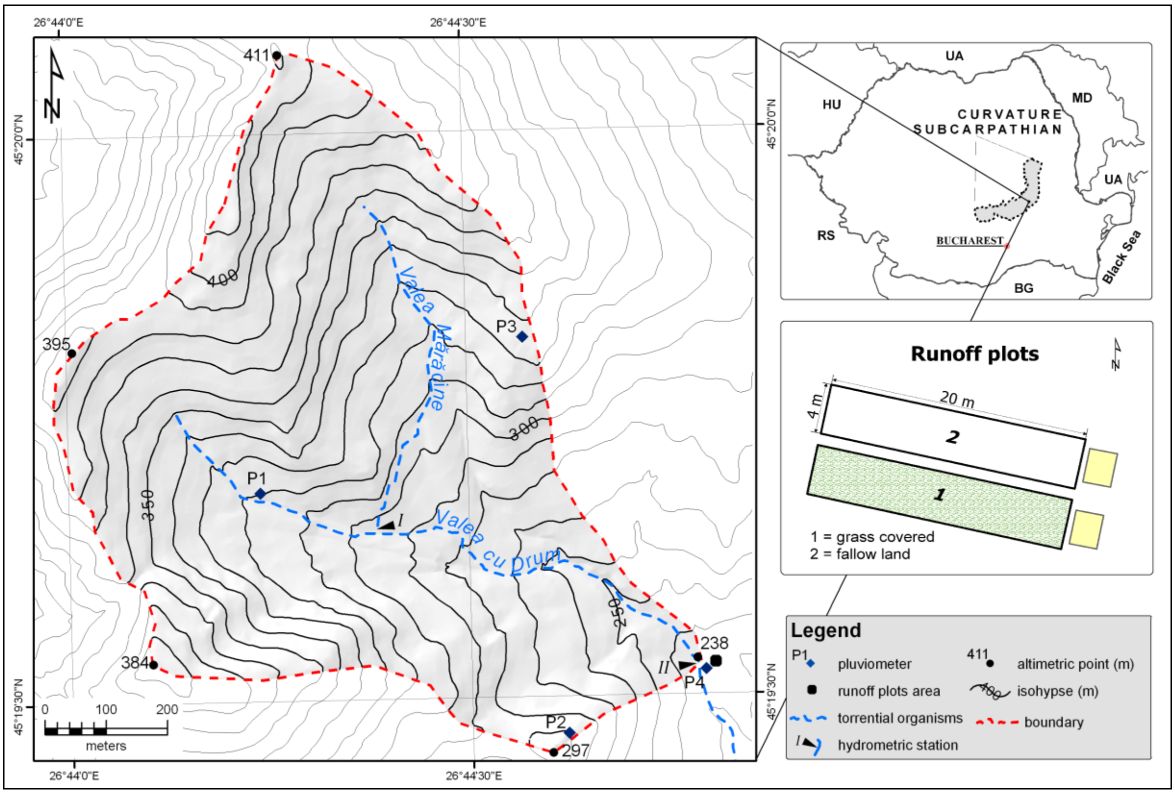


Fig 2. The Aldeni Experimental Basin and its location in Romania and runoff plots scheme (This figure was produced using ArcGIS 9.3)

The climate of the region is moderate temperate-continental and is characterized by foehnal influences with a mean annual precipitation of 565 mm, respectively mean annual temperature of 10.5 °C (for the period 1984-2013).

On runoff plots, the soils "aluviosol coluvic", generally have clay content (33%) into humus (3.28%), the phosphorus (24%) and ph=7.2 - a neutral reaction - mildly alkaline (Muşat, 2006; Radu et al., 2010). Actual landuse is in decline (typical perennial grass), due to partial abandonment and/or unproductive land; the land use influences the genetic processes of overland flow, as the degradation of the soil improvement activities (such as: abandoned agricultural terraces; gullies clogging) determines the appearance of diffused (lamellar) discharge of water currents through rills, ephemeral gullies and gullies.

MONITORING THE ELEMENTS OF THE WATER BALANCE

Hydrological monitoring and experimental investigations at micro-scale in AEB's are oriented towards: (a) determining parameters of water balance equation, during natural and simulated rainfall, (b) research of runoff genetic and soil erosion processes and (c) transfer relation of runoff coefficients form a small scale to medium scale. The AEB hydrological observations program includes: observations and measurements involving 2 observers (a Hydrometer and a Hydrological Technician) and a continuous recording of data related to major elements in the water balance (such as water level, rain etc.), by using both classic measurement instruments (e.g. limnigraphs, pluviograph, thermograph), as well as modern sensor technology.

Equipment used in observations

Hydrometric equipment is meant for measuring the principal elements of water balance equation and consists of calibrated flumes, runoff plots, pluviometric networks and a rainfall portable simulator with nozzles. The instruments are distributed as follows:

(i.) on torrential formations (gullies) 2 hydrometric stations „Mărăcine" and „Sondă" were established (Tab. 1) with calibrated flumes, which allow the determination of water discharges on the basis of limnimetric keys; from a hydrological standpoint, the hydrologic regime through the drainage system containing erosion formation - rills and gullies – is temporary; the process of formation and transit of water resources and suspended sediment load reflects: the pluvial regime (frequency, depth, duration and intensity) and the actual landuse (degraded terracing, storm drains/ditches clogged and filled with hay and pasture land);

Table 1. Data on the hydrometric stations from the AEB

Hydrometric station	A (sq km)	H (m)	I (%)	FR (%)
Mărăcine	0.14	356	25.8	9
Sondă	0.60	331	23.3	12.2

A = area; H = average altitude; I = average catchment slope; FR = forest ratio.

Data source: data obtained by processing topographical plans (scale 1:2000) corroborate with the orthophotos (scale 1:5000).

(ii.) on the premises of the station, 2 runoff plots were set up, according to the requirements and design described by Mutchler (1963), Toebes & Ouryvaev (1970); these have an area of 80 sq m, 5.6% average slope, WNV-ESE aspect; one of them is covered with grass (nr. 1), while the other is „fallow land" (nr. 2) and devoid of grass through digging and grass removal and the structure of the first soil horizon measuring 20 cm is modified from that of the first runoff plots, which led to a higher degree of infiltration compared to the first (Fig. 3.A); the runoff plots are provided with boundaries (concrete walls), collection channels composed of gutters, underground pipes, and at their lower part there are shelters containing metal tanks water removal installations; flow rates from runoff plots are measured with the help of the mechanic limnigraph and automatic flow measurement device; automatic and continuous recordings of the water drained from the parcels into tanks is done by means of a limnigraph (Valdai model), with daily change of diagram (limnigrama), which permits the recording of any change (volumetric method and variation in spillway) of the water level collected in the tank (that has a capacity of 0.46 m^3); the limnigraphs record the variation in water levels both inside the tank with the help of a floater and also at the spillway; tanks have a spillway with an opening at 45° (Fig. 3.B); the water discharge calculation is done through the partial volumetric method (through division), the relationship being Q=f(H); also, water level measurements are conducted with the help of sensors (pressure sensors); soil temperature and soil moisture are measured (Fig. 3.A);

(iii.) the portable rainfall simulator with nozzles is used for the studies concerning runoff; this tool generates artificial rains with a controlled depth, intensity and duration;

(iv.) in the basin, one can find a pluviometric network consisting of 4 pluviometers, while on the premises of the stations there are: one combined pluviometric - pluviograph and 2 sensor pluviometers (Fig. 3.A).

Fig. 3. Runoff plots "kept fallow" (A) with pluviometer (up) and sensors for determining soil temperature and soil moisture (down), and shelter house (B) provided with tanks, limnigraph and level sensor

Hydrological Monitoring

The observation and measurement program at AEB is carried out following the instructions and standard guidance of the NIHWM, e.g. A guide for the activity in the representative and experimental basins, Volume IV (Adler & Minea, 2014). The instructions and guidebooks are made in accordance with the recommendations of Toebes & Ouryvaev (1970), Technical regulations, Volume III (WMO, 2006) and Guide to Hydrological Practices, Volume I (WMO, 2008). According to WMO (2006), this falls in the "*hydrological stations for specific purposes*" category, and the observation program is typical for a hydrometric station and for *„climatological stations and precipitation stations for hydrological purposes"*. The complex observations, measurements and samplings are conducted at hydrological and climatologic terms (Tab. 2), thus:

a) at the hydrometric station, observations (evaluated subjectively) follow river stage at staff gauge and water turbidity (depending on rainfall and runoff magnitude); concerning the measurement of water turbidity (ρ), this is done through the "filtering method"; the procedure consists of collecting water samples (500 ml) from tanks - for runoff plots, their filtering and their oven drying, followed by the calculation of associated sediment losses, after one rainfall;
b) at the runoff plot scale, observations during natural and simulated rainfall events and following water depth and water turbidity at 2 runoff plots; soil temperature and soil moisture are also measured on runoff plots by using radiological waves (Fig. 3.A);
c) at the meteorological platform, the observed parameters are: precipitations (amount, time of occurrence, intensity at pluviometers and pluviograph); air temperature (thermograph); air humidity (hygrograph); wind; snow cover (movable snow stake and weighing snow sampler); soil temperature (with liquid-in-glass thermometer at 0.20 m) and soil moisture (in the top layer 0.02 m down to 0.40 m depth), directly (gravimetric).

Hydrological Data Acquisition and Transmission

The current modernization of the process of observation, collection and recording of the elements necessary for a quantitative estimation of the water balance equation, involves the renewal and replacement of out-dated equipment and instruments with modern equipment. The newest pieces of equipment acquired are: (1) an automatic weather station (temperature sensor, wind vane, cup anemometer); (2) for measuring height, quantity and the intensity of the rainfall, we are currently using sensor pluviometers with tilting cups, connected to a data-logger and powered by the 220V network; (3) temperature sensor; (4) sensors for the measurement of soil humidity (Fig. 3.A), which directly measure the apparent dielectric permittivity and indirectly measure this parameter with the Topp equation for determining volumetric humidity.

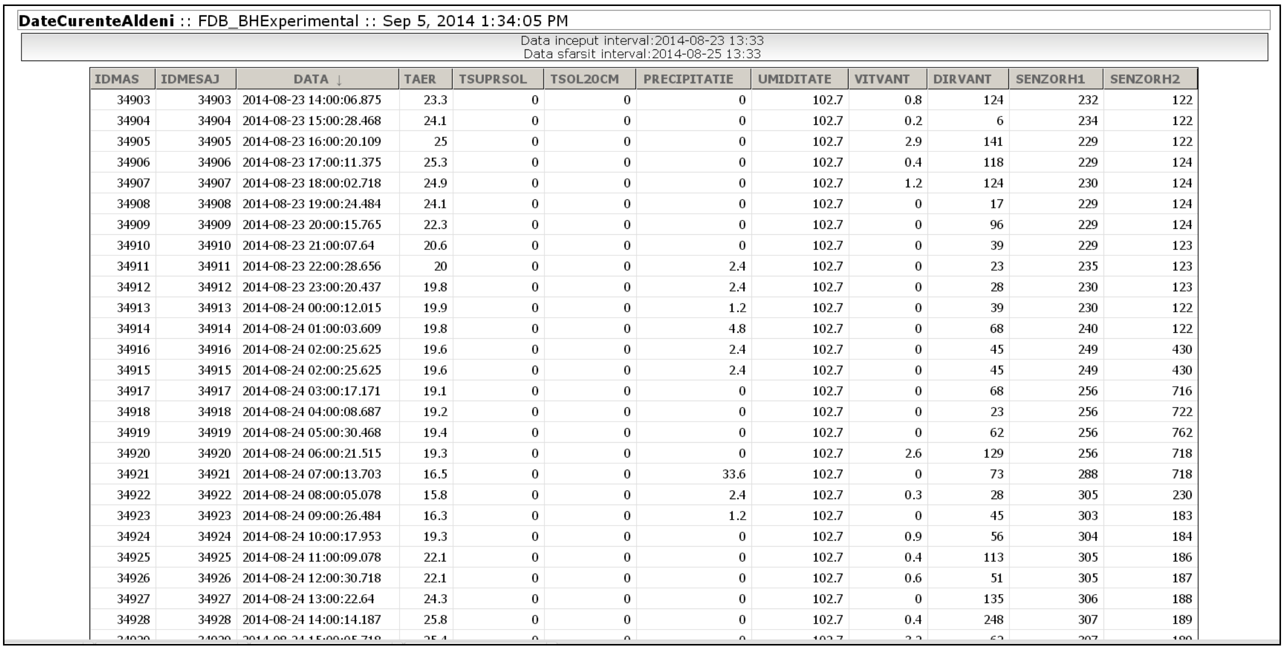
The measurements of the hydro-meteorological elements in automatic system, using the sensors, are nowadays used to compare the results with those from the classical systems for instruments' calibration.

The modernization process concerns: data acquisition (at hourly intervals), storage, data transfer; terminal emulation, numeric output and export functions. Transmission of hydro meteorological data is conducted though the Global System for Mobile Communications (GSM) to the NIHWM server or is downloaded from a data-logger directly on a portable PC. Data transmitted through GSM from AEB is consulted for the required time interval (*time taken and finish time*) and can be viewed online in table form (such as: browser grid/data table/plain/fancy; spreadsheet .xls/zip) and downloaded (Fig. 4).

Table 2. Observational and measured aspects of principal hydrological elements

Nr. crt	Hydrological elements	Observing station[1]	Determined characteristics
1	air temperature	meteorological platform[2]	daily reading of maximum and minimum value of ordinary thermometer, at hourly climatologic terms 7, 13 and 19h; deciphering thermograms with hourly and extreme values;
2	air humidity		deciphering hygrograms concerning hourly and extreme values
3	rain	- collected in 4 pluviometers (3 distributed in the basin and one at the weather platform afferent to the station* - measured and recorded with 1 the pluviograph (no. 4) and 2 sensor pluviometers situated on the weather platform	measurement of collected quantity/water strata (7 and 19h) and the computation of quantity/24h collected depth; deciphering pluviograms and the calculation of depth, duration and intensity
4	snow cover	triangular plot (10 m) snow-gauge profiles (860 m and 560 m)	snow thickness and snow density (on the 5th, 10th, 15th, 20th, 25th and last day of month) and water equivalent snow depth;
5	soil moisture	adjacent to the pluviometer no. 4	sampling, oven method and calculations for samples taken from depths 2, 10, 20, 30 and 40 cm (on the 5th, 10th, 15th, 20th, 25th and last day of month);
6	wind	meteorological platform	daily observations at hourly climatologic terms (7, 13 and 19h), concerning speed and direction of wind;
7	water	*„Mărăcine”* (I)** and *„Sondă”* (II)** hydrometric stations	daily reading (6 and 18h) of water level at the staff gauge; supplementary reading during floods;
		runoff plots	limnigraph deciphering and calculation of water depth and volume;
8	water turbidity	„Sondă” hydrometric station and at runoff plots	sampling, oven drying and calculations for samples taken during the water discharge;

[1] - place for measurement/collection/sampling; [2] - climatological station for specific purposes; * - See location on map - *Fig. 2* **- to be seen *Fig. 2.*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IDMAS	IDMESAJ	DATA ↓	TAER	TSUPRSOL	TSOL20CM	PRECIPITATIE	UMIDITATE	VITVANT	DIRVANT	SENZORH1	SENZORH2
34903	34903	2014-08-23 14:00:06.875	23.3	0	0	0	102.7	0.8	124	232	122
34904	34904	2014-08-23 15:00:28.468	24.1	0	0	0	102.7	0.2	6	234	122
34905	34905	2014-08-23 16:00:20.109	25	0	0	0	102.7	2.9	141	229	122
34906	34906	2014-08-23 17:00:11.375	25.3	0	0	0	102.7	0.4	118	229	124
34907	34907	2014-08-23 18:00:02.718	24.9	0	0	0	102.7	1.2	124	230	124
34908	34908	2014-08-23 19:00:24.484	24.1	0	0	0	102.7	0	17	229	124
34909	34909	2014-08-23 20:00:15.765	22.3	0	0	0	102.7	0	96	229	124
34910	34910	2014-08-23 21:00:07.64	20.6	0	0	0	102.7	0	39	229	123
34911	34911	2014-08-23 22:00:28.656	20	0	0	2.4	102.7	0	23	235	123
34912	34912	2014-08-23 23:00:20.437	19.8	0	0	2.4	102.7	0	28	230	123
34913	34913	2014-08-24 00:00:12.015	19.9	0	0	1.2	102.7	0	39	230	122
34914	34914	2014-08-24 01:00:03.609	19.8	0	0	4.8	102.7	0	68	240	122
34916	34916	2014-08-24 02:00:25.625	19.6	0	0	2.4	102.7	0	45	249	430
34915	34915	2014-08-24 02:00:25.625	19.6	0	0	2.4	102.7	0	45	249	430
34917	34917	2014-08-24 03:00:17.171	19.1	0	0	0	102.7	0	68	256	716
34918	34918	2014-08-24 04:00:08.687	19.2	0	0	0	102.7	0	23	256	722
34919	34919	2014-08-24 05:00:30.468	19.4	0	0	0	102.7	0	62	256	762
34920	34920	2014-08-24 06:00:21.515	19.3	0	0	0	102.7	2.6	129	256	718
34921	34921	2014-08-24 07:00:13.703	16.5	0	0	33.6	102.7	0	73	288	718
34922	34922	2014-08-24 08:00:05.078	15.8	0	0	2.4	102.7	0.3	28	305	230
34923	34923	2014-08-24 09:00:26.484	16.3	0	0	1.2	102.7	0	45	303	183
34924	34924	2014-08-24 10:00:17.953	19.3	0	0	0	102.7	0.9	56	304	184
34925	34925	2014-08-24 11:00:09.078	22.1	0	0	0	102.7	0.4	113	305	186
34926	34926	2014-08-24 12:00:30.718	22.1	0	0	0	102.7	0.6	51	305	187
34927	34927	2014-08-24 13:00:22.64	24.3	0	0	0	102.7	0	135	306	188
34928	34928	2014-08-24 14:00:14.187	25.8	0	0	0	102.7	0.4	248	307	189

Fig. 4. Interface capture image of hydrological elements registered between 14:00, 23.08.2014 and 14:00, 24.08.2014

Data processing, quality control and storage

Periodically (at the end of each month and year), after data collection – usually checked by a Hydrological Technician - in printed work format and electronic format (Excel format), the data are used for the hydrologic process of verification and expertise (data quality control). Afterwards, following positive solutions (validations), the data are stored in the database. Data are used and disseminated through: relations updates (e.g. rainfall-runoff); multiple correlations to reflect the role of various factors, research themes/projects; yearbooks of basic data (Experimental Basins Yearbook) and scientific papers.

CONCLUSIONS AND PERSPECTIVES

Aldeni Experimental Basin is a research unit equipped with hydrometric instruments for the conduct of experimental hydrological studies. Hydrological monitoring is currently undergoing a process of modernization due to the appearance of new tools based on sensor and electronic data transfer technologies.

The valorization of data acquired allows the realization of studies, at micro-scale concerning the determination of the elements that make up the equation for water balance, in order to expand the application of the relation between runoff coefficients form a small scale to a medium scale.

The future plans involve implementing research projects on subjects related to rainfall, runoff and sediment transport modeling, in order to substantiate the relationship between drainage and genetic and conditional factors.

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Conservation Status and Conservation Strategies of threatened aquatic fern Marsilea quadrifolia L. in Europe

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Abstract

The aquatic fern Marsilea quadrifolia L is a rare and threatened species in entire Europe due to wetland habitats destruction and changing agricultural practices. To protect it, in situ and ex situ conservation methods are approached in European Union an in other countries. The in vivo and in vitro collections that were developed in botanical gardens in the last two decades are used for reintroduction and for restoration of M. quadrifolia populations in natural sites as well as in agro ecosystems that are analogous to natural habitats. Natural establishment of several M. quadrifolia populations in its natural range is an evidence that it can colonize new suitable habitats, including anthropogenic habitats. Despite conservation strategies approached within the European Union, its area of occupancy has decreased, thereby this species has become vulnerable at European Union level. The main threats are the small size populations, low genetic diversity and genetic erosion of populations, habitat degradation and chemical pollutions of waters by herbicides and fertilizers used in modern agricultural practice.

Keywords: *Marsilea quadrifolia L., threatened species, conservation status, in situ conservation, ex situ conservation, Red List*

Rezumat. Starea de conservare şi metode de conservare a ferigii acvatice Marsilea quadrifolia L. în Europa

Feriga acvatică *Marsilea quadrifolia* L. este o specie rară şi ameninţată în intreaga Europă din cauza distrugerii habitatelor naturale (zone umede) şi a tehnicilor agricole moderne. Pentru protejarea şi conservarea acestei plante, în Uniunea Europeană precum şi în alte ţări europene, sunt abordate strategii de conservare *in situ* şi *ex situ.* Colecţiile *in vivo* şi *in vitro* care au fost dezvoltate în ultimii douăzeci de ani în cadrul grădinilor botanice sunt folosite pentru reintroducerea şi pentru refacerea populaţiilor de *M. quadrifolia* în cadrul habitatelor naturale precum şi în agro-ecosisteme, analoage habitatelor naturale. Apariţia unor populaţii de *M. quadrifolia* în cadrul arealului său natural este o dovadă că această specie are abilitatea de a coloniza noi habitate favorabile, inclusiv pe cele antropice. Î nsă, în ciuda tuturor strategiilor de conservare abordate la nivelul Uniunii Europene, suprafaţa ocupată de populatiile *M. quadrifolia* a scăzut iar specia, evaluată potrivit criteriilor IUCN, este considerată vulnerabilă. Principalele ameninţări ale acestei plante sunt mărimea mică a populaţiilor existente, diversitatea genetică redusă şi eroziunea genetică în cadrul populaţilor curente, degradarea habitatelor, poluarea chimică a apelor cauzată de fertilizatorii şi ierbicidele folosite de agricultura contemporană.

Cuvinte-cheie: *Marsilea quadrifolia L., specie ameninţată, starea conservării, conservare in situ, conservare ex situ, Lista Roşie*

Introduction

Marsilea quadrifolia L., commonly known under vernacular name as „water clover" or „four leaf clover", is one of the four ferns species belonging to Marsilea genera, Family Marsiliaceae, that exist in the flora of Europe (Akeroyd, 1993).

The plant is an ancient amphibious leptosporangiate fern that is characterized by unusual leaves, reproductive structures and heterospory (Iamonico, 2012). Its ability to develop heterophyll - emergent and water leaves in aquatic habitats and terrestrial leaves in terrestrial environment - is an adaptive trait enabling this amphibious fern to survive in contrasting habitats (Wu & Kao, 2011) and to withstand the episodic moisture constraints. Furthermore, it has an important significance in the evolutionary history of plants (Nagalingum et. al., 2007).

This aquatic fern is native to Mediterranean and temperate Europe, in tropical and warm temperate regions from Southern and Eastern Asia, including Japan (Osawa et al., 2013). Also, it is spread in North America, especially in the United States of America, but there it is a nonindigenous species and, in some regions, it is assessed as an invasive species, very aggressive in natural and disturbed wetland habitats (Les & Mehrhoff, 1999). Because of this, in USA campaigns against the spreads of the „European water clover" in the natural aquatic habitats from New World are taken (Thiébaut, 2007; Serviss &Peck, 2008; Campbell et. al., 2010).

M. quadrifolia was once quite common in the wetlands of central and southern Europe, including Romania (Jalas & Suomen, 1970), corresponding to the major river valleys and their catchments. In the last decades of former century, it has become a rare and threatened taxa throughout its natural range in

Europe (Godreau et al. 1999; Akeroyd, 1993; Lozano et al,. 1996; Estrelles et al., 2001a; Bruni et al., 2013).

The decline of *M. quadrifolia* in Europe can be attributed to the loss of natural habitats (wetland habitats), mainly due to modifications of river courses by channeling and embanking works, drainage of floodplain and others wetlands, changes of agricultural practice, high fertilization and use of herbicides in the second half of the 20th century (Godreau et., 1999; Poschlod et al., 2005). Based on IUCN (International Union for Conservation of Nature) criteria for a regional level evaluation (species trend at the temporal and spatial scales), in Europe *M. quadrifolia* can be considered in progressive extinction, that is why it was included in many national red lists of plants and red books. For western European countries, its protection started with Bern Convention of the Council Europe (1979, 1992b), followed by Habitats Directive of the Council of the European Community (1992). Thus, it is a species of EC interest (Natura 2000 code: 1428) for which 94 Natura 2000 sites are designed, belonging to Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto- Nanojuncetea habitat (Natura 2000 code: 3130 habitat).

In addition to the ecological significance for wetlands habitats, *M. quadrifolia* is an edible plant and it has ethno-medicinal values. Leaves, stems, and juice made from it are used by tribal communities from south Asia as a remedy for treating fever, snakebites, abscesses, hypertension, sleep and nervous disorders, all type of body aches, cough, respiratory troubles, mouth lesions (Soni & Singh 2012), to improve lactation after childbirth (Shahidullah et al,. 2009), and to cure diarrhoea and dysentery (Sen & Behera, 2008). Experimental studies showed that extracts of leaf and stem of *M. quadrifolia* have significant anti-epileptic efficacy (Sahu et al., 2012), extracts of leaf possess vast potential as medicinal drug in breast cancer treatment (Uma & Pravin, 2013), Alzheimer's disease (Ashwini et al., 2012), and antimicrobial and antifungal activity against human pathogenic microorganisms (Gopalakrishnan & Udayakumar, 2014).

Data and methods

This paper presents a review a state-of-the-art conservative status of *M. quadrifolia* in Europe derived from an examination of the published literature and national Red Lists. Also, we carried out a survey of strategies and methods of protection and conservation which are applied to this threatened fern within the European Union and in other countries. The main threats of natural population and *ex situ* collection of *M. quadrifolia* are highlighted.

Results and discussions

Legal framework and tools for the protection and conservation of threatened plants in Europe

The red lists which asses the threat status of a species within the boundaries of particular territory - national, regional, continental or worldwide – using the IUCN criteria are an important tool for species conservation. Then, national legislation, in accordance with international agreements, came to protect and support conservations strategies if that species is threatened (Glowka, 1994).

Starting from Global Strategy for Plant Conservation (GSPC, http://www.cbd.int/gspc/strategy.shtml), which is an international initiative as part of the Convention on Biological Diversity (CBD), adopted at the Earth Summit in Rio de Janeiro in 1992, Plantlife International (http://www.plantlife.org.uk/) has launched the Important Plant Areas (IPAs) programme for seven Central and Eastern European countries (Anderson, 2002); Romania being one of them (Sârbu, 2007). Then, *Planta Europa*, the network of (Government and Non-Government) organizations that work for plant conservation and their habitats in Europe, has developed the *"European Strategy for Plant Conservation 2008-2014"* with the following stated purpose: "To secure and begin to restore plant diversity by 2014*" (Planta Europa, 2008).*

For all member states of the European Union, there are two important instruments for species conservation: the Berne Convention and Habitats Directive (92/43/EEC).

The national and European strategies for plant conservation include both *in situ*, in protected areas like Important Plants Areas, Plant Micro-reserves, Natura 2000 sites, and *ex situ* conservation (*in vivo* and *in vitro* collections). Although *in situ* conservation of wild plants is the most essential component of the strategy, *ex situ* conservations is at least as important because according to Article 9 of CBD, parties shall use *ex situ* techniques "as far possible and as appropriate, and predominantly for the purpose of complementing *in situ* methods" (UNEP, 2000).

The importance of botanical gardens in conservation of endangered plants species was highlighted starting with the first International Congresses for Nature Protection from 1923 (Heywood, 1991). Then, at the middle of the 20th century, it was suggested that in the botanical gardens there must be created a specific *ex situ* conservation facilities (*in vivo* collections), closely associated with protected areas (Volis & Blecher, 2010).

A new conservation approach is the "inter-situ" conservation, which according to Burney and Burney (2007), means „the restoration of declining species in areas that are outside their current range but within historical range". *Inter-situ* planting can be established in wild or semi-wild situations analogous to the wild populations, but need to be sufficiently large to maintain the genetic diversity of a population or species. The advantage of this *inter-situ* method is that it can be applied to the land of low economic value such as abandoned agricultural lands, and that it allows simultaneous reintroduction of larger number of species (Poschold et. al., 2005; Volis & Blecher, 2010; Osawa, 2013). Another way of inter-situ approach is to use the ex-situ collections in natural or semi-natural environments as a part of a complex ex situ-in situ conservation strategy because this "quasi in situ" conservation is a good strategy to preserve both neutral and adaptive genetic diversity (Volis & Blecher, 2010). Thus, the inter situ methods make bridge between *in situ* and *ex situ* conservation (Cochrane et al., 2010).

Recently, the European Commission made proposals for the Common Agricultural Policy regarding the development of the rural areas, the restoration of biodiversity in agro-ecosystems and the adoption of conservation strategies for protecting threatened species in agro-ecosystems (European Environment Agency, 2010).

Overview on Conservation Status of Marsilea quadrifolia L.

Globally, according to IUCN Red List 2014.1 (Lansdown, 2013), the status of *M. quadrifolia* is Least Concern (LC). At European level, on the Red List of Vascular Plants, it is classified as Near Threatened (NT) for the entire continent as well as regionally, for the European Union (Bilz et al., 2011). But at least at UE level, this conservative status seems to be inaccurate because a recent review of the occurrence of *M. quadrifolia* within the European Union notifies that its area of occupancy has decreased in the last decade from 620 to 400 km^2 (Bruni et al., 2013). In these circumstances, the threat status of plant needs to be changed from Near Threatened to Vulnerable (Bruni et al., 2013).

Summarizing the information from the published literature regarding the risks assessment for *M. quadrifolia* according to IUCN criteria, this fern is: Extinct in Greece (Papastergiadou & Babalonas, 1993) and Germany (Schninttler & Günther, 1999); Extinct in the Wild in Poland (Schninttler & Günther, 1999; Zarzycki & Szeląg, 2006), Spain (Estrelles & Ibars, 2001a, 2001b; Bañares *et al.,* 2008; Moreno, 2008), Portugal (De Sequereira et al., 1997, 1999), *Switzerland* (Schninttler & Günther, 1999; Käsermann & Moser, 1999; Moser et al., 2002), and Montenegro (Bruni et al., 2013); Critically Endangered in Bulgaria (Ivanova & Tzonev, 2011); Endangered in Croatia (Nikolić & Topić, 2005; Sandev et.al., 2013), Albania (Xhulaj & Mullaj, 2002; Kashta, 2007; Skuka et al., 2008; Rakaj & Kashta, 2010), Italy (Conti et al., 1992; Bruni et. al, 2013) Slovakia (Schninttler & Günther, 1999), and Hungary (Schneider-Jacoby, 2006; Király, 2007); Vulnerable in France (Olivier et al., 1995; Schninttler & Günther, 1999), Serbia (Stevanovič, 1999, quated by Bilz et al., 2011; Dítě et al. 2012), Romania (Oltean et al., 1994), Slovenia (Schninttler & Günther, 1999; Lansdown, 2013), and Ukraine (Witkowski et al., 2003; Bruni et al., 2013).

Based on the country reports for Article 17 under the Habitats Directive that presented information about habitats and species for the EU member states (Commission of the European Communities, 2009), *M. quadrifolia* has the most occurrences in France, with 93 localities, followed by Italy, but even so the population trend is decreasing as it is within the whole continent (Bruni et al., 2013).

However, globally, sozological status of this fern species is contradictory, ranging from threatened species, in Europe and Japan (Osawa, 2013), to invasive species in North America (Thiébaut, 2007; Serviss & Peck, 2008,), and noxious weed in India (Kathiresan, 2006; Luo & Ikeda, 2007).

In situ conservation strategies

In the European Union, plants conservation has gained deserved attention thanks to a significant presence of protected areas. The conservation of *M. quadrifolia* aquatic fern is undertaken both *in situ* and *ex situ*.

In situ conservation of *M. quadrifolia* is provided by a network of different categories of protected areas: natural parks, national parks, Ramsar sites, Biosphere Reserve, Important Plant Areas and Natura 2000 sites - Special Protection Areas and Special Areas of Conservation, which have been designated by each EU member state. According to EUNIS database (http://eunis.eea.europa.eu/species/150005#protected), *M. quadrifolia* occurs in 94 Natura 2000 sites. As it can be seen in Figure 1, in all member states of EU that are in its natural range, there is at least one protected area with *M. quadrifolia* population.

In Romania, *M. quadrifolia* is cited in three IPAs (Sârbu, 2007), which are included in other different categories of protected areas as it folows: Comana Natural Park, the Danube Delta Biosphere Reserve, and the Vedea river Natura 2000 site ROSCI0386. Its occurrence is also mentioned in another ten Natura 2000 sites (Strat, 2012). The fern is motorized at national level and fluctuations in the number and the size of populations that occur because of fluctuation in environmental conditions are reported in at least three Natura 2000 sites from Arad Plain, western Romania (Raport Plante 2013).

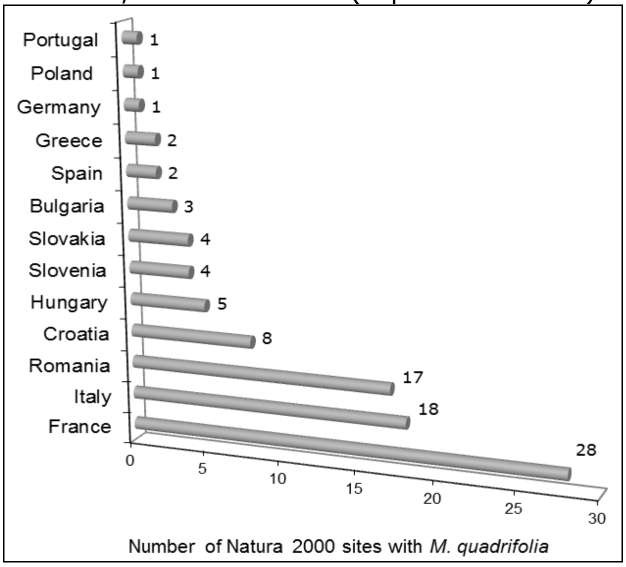

Fig. 1: Natura 2000 sites with *Marsilea quadrifolia* populations according EUNIS data base (http://eunis.eea.europa.eu/species/150005#protected)

It should be noted that Dihoru and Negrean (2009) do not mention *M. quadrofolia* in the most recent red book of vascular flora from Romania.

Ex situ conservation strategies

The *ex situ* conservation includes in vitro, classical micropropagation, and in vivo methods - cultivation in botanical gardens, respectively. Following the European Strategy for Plant Conservation, the most significant aims for botanical gardens is that 75% of threatened plant species to be conserved in *ex situ* collections by 2020, and 20% have to be available for recovery and restoration programs (Samain & Cires, 2012).

For *M. quadrifolia*, in vivo conservation programs are carried out in the botanical gardens from Italy (Del Prete et al., 2006; Dallai et al., 2010; Rolli et al., 2009; Rolli et al., 2013), Poland (Stefaniak & Bomanowska, 2012*),* Croatia (Sandev, 2013), and Switzerland (Kässerman & Moser, 1999).

The main disadvantages of *in vivo* method are small size of populations and low genetic variety because in this form of captivity, the plant usually has clonal multiplication, it does not make reproductive structures. Also, the maintenance and survival of *ex situ* living collections for long periods is difficult because they are critically dependent on continued human care, and in case of any prolonged disturbance the population cannot survive (Dallai et al., 2010).

In vitro micro propagation methods are carried out with good results in Italy (Bonafede et al., 2002; Rolli et al., 2009; Rolli et al., 2014) and Romania (Banciu et al. 2009; Brezeanu & Banciu, 2009).

However, both *in vivo* and *in vitro* methods have produced a large stock of plantlets that were used for *ex-situ conservation in order* to increase and improve living collections, and for *in situ conservation,* namely, for restoration of populations in the natural sites (Dallai et al., 2010).

Reintroduction in the wild and inter situ conservation

Reintroduction, which means "the deliberate establishment of individuals of a species into an area and/or habitat where it has become extirpated with the specific aim of establishing a viable self-sustaining population for conservation purposes" (Maunder, 1992), may involve the establishment of an extirpated species into a relatively intact habitat or it can be part of the restoration of a degraded habitat (Heywood & Dullo, 2006). Moreover, reintroduction programs can be considered an ideal follow up activity for *ex situ* conservation initiatives because in this manner, *in situ* and *ex situ* techniques are integrated in a complementary way.

Several recovery and reintroduction programs with the aim of establishing new populations of *M. quadrifolia* in the wild within restored habitats have been set-up successfully in Switzerland (Nöel et al., 2011), Spain (Estrelles et al., 2001b; Estrelles & Ibars, 2002), Portugal (de Sequereira et al., 1999), Italy (Bonafede et al., 2002; Del Prete et al., 2006), Poland (Schweitzer & Polakowski, 1994; Wołk, 2001), and Switzerland (Käsermann & Moser, 1999; Nöel et al., 2011).

Reintroduction programs aimed at establishing or maintaining populations of *M. quadrifolia* into agro-ecosystems and other anthropogenic habitats were conducted in Spain, in old rice fields inside the Natural Park of the Ebro Delta, as an *ex situ* conservation measure applied on this species that traditionally is part of the communities of Orizetea sativae (Estrelles et al., 2001b), and also in Japan (Osawa, 2013).

Even the success of some *M. quadrifolia* reintroduction is somewhat sustained by its ability to colonize new habitats (Burk et al., 1976), and its pioneer capabilities that were observed in disturbed habitats are the result of the capacity for vegetative reproduction (Dallai et al., 2010), the number and genetic diversity of plants introduced at a site (Nöel et al., 2011) are an important factor that it is likely to contribute to the successful reintroduction

However, amplified fragment length polymorphism analyses show low genetic variability among and within *M. quadrifolia* populations tested from several protected areas in Europe (Bruni et al. 2013).

Therefore, if the initial pool of introduced individuals does not have sufficient genetic diversity, the plants may suffer from genetic problems (Kircher et al., 2006), which can be a critical element for adaptations to environmental change and for the long-term survival of the species (Weeks, 2011).

New occurrences in the wild and antropogenic habitats

Surprisingly or not, although this plant is already extinct or is critically endangered in some regions, it finds refuge outside the historical areal of distribution. Thus, Drock and Weeda (1999) reported *M. quadrifolia* as a new species to the flora of the Netherlands, being found in pioneer vegetation belonging to *Eleocharito acicularis-Limoselletum association*, resembling its past occurrence in similar plant communities in the Hungarian rice fields and in the Upper Rhine Valley. The fern was discovered in a suitable habitat created by transformation of farmland along river into wetland (Bremer, 2007). Its migrations toward the north, and thus extending its natural range, is explained as a consequence of climate changes: mild winters without frosts from last decades of the 20th century in the Netherlands (Bremer, 2007).

On the other hand, the potential dispersal ability of *M. quadrifolia* in new areas with suitable climates from the Iberian Peninsula, that have resulted due to climate change in Europe, was assessed by Alagador et al. (2011). The authors found that *M. quadrifolia* is not equipped to follow the pace of climate changes. But because anyway suitable climate conditions are predicted to occur in some areas of the Iberian Peninsula and, by extrapolation, in other regions of Europe also, in these circumstances there are three conservation mechanisms that may rescue the fern from regional extinction: i) averting habitat fragmentation and increasing landscape connectivity; ii) increasing carrying capacity and „in situ" adaptation that improve species resilience and recovery to changes (Jones & Monaco, 2009; Sgro et al., 2010); iii) using assisted colonization, a manipulative mechanism to physically relocate species in location outside of its existing or historical range.

New occurrences in natural habitats within the pale of its natural range has been reported in France (Conrad, 2005), Italy (Pistoja et al., 2006), Croatia (Hulina, 1998), and Romania. Besides, reappearances in places whereit was previously declared extinct are reported in Italy (Pistoja et al., 2006).

All these cases reveal that establishment of new wetlands in its natural range, both by natural or anthropogenic means, increases chance of developing new *M. quadrifolia* populations in a natural way, as it happened in Italy and Netherlands (Pistoja et al., 2003; Drock & Weeda, 1999).

The means by which *Marsilea* reach in a natural way isolated habitats is not well documented. The potential dispersers are water-birds. Despite the fact there are not strong evidences, for several authors was reasonable to hypothesize that Marsilea might be zoochorus dispersed by water birds, both externally by adhering of spores or sporocarps to external surface of feet and feathers (Guppy, 1906), and internally by feeding sporocarps (McAtee, 1939; Malone & Proctor, 1965; Nelson, 2000). Nevertheless this supposition is plausible because water-birds are abundant, widely distributed across the world's wetlands, and highly mobile at local, regional, and continental scales (Charalambidou & Santamaria, 2005).

However, sometime this fern had to bridge a gap of hundreds of kilometers to establish themselves in the new suitable sites, including sites located outside of its known natural range, like in Netherlands (Drok & Weeda, 1999), but not only.

Although escaping from cultivation seems to be more plausible for its spread in North America (Les & Mehrhoff, 1999), Meehan (1882) speculated that *M. quadrifolia* might have arrived there by Siberian water birds. On the other hand, Martin and Uhler (1939) suggest that aquatic birds have facilitated its post-introduction dispersal in North America.

In Europe, its reappearance in places where it was declared disappeared might be explained, *inter alia*, by the maintenance of the viability of the spores within the sporocarps, which have high resistance to desiccation, being able to remain dormant in the substrate for long periods of time (Jones, 1998) and after that to germinate if the suitable conditions are restored (Nagalingum et al., 2007).

Thus, after the plantlets formed by spore germination adhere to the muddy bottoms of shallow lakes and ponds, the fern immediatelly adopt clonal reproduction, which is a better strategy for the conquest of a new habitat, with less energy consumption than sexual reproduction.

The strategy of vegetative propagations allow the *M. quadrifolia* to colonize new growth sites and the spread of this species in its distribution range and even in non-native areas (Burk et al., 1976), thereby perpetuating the persistence and self-maintenance of the populations (Dallai et al., 2010; Bruni et al. 2013) in the new places.

Threats to populations. The factors threatening M. quadrifolia populations are: small size of populations, low genetic diversity between populations, fragmented populations, demographic stochasticity, human pressure, and natural responses to climatic change.

In Europe, for the *M. quadrifolia* populations who are located in agro-ecosystems, herbicides represent one of the principal threats to the survival of this species (Bruni et al., 2013) in south Asia, particularly in India, it is quoted as a weed of rice fields that is tolerant to most of the grass killer herbicides (Kathiresan, 2006).

The abandonment of low-intensity agricultural practices for intensive modern agricultural practices could be a big threat for many listed habitat types and species of the Habitats Directive (Ostermann, 1998). Thus, agriculture in its traditional form is seen as a mechanism maintaining habitats that are hot spots for species diversity. Because in the Mediterranean countries, *M. quadrifolia* might occurs in rice fields that are temperate freshwater ecosystems, it is one of the species that has some kind of dependence on low-intensity farming systems (Moreira et al., 2007).

Similar to many aquatic and wetland plant populations, *M. quadrifolia* appears to function as dynamic metapopulations (Bruni et al., 2013), which means that these populations are linked by exchange of genetic material, thus increasing their resilience to natural changes in the availability of suitable habitats. As a consequence of modified wetland systems and complexes, the connections between populations within metapopulations have been disrupted and the increasing distance between patches further enhances the probability of species extinction.

Fragmentation of wetland habitats also leads to the decrease in the total surface area and thus in the total size of populations, as well as the size of the remaining habitat patches which increases their vulnerability.

In terms of the potential survival of the species, the numerical abundance of a particular *M. quadrifolia* population does not guarantee that the population members are genetically identical or show very low genetic diversity (Nöel et al., 2005). On the other hand, demographic stochasticity threats especially small size populations.

M. quadrifolia is vulnerable to any change in climate if that might affect the depth and seasonality of its habitat. Otherwise, climate change can be an advantage for *M. quadrifolia* because it can be physically relocated, deliberately, using assisted colonization in locations outside of its historical range that have become climatic suitable as is anticipated (Alagador et al., 2011).

A natural threat for *M. quadrifolia* population can be the neophyte species *Azolla filiculoides* (Anastasiu et al., 2007). This small floating fern competes for light with water clover if it forms dense mats populations previously emerging Marsilea leaves. Thus, if in Europe this ecological relationship is seen as a threat, in India it is used for biological control of *M. quadrifolia* in the rice fields (Satapathy & Singh 1985).

Conclusion

Once common in wetlands within temperate Europe, nowadays *M. quadrifolia* has a scattered distribution and, acording to IUCN criteria, it is considered vulnerable species.

Strategies to protect it were enacted in almost all countries where it is native. Its inclusion on Bern Convention and Habitats Directive - Annex II and IV - reflects its restricted distribution and decline in the UE. Based on*in situ* and *ex situ* conservation methods, programs to reintroduce it in its natural habitats are undertaken in countries where *M. quadrifolia* has been declared extinct in the wild.

Despite the protection and conservation measures, and the fact that new populations that were naturally formed in the wilderness have been reported, the assessments of *M. quadrifolia* populations trend at the temporal and spatial scales showed that they continue to be in decline in UE region. The water pollution was and still is the primary cause of population reduction due to nutrient load and the use of herbicides and pesticides.

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Geomorphological Risk and Denudational Index (Land Erodability) in Karstic Terrain of Anina Mining Area (Banat Mountains, Romania)

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Abstract

Anina Mining Area was defined by Vasile Sencu in 1977 as the area that is surrounding Anina town and may be exploited by mining activities.

The aim of this paper is to present two parameters regarding geomorphometry in Anina Mining Area, naming here Geomorphological Risk and Denudational Index (Land Erodability Index). These two morphometric parameters are obtained using geomorphological parameters that we obtained in previous works, as slope, hypsometry, drainage density, depth drainage and morphodynamic potential. The methodology to derive Geomorphological risk and Denudational index (Land Erodability Index) is based on GIS techniques.

The results we obtained point out that the study area of this paper is a region where parameters such as geomorphological risk and denudational index have small incidence. This fact is due to the large homogeneous areas from the standpoint of geology and land cover, but also as an effect of large surfaces with a planar aspect as karstic plateaus.

From the analysis of these two parameters we must conclude that Anina Mining Area represents a space with small surfaces which are prone to risks associated with geomorphological process and also with small areas where denudation may have high rates due to the large areas where vegetation is present and also due to large plateaus where the primary processes are related to karstification, and these ones are very slow processes.

Keywords: *karst, morphometry, applied geomorphology, Anina*

Rezumat. Riscul geomorfologic și erodabilitatea terenului (indice de denudare) în carstul Câmpului Minier Anina (Munții Banatului, România)

Câmpul Minier Anina a fost definit de către Vasile Sencu (1977) ca arealul din jurul localității Anina, care poate fi valorificat prin activități miniere.

Scopul acestei lucrări este acela de a prezenta doi parametri referitori la geomorfometria în Câmpul Minier Anina, numind aici riscul geomorfologic și indexul de denudare (erodabilitatea terenului). Acești doi parametrii morfometrici sunt obținuți folosind parametrii geomorfologici pe care i-am obținut în lucrări anterioare, precum panta, hipsometria, densitatea fragmentării reliefului, adâncimea fragmentării reliefului și potențialul morfodinamic. Metodologia de obținere a riscului gemorfologic și a indicelui de denudare (indicele de eroziune a terenului) s-a bazat pe tehnici S.I.G.

Rezultatele obținute scot în evidență faptul că arealul care face subiectul acestui studiu de caz este o regiune unde parametrii precum riscul geomorfologic și indicele de denudare au o incidență redusă. Acest lucru se datorează suprafețelor întinse omogene din punct de vedere al geologiei și al utilizării terenului, dar și suprafețelor întinse cu aspect plan cum sunt platourile carstice.

Din analiza acestor doi parametri putem concluziona faptul că arealul Câmpului Minier Anina reprezintă o regiune cu suprafețe reduse predispuse riscurilor asociate proceselor geomorfologice și, de asemenea, acest areal are suprafețe mici unde indicele de denudare are valori ridicate ca urmare a faptului că există suprafețe foarte întinse acoperite cu vegetație și ca urmare a întinselor platouri carstice unde principalul proces, carstificarea, este un proces foarte lent.

Cuvinte-cheie: *carst, morfometrie, geomorfologie aplicată, Anina*

Introduction

Geomorphology is dealing with understanding the processes that are modelling ground surface, the forms that result and the history of its development (Ford & Williams, 2007). Karstic geomorphology is concerned with the study of landforms, both on the surface and underground, that are developing on carbonate rocks as an outcome of dissolution and other processes related to dissolution (De Waele et al., 2009). Geomorphic processes developed on karst terrain slopes are different than those developed on slopes of other geomorphic systems. Processes on karst terrain slopes are determined simply by mechanical and chemical weathering of bedrock, mass movement and the accumulation of weathered material at footslope (Stepisnik & Kosec, 2011).

Geomorphological risks, natural hazards and disasters are one of the main topics in research area of environmental science during the last decades. Demek et al. (2006) have developed a study regarding geomorphological hazards and risks in the Czech Republic; Alcántara-Ayala, I. (2002) dealt with geomorphic hazards, vulnerability in developing countries; De Waele et al., (2011) have written a review about geomorphology and natural hazards in karst regions.

Mountain areas present very high morhophodynamic energy. Nowadays some mountain regions tend to be overexploited, being supposed to "release" this energy as extreme processes, hazards or disasters (Heuberger & Ives, 1994).

Increasing our knowledge regarding karst geomorphology and hydrology helps us to live with karst, instead of living on karst, for a sustainable use of karst resources in the near future (De Waele et al., 2011).

In areas with high recreational attractions, we should pay attention to the risk that might occur in the interaction of geomorphic processes. The assessments of these risks are rather significant in regions with high relief dynamics (Blinova & Bredikhin, 2013).

In Romania, there are also studies regarding geomorphological risks, most of them about landslides: Bălteanu et al. (1996); Micu & Bălteanu (2009); Bălteanu et al. (2010); Grecu & Sandu (2012). But regarding geomorphic risks in karst areas, papers are missing, even if Romania has many interesting karst regions.

The aim of this paper is to present two parameters regarding geomorphometry in Anina Mining Area, naming here Geomorphological risk and Denudational index (Land Erodability Index). These two morphometric parameters were obtained using geomorphological parameters that we obtained in previous works, as slope, hypsometry, drainage density, depth drainage and morphodynamic potential. The methodology to derive Geomorphological Risk and Denudational Index (Land Erodability Index) is based on GIS techniques.

These parameters involve in their analysis some other elements related to geomorphometry. It is worth mentioning slope, land use, geology, and morphodinamic potential. Some of these parameters such as slope (Artugyan, 2013) and morphodynamic potential (Artugyan, *in press*) were obtained in previous works.

Morphometric and morphographic aspects are decisive for the importance of percolation water flow, especially in karst terrains. Planar surfaces in karst terrains are more prone to develop karstification processes. Among the terrain parameters, slope, drainage density, drainage depth, orientation and sinkholes (Ilie, 1970b) are the most important in karstification processes.

Limestones are subject to dissolution processes, independently of slope conditions. In forested areas, even if carbonate rocks are covered with soils (rendzinas), they are conditioned by slowly dissolution processes, because humic acids have easy access through water at the contact with the bedrock (Mihai, 2005).

The density and size of sinkholes indicate the degree of dissolution that geological substrate has undergone locally (Shofner et al., 2001).

Study area

Anina Mining Area is situated in the South-West of Romania, within the Banat Mountains, more precisely in the centre of a subunit of Banat Mountains, Anina Mountains (Fig. 1).

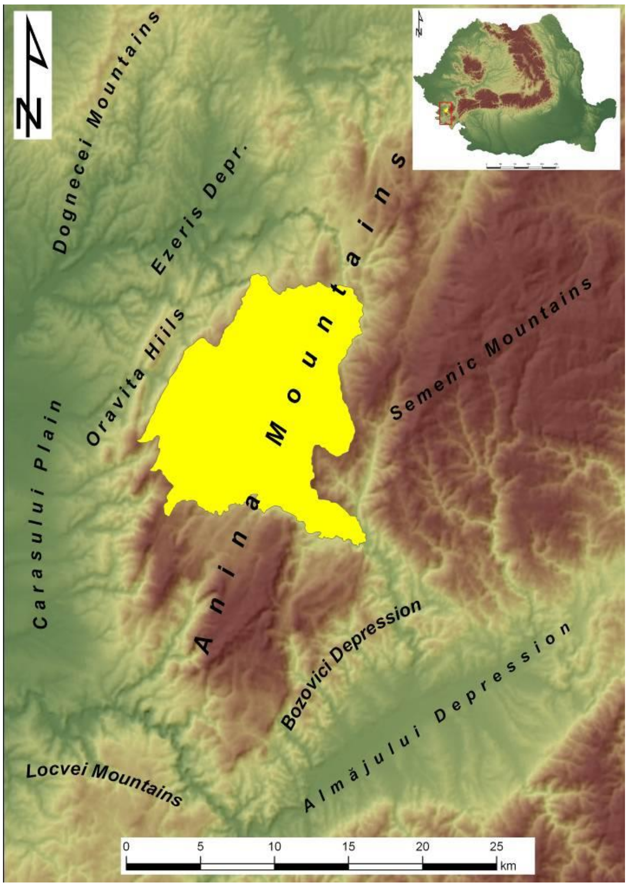

Fig. 1: Location of the study area in Romania and in Banat Mountains

Anina Mining Area was defined by Vasile Sencu in 1977 as the region that is surrounding Anina town and which may be exploited by mining activities. The paper of Sencu (1977) regarding Anina Mining Area is a work based on two previous papers regarding two important karstic regions situated in this area: the first was about the karst of Anina and Buhui creeks (Sencu, 1963) and the second was about the karst region of Steierdorf and Ponor creeks (Sencu, 1964). Based on his surveys, after many years of field work and geomorphological approaches, Sencu also published a tourist guide where he presented Anina Mountains from the tourist's point of view (Sencu, 1978).

Anina Mining Area is located in the central area of Reșița - Moldova Nouă Synclinorium, the largest and most compact surface covered by carbonate rocks in Romania (Orășeanu, Iurkiewicz, 2010).

Based on the geology, our study area is located in the structural Reșița - Moldova Nouă

Synclinorium, in the geographical unit of Anina Mountains (Fig. 2a).

The large number of faults is favourable in the karstification processes. Faults orientation is passed on the main drainage direction. These tectonic features act as boundaries between the main karst systems in the region (Iurkiewicz et al., 1996a).

The relief shows an alternation of limestone ridges and plateaus, separated by deep valleys that succeed from West to East in the focusing of the geological structure, NNE-SSW. The main orientation is very well explained by the rose diagram that is showing the large number of faults that are imposing the general aspect of the morphology. Some faults orientated W-E acts as brakes in the relief continuity. The development of large areas with a high degree of fragmentation has as consequences peaks and disorganized valleys (Fig. 2b).

In the past, this region was very significant for the Romanian economy due to the coal reserves. Nowadays Anina karstic area is a very poor one, with many social and economic problems. This state of affairs is the consequence of the fact that in 2006 the mining activities were closed. Tourism appears to be one of the best options to revitalize this karstic region, but the development of tourism should be done based on sustainable principles.

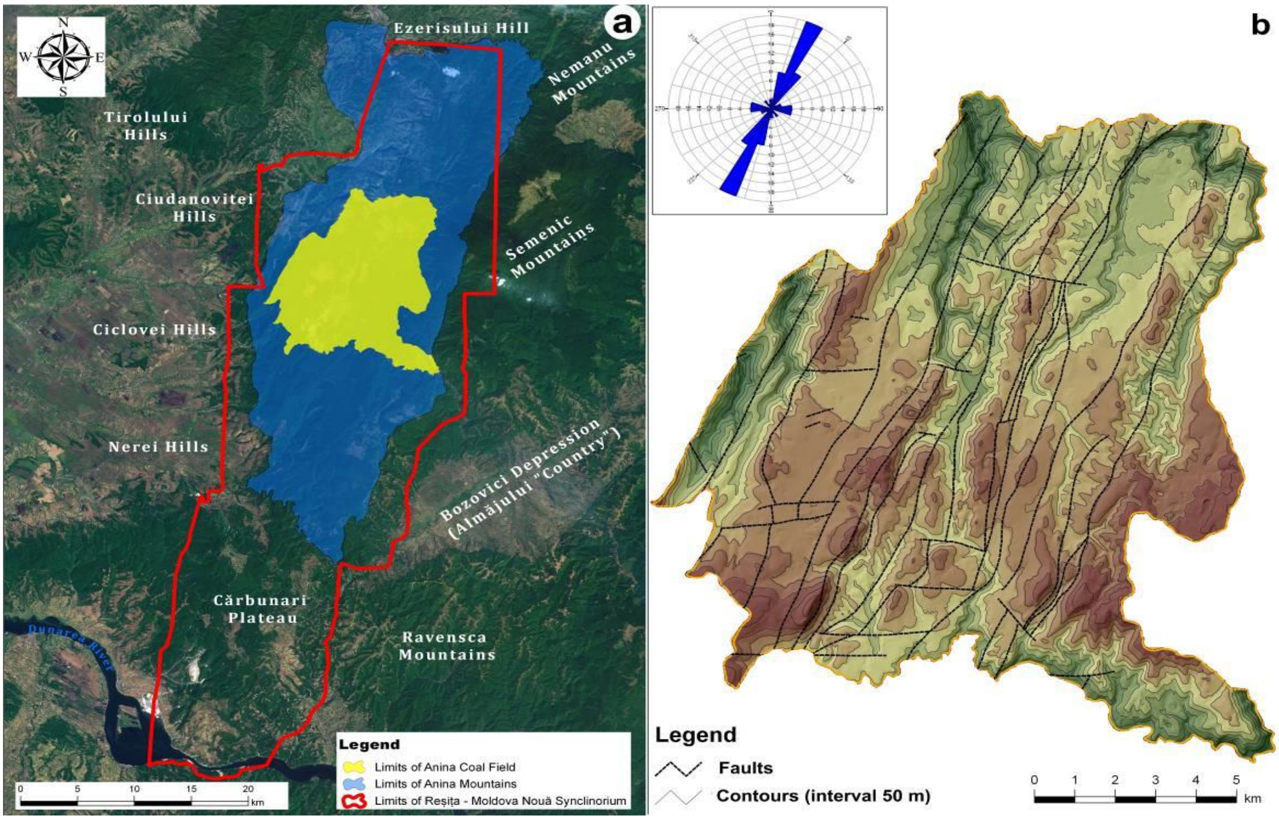

Fig. 2: Location of Anina Mining Area within structural area of Reşiţa - Moldova Nouă Synclinorium, in the centre of the geographical unit of Anina Mountains (a); the main aspect of morphology and the main orientation of relief in Anina Mining Area (b)

Research methodology

We have chosen to determine two morphometric parameters as a preliminary study in the Anina karstic area to identify using GIS methods those areas that presents high risks as consequence of different geomorphic processes.

Materials

To obtain these two parameters we used as materials topographical maps of scale at 1:25,000, a karstic map of the Anina Mining Area of scale at 1:50,000 (author Vasile Sencu, 1977), a geological map of scale at 1:50,000, L-34-104-D-121d Anina (National Geological Institute) and Corine Land Cover data from 2006 (http://www.eea.europa.eu).

Data

All the input data necessary to derive geomorphological risk and denudational index were generated from the materials mentioned above. A DEM was obtained by extracting contours from the topographical map's scale of 1:25000 and then we interpolate these isolines using Topo to Raster tool from ArcGIS 10. Using the DEM we generate hypsometry, slope, orientation and drainage depth. The next step was to involve in our analysis hydrographic network to obtain drainage density. These parameters were used to derive morphodynamic potential.

We also need litohology in our analysis. We referenced the geological map L-34-104-D-121d Anina, and then digitized the lithological units from this map. To be able to utilize in our work, we used the Conversion tool from ArcGIS 10 to transform the vector information into a raster one.

The data regarding land use and land cover was downloaded as vector data. To be usable with the other data, we performed again a conversion to raster format, to induce the entire data into a raster format. The next step in our processing methodology was to reclassify the raster data into the same number of classes, to be able to introduce in a map algebra operation in ArcGIS.

The last step was to overlap the sinkholes as points on geomorphological risk parameter and denudational index. These karstic depressions are the most specific surface karst features present in the Anina Mining Area. We intend to observe the distribution of these features regarding the two geomorphological parameters. The karstic depressions were extracted from the karstic map of Anina Mining Area scale at 1:50000 (author Vasile Sencu, 1977) as points. Using Extract Values to Points tool from ArcGIS 10 we counted the number of sinkholes that are situated in different classes of those two geomorphometric parameters.

Working steps

Geomorphological risk (Gr)

To obtain the geomorphological risk we should take up a workflow presented in brief in figure 3. This index is based on the next formula:

Gr = ∑ (S, Mp, LU, L), (Mihai, 2005),

where:

Gr – Geomorphological risk;

S – Slope;

Mp – Morphological potential;

L – Lithology;

LU – Land use.

We reclassified the following parameters: slope, land use, potential morphodynamic and geology. These parameters were used in the formula given above (Mihai, 2005). Reclassification involved a type of sorting of different classes within a parameter on the basis of their contribution toward geomorphological risk parameter.

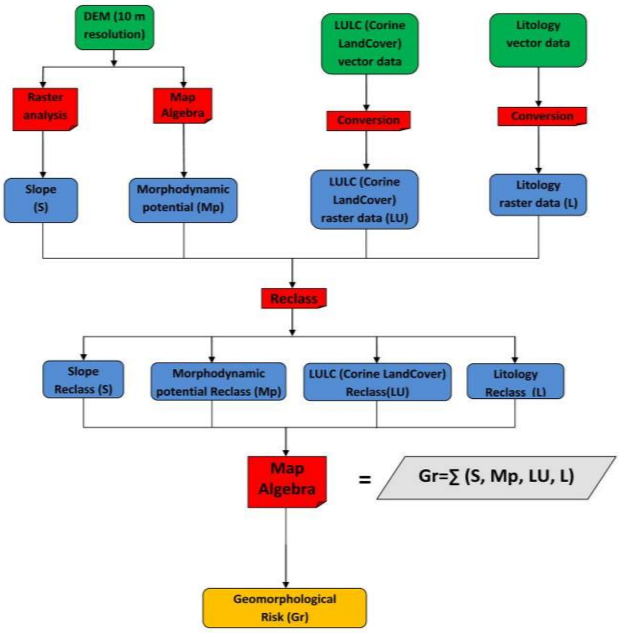

Fig. 3: Workflow to obtain the geomorphological risk (Gr)

The Gr map is the result of algebraic operations with the reclassified parameters obtained before (Artugyan, 2013). In the final map, a pixel value represents the Gr, as areas with small, medium or large risk. Parameters have been set so that the slope represents the value of thousands (for small slope there is low risk and the value is 1000, and for high slope thre is high risk, value 3000), land use for hundreds (with values range between 100 and 300), the potential morphodynamic represents order tens (range between 10 and 30) and rocks the units (between 1 and 3). The last step was to sum the before mentioned parameters, to obtain the geomorphological risk.

Denudational Index (Di)

Terrain erosion, defined as the moving process on slopes of soil elements, rocks, eluvials, deluvials, becomes a highly economic problem. Terrains degradation, independently of terrains use, is characterized by soil loss and is requiring activities for protection (Latulippe & Peiry, 1996).

The goal of GIS analysis regarding terrain denudation is to generate a cartographic representation, to locate and estimate those areas with high rates of vulnerability. The steps to derive the denudational index are presented in the next workflow (Fig. 4). We have reclassified geomorphological risk, slope, land use, potential morphodynamic and geology. The vulnerability to erosion index needs an additional element to be derived, the geomorphological risk, which was obtained earlier.

The reclassification of the parameters used in the calculation of denudational index is based on Table 1 (after Mihai, 2005), which was adapted to our study site.

Table 1: (modified after Mihai, 2005)

Morphodynamic Factor	High Denudation	Average Denudation	Low Denudation
Geology (Lithology)	Gravels, sands, marls, flysch	Conglomerates, sandstones	Limestone
Slope	20-90°	5-20°	Smaller than 5°
Land Use	Pastures and meadows, thickets, settlements, land erosion	Pastures and meadows, glades, thickets, orchards and meadows	Forests
Morphodynamic potential	Slips, disintegration, collapse, torrents	Wash in surface, torrents	Wash in surface, alluvial
Geomorphologycal risk	High	Average	Low

Using the next formula, we may obtain the denudational index (Mihai, 2005):

Di = ∑Div (S, L, LU, Mp, Gr), (Mihai, 2005), where:

Di - Denudational index
Div - Denudational index variables
S – Slope
L - Lithology
LU – Land Use
Mp - Morphodynamic potential
Gr – Geomorphological risk

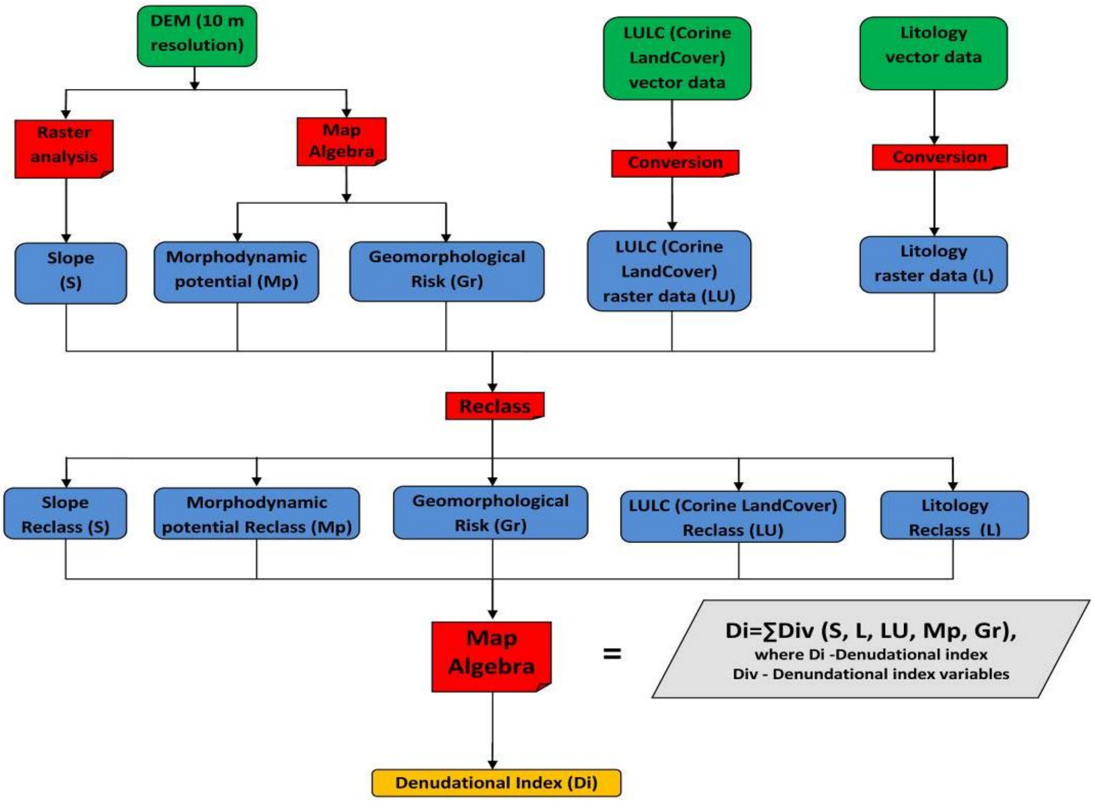

Fig. 4: Workflow to obtain the denudational index (Di)

Results

The results obtained are influenced by the parameters involved in the analysis. The most important factor is slope which is decisive in both parameters because steep slope favoursthe production of different processes that may be seen as a risk from the geomorphologic perspective, but also favourable for erosion, denudation.

Geomorphological Risk (Gr)

Due to the classification of the parameters included in the geomorphological risk, the final result is also reclassified into the following three categories:

a. Areas with high risk are representative for those areas where on the map are located deep valleys and gorges (Caraș, Celnicul Mic, Jitin, Gârliște, Buhui) (fig. 5b), based on slope parameter and a morphodynamic potential index. These areas cover a little more than 6% of the total region (Fig. 6). Some other areas with high risk are Crucii Hill, Tâlva Ştefan Hill, Tâlva Zânei Hill (Fig. 5b).

b. Medium-risk areas cover those surfaces which ensure the transition from the steepest slopes to the planar surfaces located in the karstic plateaus (Fig. 5b). The percentage of these values confirms the map because it covers more than 48% (Fig. 6). Such areas we may find in Marila area, in Moghila Hill, on Cârneală Plateau and on the Mociur Hill.

c. Areas with low risk are found in most planar areas, naming here the karst plateaus (Brădet, Colonovățul Mare, Colonovățul Mic, Ravniștea Mare, Mărghitaș) where the slope is very small, and also morphodynamic processes are given very small values. Due to large areas that are representing these plateaus, areas with low geomorphological risk values covers more than 45%.

Sinkholes are located especially in areas with low risk and only a few of them are situated in areas with medium risk (Fig. 5a). We counted a total of 975 sinkholes on the map and 781 of them (80.1 %) are overlapping areas with low Gr, 198 (20.3 %) sinkholes are situated in medium risk and 4 (0.5 %) in high risk areas. This data are valuable because they point out that in this karstic region geomorphological risks based on DEM analysis are prone to appear in regions with rich valleys and gorges, excluding karstic plateaus.

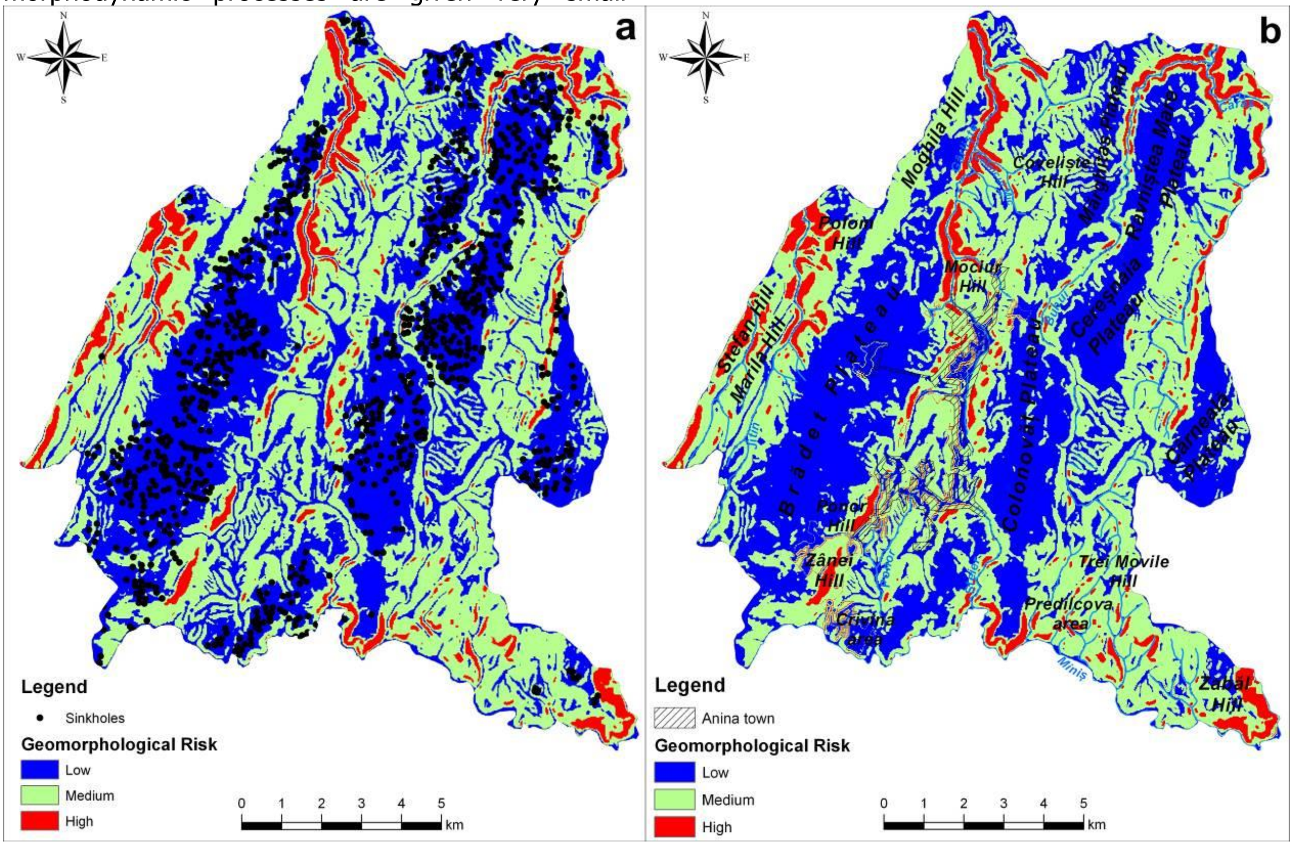

Fig. 5: Geomorphological Risk parameter and sinkholes in Anina Mining Area (a); Geomorphological Risk parameter and most representative sites in Anina Mining Area (b)

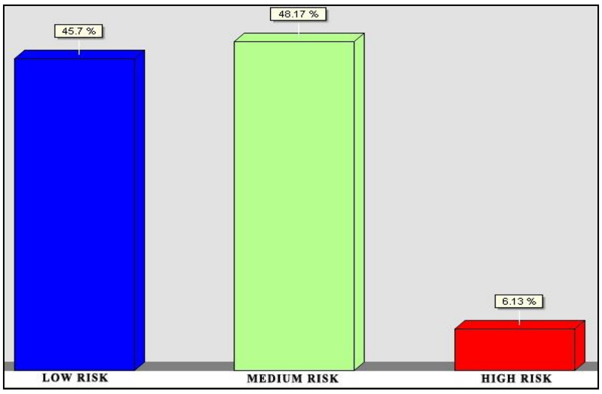

Fig. 6: Histogram of Geomorphological Risk parameter

Denudational Index (Di)

Slope terrain is the main factor that is imposing the land erodability or denudation. Besides, denudational index is highly influenced by morphodynamic potential and geomorphological risk parameters. Higher values for those parameters will also give a higher value for Di, because dynamic processes on terrain are sometimes given by erosional processes.

Founded on the workflow presented above (Fig. 4) and on the parameters involved in the analysis,

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the result of the denudational index was be also reclassified into three classes:

a. Areas with high denudation index.

These areas are located near or along the valleys and gorges (Caraș, Celnicul Mic, Jitin, Gârliște, Buhui). This is due to the slope parameter which in these regions has favourable values for erosion due to the inclination of the slope (Zabăl Hill, Tâlva Ponor Hill, Tâlva Zânei Hill or Tâlva Ștefan Hill) (Fig. 7b) and also due to the fact that most of these surfaces are covered with bare rock and the vegetation is often missing. The high denudation index covers nearly 9% of the studied area (Fig. 8).

b. Areas with average denudation index cover surfaces that are making the transition between planar plateaus and deep valleys (Fig. 7a). These regions are defined by parameters as slopes, geomorphologycal risk and morphodynamic potential with medium values, but also by bedrock which is more suitable to erosion. Such areas are located in Trei Movile Hill, Predilcova area, Iudina Mare area, Polom Hill, Tâlva Lupului Hill, Colonovățul Mic area, Straja Hill, Moghila Hill, Coveliște Hill (Fig. 7b). This class represents less than 45% of the Anina Mining Area (Fig. 8).

c. Areas with low denudation index are situated in the plain regions, the karstic plateaus (Brădet, Ravniștea Mare, Mărghitaș, Cârneală, Colonovăț) in Anina Mining Area (Fig. 7b), and the most compact are the plateaus which have low values of erosion index due to the small values of slopes, geomorphological risk and morphodynamic potential. Other areas with low index are located in Culmea Frumoasă area, Crivina area and Cereșnaia area. The class representing the lowest values of this parameter covers almost the same as the medium class, 45% (Fig. 8).

Overlapping the sinkholes with Di, we notice that most of them are situated on surfaces with low value of denudational index, naming here karstic plateaus (Fig. 7a). From 975 karstic depressions counted in this map, 781 of them (80.1 %) are situated in areas with low Di, 186 (19.1 %) in areas with medium Di and 8 (0.8 %) sinkholes in surfaces with high Di.

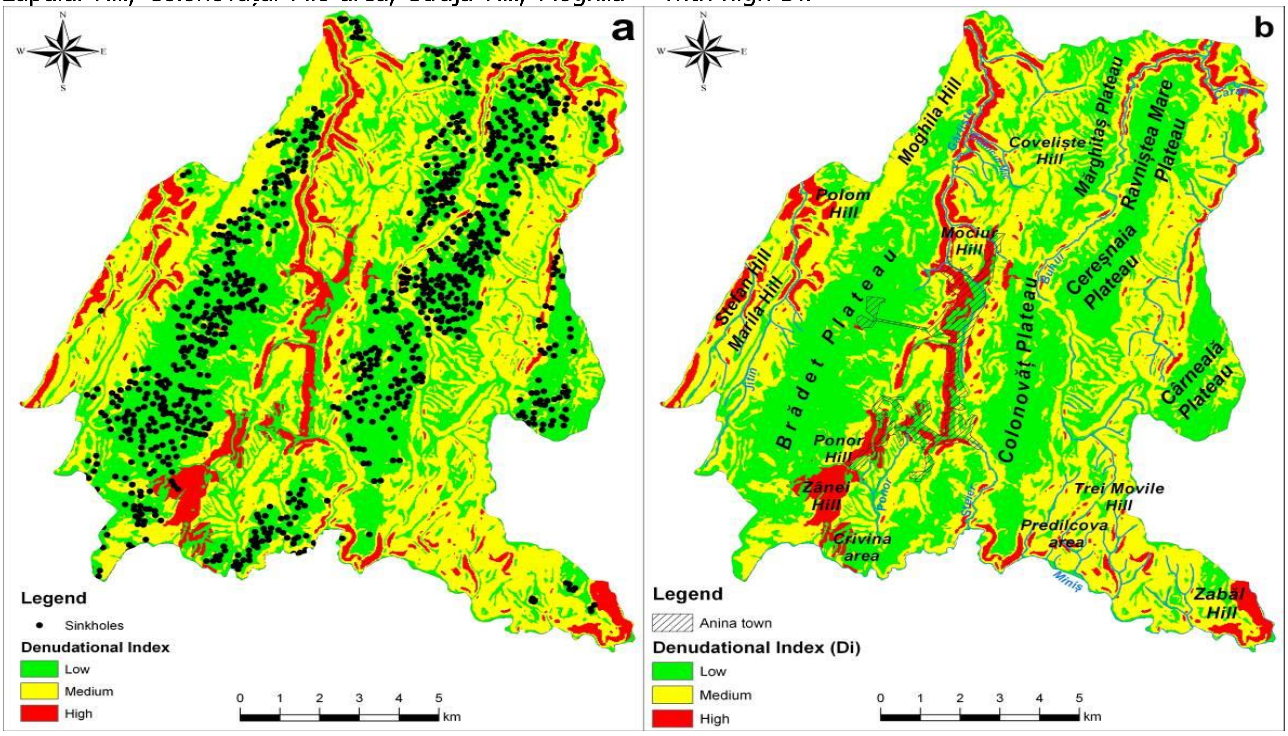

Fig. 7: Denudational Index parameter and sinkholes in Anina Mining Area (a); Denudational Index parameter and most representative sites in Anina Mining Area (b)

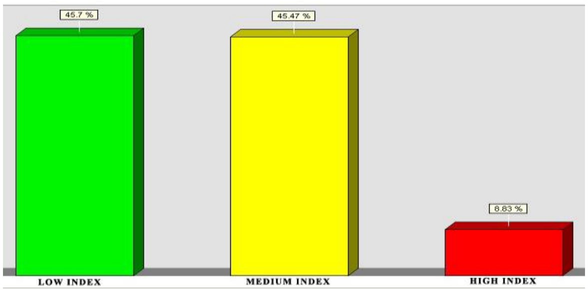

Fig. 8: Histogram of Denudational Index parameter

Discussions

Anina Mining Area is predominantly a forested area. Consequently, in the analysis of geomorphological risk and denudational index we consider more important to analyse morphometric parameters as slope and morphodynamic potential, because land use parameter in our case would not have had a major impact in the analysis due to its homogeneity.

Another factor which we prefer not to focus very much when we discuss the results is lithology. The reason is the same as in the situation of land use parameter, because the lithology of the Anina Mining Area is very homogeneous regarding the bedrock, almost the entire area comprising carbonate rocks (different types of limestone and marl). Because of this we chose to yield a higher importance to the slope factor and other parameters derived based on the slope, namely morphodynamic potential and geomorphological risk.

This approach could be considered as the first step in studying a karstic area from the geomorphological risk perspective, based on digital data and using GIS methods. The validation should be done using more accurate data, as aerial photos, high resolution DEMs and field validation.

For better results and a complete analysis, we would need the sinkholes as polygons, to be able to calculate the area represented by these karstic depressions in each class of those two parameters, Gr and Di. For more accurate results, a DEM with a better resolution would be very helpful. The limits regarding the methodology are speaking about the data that we analyze, only digital elevation model derived parameters. In consequence, some local landforms, which may be smaller than the DEM resolution, could not be included in our analysis. Another restriction of this methodology could be the inductive reasoning that is received after the reclassification step.

The results presented in this paper could be useful in different projects by local authorities. This area is proposed for a touristic development in the near future, with many investments in building accommodation spaces. Our results could be helpful to establish those areas that might be considered as high risk areas from the geomorphological perspective.

Both parameters present highest risk areas across gorges sectors or in the neighbourhood. Many tourist paths are "painted" on the gorges sectors, these landforms representing one of the most important touristic attractions in the region. It should be important for tourists administrations to mind our results and produce a more elaborate written report in these gorges sectors to prevent any possible incident related to tourist activities.

The interpretation of Gr and Di maps should be managed as a correlation between GIS analysis and field characteristics. Large forested areas, large areas with low geomorphological risk and denudational index (> 45% for both of these parameters) represents good conditions for a sustainable development at local or regional scale.

Conclusions

Anina Mining Area is an area with small surfaces which are prone to risks associated with geomorphological process and also with small areas where denudation may have high rates. This is due to the large forested areas and also due to large plateaus where the primary processes are related to karstification, and these ones are very slow processes.

Our GIS approach has captured mainly general aspects of geomorphological risks. There stands out in local differences given by thematic layers as lithology, land use or small landforms that are not highlighted in our Digital Elevation Model.

We intend to use in the analysis of geomorphological risk and denudational index more accurate data regarding surface landforms (karrens, dry valleys, sinkhole valleys etc.), to obtain local indices where karstic surface landforms are present.

The indices calculated for geomorphological risk and land erodability index could be used in territorial planning works, for example to identify those areas that require attention in arranging tourist routes.

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Quality assessment indicators of surface waters and soils in the vicinity of the former sulfur mine in the Călimani Mountains

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Abstract

A native sulfur mineralization was quarried out intensively for a period of almost 30 years in Călimani Mountains, the Eastern Carpathians. The waste resulted from this exploitation activity was stored in four waste dumps, while the residues resulted from the processing were disposed in a settlement pond. Although mining operations closed in 1997, the remains of the former sulfur mining are listed among the major pollutants in Romania.

The present paper intends to present a preliminary analysis and the current state of the impact of pollution of the former mining exploitation on different environmental factors, by assessing some quality indicators of surface waters and soils. Water and soil samples from different areas situated in the proximity of the former mine were collected and analyzed, performing pH, conductometric, turbidity, chemical and microbiological determinations.

The results of this study demonstrate that the pollutant potential of the former sulfur mining from the Călimani Mountains is still very high, a fact proved by the acidic pH of the surface waters and soil, high turbidity and conductivity of the water respectively by the high number of impurities detectable through a simple preliminary chemical analysis.

Keywords*: sulfur mining, the Călimani Mountains, pollution, pH, turbidity, chemical analysis, microbiological analysis, quality assessment*

Rezumat. Indicatori de evaluare a calității apelor de suprafață și solurilor în proximitatea fostei exploatări de sulf din Munții Călimani

Zăcământul natural de sulf din Munţii Călimani, Carpaţii Orientali, a fost exploatat intensiv de-a lungul unei perioade de aproape 30 de ani. Sterilul rezultat din activitatea de exploatare s-a depozitat în patru halde de steril, în timp ce reziduurile rezultate din procesarea minereului s-au evacuat într-un iaz de decantare. Deşi operaţiunile miniere au fost sistate în anul 1997, rămăşiţele fostei exploatări de sulf sunt clasificate printre principalii factori poluanţi din România.

Lucrarea de faţă are ca scop prezentarea unei analize preliminare şi a stadiului actual al impactului poluării fostei exploatări miniere asupra factorilor de mediu, prin evaluarea unor indicatori ai calităţii apelor de suprafaţă şi a solurilor. Probe de apă şi sol au fost colectate din diferite regiuni aflate în proximitatea fostei mine şi au fost analizate, efectuând determinări de pH, conductometrice, turbidimetrice, chimice şi microbiologice.

Rezultatele obţinute demonstrează faptul că potenţialul ca şi agent poluant al fostei mine de sulf din Munţii Călimani este în continuare foarte ridicat, fapt reliefat de pH-ul acid al apelor de suprafaţă şi a solului, conductivitatea şi turbiditatea ridicată a apei respective prin numărul ridicat de impurităţi detectabile printr-o simplă analiza chimică preliminară.

Cuvinte-cheie: *exploatarea sulfului, Munţii Călimani, poluare, pH, turbiditate, analiză chimică, analiză microbiologică, evaluarea calităţii*

Introduction

The Călimani Mountains are the largest mountain unit of the Oriental Carpathians, with a total area of about 2000 km^2, being considered as the highest and the most spectacular volcanic mountain in Romania. But not everything linked with Călimani Mountains can be described in idyllic colors; thus few know of the existence of more than 300 hectares of bare mountain without any trace of green vegetation. This is the present picture of the Negoiu Românesc peak, or rather the picture of its remains. The former sulfur mine exploitation, opened during the communist regime is responsible for the destruction of wildlife and vegetation, right in the middle of the protected Călimani National Park is.

The sulfur deposit from the northern part of Călimani Mountains is located, from the administrative point of view, on the territory of Şarul Dornei village. The first written attestation of the presence of sulfur ore in the region of Negoiu peak, appeared in the second half of the 19th century, but the exploitation activities began only in 1969, as the seventies were a economic period in which chemistry was considered an engine for the national economy, requiring high amounts of sulfur containing substances. As market demands were high, the sulfur was highly sought after; consequently the damages caused to the environment have been neglected, excelling only the economic interest. The mine was closed by government decision in 1997, the primary motivation being that sulfur exploitation cost three more time than its production value; according to these conclusions the mine lasted for almost 30 years due to the reported false production figures, and was never profitable (Georgescu et al. 2005; Ştumbea, 2010; Teodor, 2010).

From a valuable source of sulfur supply for the Romanian steel industry, nowadays the sulfur mine became a headache for environmentalists. Today, the remains of the former sulfur exploitation seem a "bad joke" thrown in the middle of the Călimani National Park area.

The sulfur exploitation from the Călimani Mountains remains one of the biggest ecological disasters in Romania and in the range of the Carpathians. The intensive mining activities led to the physical destruction of a mountain (Negoiul Românesc), 300 hectares of highly damaged land, heavily polluted water and soil and ultimately became a major threat for the health of exploitation workers and locals from the region.

The mineralization contained sulfur associated with pyrite and iron oxides; the sulfur occurred as diffused impregnations, nests and thin layers within the structure of ore bodies containing pyrite, aluminous limestone, silica, clay minerals and iron oxides. The sulfur was being extracted from rocks in a specially designed grinding plant and the sterile material was laid nearby as waste dump. The waste resulted from the exploitation, were stored in four waste dumps (Dumitrelu, Ilva, Pinu, Puturosu) while the waste resulted from ore processing using floatation and subsequent treatments were disposed in a settlement pond (Dumitrelu pond) (Georgescu et al. 2005; Teodor, 2010, Surdeanu et al, 2011).

The degraded soils, the waste dumps are often very unstable and become sources of pollution; the direct effects are related to the loss of forest or grazing land while the indirect effects include air, soil and water pollution (Rojanschi et al. 1997).

The ecological restoration of the land started, stopped and then started again in the last years. The workers' town was demolished and just one or two abandoned buildings are left testimony for the daily presence of thousands of people at the exploitation during its golden years of existence. However, it will take many years and huge financial efforts to alleviate the environmental disaster.

Surprisingly, there are only a few published articles regarding the impact of the pollution generated by the former mining exploitation, and the data on pollution levels and ecologization efforts can be considered controversial (Ditoiu and Ciobanu, 2002; Georgescu et al. 2005; Ştumbea, 2010; Stoica et al. 2011; Surdeanu et al. 2011).

The large majority of the published studies approach the relationship between the geomorphic processes such as landslides, debris-flow or hyperconcentrated flows and vegetation colonization processes, focusing on the development of natural rehabilitation strategies (Ditoiu and Ciobanu, 2002; Pop et al. 2009; Surdeanu et al. 2011).

The paper aims at presenting a preliminary analysis of water and soil samples collected from different areas in the vicinity of the former mining area, as a conclusive evidence of the effects of long term human intervention over the environment in its reckless pursuit of rapid exploitation of natural resources.

Methods

1. Sampling

Solid soil samples (S1-S4) from the quarry, waste dumps and water samples (W1-W4) from the seasonal puddles developed onto the plateaus of the quarry, waste deposits and from Neagra Şarului stream were collected and analyzed. The samples were collected from representative areas, thus to cover a distance of about 5 km around the mining operation region. Samples were collected from the epicenter of the mining area (S1, W1), from the plateau of the Puturosu waste deposit (S2, W2), from the stream crossing the mining area (S3, W3) and from the stream at the entrance of Neagra Şarului village (S4, W4) (Fig. 1). All the samples were collected from the designated areas in June 2013.

Neagra Şarului stream gathers its waters of the northern side of the Călimani Mountains inside the volcanic crater, being by far the most affected creek by the mining activities. Neagra Şarului village is the nearest settlement to the mine and it stretches near the confluence of the Hăita and Neagra Şarului streams.

For sampling we used plastic (polyethylene) sterile containers; two samples were taken from each designated area (sample and counter-sample), the samples were kept in a cooler (2-5 C) during transport.

Organoleptic analysis pH, turbidity and conductometric determinations were performed 24 hours after sampling. Microbiological and chemical purity analyses were performed 48 hours after sampling.

Samples collected on the field were processed according to the type of determination. In order to carry out pH, conductometric and chemical determinations from soil, the solid samples were immersed in distilled water in a 3:1 ratio (3 parts distilled water: 1 part solid sample), centrifuged at 3500 rpm for 5 minutes, and left for sedimentation for 30 minutes before every determination, as the measurement were made from the supernatant.

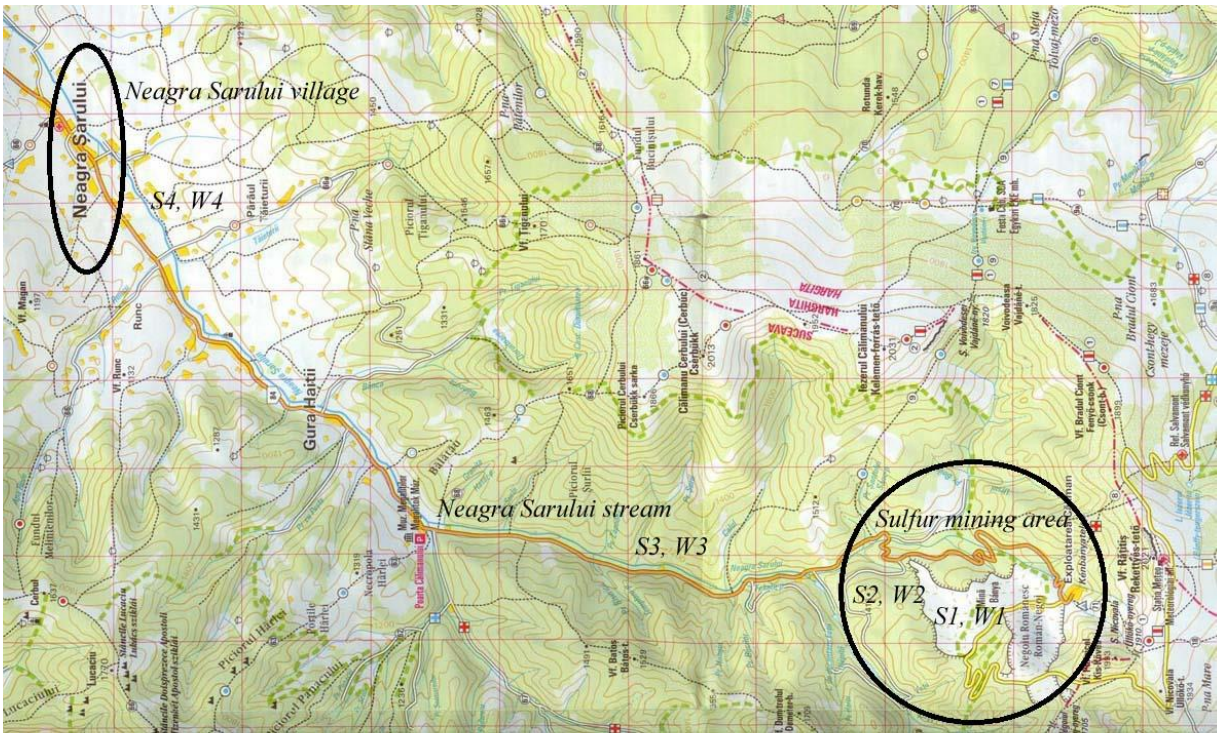

Fig. 1: Map of the former Călimani sulfur mining exploitation area and its vicinity

2. Apparatus

For the pH and conductometric determinations we used a multiparameter electrochemical potentiometer InoLab Multi 740 equipped with a glass electrode, and a calomel reference electrode immersed in a saturated solution of potassium chloride.

For the turbidity determination we used a Turb 555 turbidimeter, using a nephelometric measurement method.

The elemental chemical analysis was performed according to the stipulation of the Romanian (Farmacopeea Română, 10th edition) and European (European Pharmacopoeia, 7th edition) Pharmacopoeias.

The soil samples were centrifuged with a Centurion Scienatific Ltd centrifuge using 15 ml polypropylene conical centrifuge tube.

Results and Discussions

1. Field Research

An area covering more than two kilometers all around the former quarry operation is affected by the presence of sulfur. We could notice the lack of vegetation and the heavy sulfur smell the air. The water samples collected from the puddles developed onto the plateaus of the quarry and waste deposits were murky, yellowish and had a characteristic sulfur smell.

There were also noticed crashes and shifts of boulders and rocks on the bare slopes. The shaped forms of terraces testify for the influence of rainwater flows. The structure of altered, permeable and destabilized rocks caused the formation of drainage ditches. The frequency of landslides is high due to the existence of potential conditions: unstable and permeable rocks, steep slopes, destabilized material entrained by water rainfall or snowmelt and lack of vegetation.

Fig. 2: Image of the former mining exploitation from Călimani

2. Determinations of pH

The analysis of samples collected along the hydrographic network, draining the mining area, resulted in pH values between 2.40 and 4.40, while analysis of soil samples resulted in pH values between 3.20 and 6.80. Samples of water collected from puddles from the top of the quarry and waste deposits exhibited the most acidic pH values (table 1).

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Due to the continuous impact of environmental factors, acidic waters are produced, migrate and contaminate surface and groundwater. The high acidic water confirms the intensive acidity of waste dumps, due to the reactivity of the contained sulfide in the presence of water and oxygen.

Table 1: pH values of water and soil samples

Water samples	pH	Soil samples	pH
W1	2.40	S1	3.20
W2	2.95	S2	3.90
W3	3.60	S3	4.80
W4	4.40	S4	6.80

After analyzing the results, we can state that the water and the soil samples collected near the mining area have a very acid pH, incompatible with the aquatic life. We also observed that, following the seasonal water level rise, the sensitive vegetation at the bank of the stream was heavily affected, especially the adjacent coniferous species (Fig. 3).

Fig. 3: Effects of water acid pH from Neagra Şarului stream on the vegetation surrounding the mining area

It is also worth mentioning and very alarming that in an inhabited village like Neagra Şarului, the pH of the water crossing the settlement is around 4.00. At the entrance of Neagra Şarului village, deposits of sediments from the mining area can be observed, due to the development of a natural dam (Fig. 4). Soil samples collected from the mining area had also disturbing acid pH values, which explains the lack of vegetation.

Fig. 4: Deposit of sediments near Neagra Şarului village

We also discovered signs of potential acid rains, as acid rains attack plants, first of all their leaves (by blocking the respiratory system and disrupting the processes of photosynthesis), but also the roots of trees (by neutralizing soil nutrients). The high concentrations of sulfur dioxide can cause acute injury to leaves as foliar necrosis, even after a relatively short exposure time (Fig. 5). The sulfur is discharged into the air as sulfur dioxide and sulfur trioxide; and these in combination with rainwater form sulphuros acid and sulphuric acid, respectively.

Fig. 5: Effects of acid rains over the leaf lamina

The release of acidic solutions from quarries and waste dumps depends on the presence of sulfides within the rock structure as well on their reactivity in the presence of water and oxygen. Drainage of acidic waters from different sources varies and depends on local prevailing environmental conditions. The release of mine waters can result in the contamination of both groundwater and surface waters, resulting in long-term environmental pollution (Ditoiu and Ciobanu, 2002; Ştumbea, 2010).

3. Conductometric determinations

Conductivity is the property of the solutions to allow electric current to pass them through. Conductivity changes when ions of different substances (salts, acids, bases) are in contact with the water; as a result, a high concentration of ions in the analyzed solution will generate high conductivities. Conductivity, in the case of aqueous solutions, is strongly influenced by the concentration of the present substances, being used as an indicator of the degree of mineralization of water (Naşcu and Jantschi, 2006).

Analysis of water samples collected along the hydrographic network resulted in conductivity values between 0.3750 and 0.0503 $\Omega^{-1}m^{-1}$, while analysis of soil samples indicated conductivity values between 0.0895 and 0.0096 $\Omega^{-1}m^{-1}$. Samples of water collected from puddles from the top of the quarry and waste deposits exhibited the highest conductivity values (table 2).

Table 2 Conductivity values of water and soil samples

Water samples	Conductivity / $\Omega^{-1}m^{-1}$	Soil samples	Conductivity / $\Omega^{-1}m^{-1}$
W1	0.3750	S1	0.0895
W2	0.3350	S2	0.0596
W3	0.1503	S3	0.0456
W4	0.0503	S4	0.0096

The standard value of the conductivity of drinking water is between 0.0005 and 0.05 Ω-1 m-1, previous studies indicating that high conductivity values can be an evidence of water contamination.

4. Turbidity determinations

The turbidity is an optical scattering of the luminous flux passing through a fluid medium containing particles in suspension or in colloidal state. Determination of turbidity is based on the Tyndall effect according to which murky water becomes bright when crossed by a light beam, because the suspended particles diffuses sideways some of the light rays (Naşcu and Jantschi, 2006).

Table 3: Turbidity values of water and soil samples

Water samples	Turbidity /FTU	Degree of turbidity
W1	317.70	40
W2	306.66	40
W3	253.84	33
W4	76.92	10

Maximum allowable turbidity value for drinking water is 5, higher values indicating contamination. All of our samples presented organic and inorganic particles in suspension, and some of them didn't form sediments in a period of 24 hours. The high turbidity of the samples (Table 3) demonstrates the presence of water contaminating elements, which may present even an epidemiological hazard because particles in suspension can be a support for pathogenic germs.

5. Chemical elemental analysis

The elemental analysis of water and soil samples was performed according to the stipulation of Romanian (Farmacopeea Română, 10th edition) and European Pharmacopoeia (European Pharmacopoeia, 7th edition), to which other specific analytical chemistry reactions were added in order to highlight the presence of potential elements (Săndulescu et al 2007).

The quantitative determination of the detected impurities requires further investigation and determinations, using modern instrumental techniques.

Numerous sulfur deposits were found on the rocks near different water flows and especially in the ford of Neagra Şarului stream (Fig. 6).

Table 4 The results impurity control limits of water and soil samples

Impurities	W1	W2	W3	W4	S1	S2	S3	S4
Acidity	+	+	+	+	+	+	+	+
Ammonium	+	+	-	-	+	-	-	-
Calcium	+	+	+	+	+	+	-	-
Chlorine	+	+	+	+	+	+	+	+
Iron	+	+	+	+	+	+	+	+
Heavy metals	+	+	+	+	+	+	+	+
Magnesium	+	+	-	-	-	-	-	-
Nitrate/Nitrite	+	+	+	+	+	+	+	+
Sulfates	+	+	+	+	+	+	+	+
Sulfides	+	+	+	+	+	+	+	+
Sulfites	+	+	+	+	+	+	+	+
Zinc	+	+	-	-	+	+	-	-

Fig. 6: Sulfur deposit on the rocks of the Neagra Şarului stream ford

The total water hardness was determined by a complexonometric method, using complexon III at a pH of 9-10 (ammonia buffer), and eriocrom T as indicator (Săndulescu et al 2007). The allowed hardness value for water is between 5 and 10 ° Ge. The hardness of the collected samples is situated between 10 – 140 ° Ge, demonstrating the presence of divalent metal ions (especially calcium and magnesium ions).

6. Microbiologic analysis

In order to study qualitatively the microbiological contamination of the samples we seeded the samples on solid culture mediums distributed in Petri dishes, the culture media were incubated in a bacteriological oven at a temperature of 37 ^{0}C for 48 hours, and after incubation the culture characters were studied and the possible biochemical characteristics of microbial cultures were evaluated.

In order to perform the seeding, the sampling process was conducted under aseptic conditions; for sampling we used a bacteriological loop, made of a platinum wire, and mounted on a support. For an easy identification of different groups of microorganisms, different specifics media cultures were used.

Samples were seeded on four different culture media: Sabourraud, blood agar, lactose agar and Chapman; and also twelve staining tests for Gram positive and Gram negative bacteria were made. The inseminated dishes were incubated and analyzed respecting the protocol for each microorganism groups.

Since the pH of collected mine waters and from local rivers was too acid, it has not allowed the development of pathogenic microorganisms, consequently all the results of seeding culture media were negative.

However, we cannot consider that the water samples are totally free of microorganisms, because mine waters with significantly high content of sulfur, nitrites, iron and heavy metals are a favorable environment for development of chemoautotrophic bacteria (Ulea and Lipşa, 2009).

A study analyzing the eventual presence of microorganism in mine tailings, detected the presence of some aerobic and anaerobic nitrogen-fixing bacteria (eg: *Azobacter chroococcum, Clostridium pasteurianum*), which are involved in nutrient cycles, creating the premises for an ecological reconstruction for degraded soils resulted from the mining activities (Ulea and Lipşa, 2009).

Conclusion

Our preliminary analysis demonstrates once more that the pollution potential in the Călimani Mountains former mining area is extremely high, even after a period of more than 15 years since the mine closed. Thus, the main objective should be to reduce acid mine drainage generation, which has severe impact on the quality of surface and groundwater, and thus on the whole environment.
The extent of the pollution impact on living natural structures is more than obvious even to the naked eye. Following the mining activity, the forest vegetation has been affected, both a direct impact through vegetation removal, and also an indirect one, materialized in the devastating effects on the forest situated near the slopes of the waste dumps, because of highly acidic waters, which wash the dumps.

It is a worrying situation that the water from Neagra Şarului stream, in which the waters washing the waste dumps flow, is characterized by a strong acidic pH (2-4), high mineral total load (high conductivity), increased turbidity, hardness, and high content of sulfates, sulfites, iron and heavy metals. The soil quality has also undergone significant changes in the mining area; demonstrated by its acidic pH, by the presence of numerous chemical impurities and also by the lack of vegetation in the proximity of the mine. We also noticed evidence of acidic rains, due to the high content of sulfur of the tailing storage, which after photochemical reactions is oxidized into sulfur dioxide, and subsequently in sulphuric acid aerosols; as evidenced on the effects on vegetation in the surroundings of the mining area.

No pathogenic microorganism could be detected in the analyzed samples, which can be correlated with the high acidity of the samples.

Happily, although late, the area of the Călimani Mountains became a national park, enjoying the legal protection of its precious nature. Although the former exploitation occupies a small part of its territory, its dramatic sight is a strong reminder of past mistakes that hopefully won't be done elsewhere in Romania.

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Gabriel Hancu contributed at field research, project coordination, photography and have written the article in English.

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Enikő Barabás contributed at the microbiological analysis.

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Recent mutations in the social-economic structure of Dolj county's population. Gender differentiations

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Abstract

The article sets out to explain the changes that occurred in the social-economic structure of Dolj county's population, taking into consideration the differences between the male and the female population. The present analysis is based on the processing and mapping a large amount of statistical data from the 2011 population census.
Identification and analysis of territorial imbalances were made on the basis of several significant indicators: the general activity rate, the economic dependency ratio, the unemployment share within the occupied population, the occupied population share in agriculture and other economic activities, the level of education of the active population.
The results of this research pointed out some significant differences between the urban and the rural areas of Dolj county, but also between the male and female population.

Keywords: *active population, unemployment, structural changes, male/female population, Dolj county, Romania*

Rezumat. Mutații recente în structura socio-economică a populației județului Dolj. Diferențieri pe sexe

Articolul explică schimbările care s-au petrecut în structura socio-economică a populației județului Dolj, luând în considerare diferențele între populația de sex masculin și cea de sex feminin. Prezenta analiză se bazează pe prelucrarea și cartarea datelor statistice obținute la recensământul din anul 2011, la nivelul județul Dolj.
Identificarea și analiza dezechilibrelor spațiale au fost făcute prin intermediul a câtiva indicatori economici semnificativi: rata generală de activitate, raportul de dependență economică, rata șomajului, ponderea persoanelor ocupate în sectorul primar sau alte activități ale economiei, nivelul de educație al populației active.
Rezultatele cercetării au pus în evidență câteva diferențe notabile între ariile urbane și cele rurale ale județului, dar și între populația masculină și cea feminină.

Cuvinte-cheie: *populație activă, șomaj, schimbări structurale, populație de sex masculin/feminin, județul Dolj, România*

Introduction

Similar to other former socialist European countries, the 1989 changing political system had major disruptive consequences on Romania's economic development, marking the shift from an over centralized, autarchic orientation of development to market economy. The pronatalist policies of the former were intended to reach the proper population growth during the late 1960s, with particular reference to active participation; achieving urban transition, mostly involving young people and social desirability of full employment were major tenets of communist ideology. On the other hand, post-communist economic restructuring was complicated by unemployment, capital shortage and inflation (Turnock, 1997, 2002, 2006, Vasile&Ioan-Franc, 2008).

Female population has been unequally affected by the transition period as compared to the male population, usually being over-represented in terms of negative economic transformations (Aslanbeigui et al., 2005).

Given the context of a traditional agricultural area, the process of forced industrialization often generated intraregional disparities in Oltenia because of the targeted investments in regional centers to the detriment of small towns, isolated in rural areas, or rural settlements (Ianoș, 1987, 1994, 2010, Muntele&Iațu, 2002, p. 44).

Labor market potential and dynamics is highly influenced by the natural growth of the population and migration intensity (Geografia României, II, 1984, p. 91). To this effect, identifying the changing variables of each group of persons (demographic, social, ethnical, educational, religious, economic) should underlie the social-economic development of any given territory as it allows to define the internal functional principles governing demographic the dynamics of the population (Vert, 2001).

Study area: demographic and economic overview

Dolj county represents a component of the South-West Development Region, Romania, along with Mehedinți, Gorj, Vâlcea, Olt, counting 0.32 per cent of Romania's population and over 31.8 per cent of the region's population at the general census of population and housing in 2011. The territory of Dolj county comprised 111 territorial basic units (the lower LAU level-LAU level 2, formerly NUTS level 5), of which 7 towns and 104 communes, Craiova, Băilești and Calafat as municipalities.

A brief analysis of the population's spatial distribution in Dolj reveals the fact that over 52 per cent of the county's population concentrates in the urban settlements, which ranks Dolj lower than the national urbanization index (53.8%), but definitely higher than other counties' in the South-West Development Region. The region's headquarters, Craiova ranks first and had a very stable position,

The highest demographic densities-over 60 inhab/sq km (Fig. 1) point out the existence of urban poles and their surrounding areas induced by natural constraints and economic development favourability: Filiași, Craiova, Bechet-Dăbuleni (an area of higher densities along the Jiu river), Calafat on the terraces of the Danube and Băilești, Segarcea, on inter-flows (Cucu, 1970, Ianoș, 1987, Erdeli&Cucu, 2007, Grecu et al., 2008, Iordache, 2009).

As seen in Fig. 2, most of Dolj county's settlements registered high decreasing rates of their population between the last two censuses, as a consequence of their negative natural and migratory balance, which primarily emphasize the continuous demographical ageing of the rural population, but also evidently influences workforce potential.

The increasing demographical rates characterize, on the one hand, the settlements surrounding Craiova, affected by obvious consequences of the suburbanization process: Șimnicu de Sus (+4.5%), Podari (+7.1%), Malu Mare (+12.8%), Cârcea almost doubled in population, while the cases of Lipovu (+4.8%) and Cerăt (+8.05%) distinguish by their atypical ethnical structure (in 2011, over 33% of their population is represented by the Rroma community, which is characterized by higher birth rates). Insular testifying for a significant hierarchic innercy as a result of the few small and medium-sized towns, less competitive centers in the monocentric urban system of Oltenia (Șoșea&Popescu, 2014, p. 101, Ianoș, 1987, p. 46). areas come apart in the territorial structure that would either represent islets of development in the North-Eastern part of the county, more stable from the point of view of the demographical and economic indices, while in the North-West and in the South, along the Danube, the problem of adaptability in a weaker region reflects the poor infrastructure, the economic backwardness and the rapid decline of several communes registering demographical ageing even before 1990, because of urban migration and the early demographical transition process (Rey et al., 2006, p. 41, Geografia României, II, 1984, p. 92).

In the post-communist period, Dolj county has undergone major economic restructuring processes which had significant repercussions on the dynamics and economic structure of the population, but also on the functional and territorial structure of the settlements. Still, a predominantly agricultural county, with a traditional economy and a high share of rural population, Dolj suffered less from the 2009 economic crisis than other developed counties in Romania as the current overall economic situation overlapped on a previously low development level, which only brought an average vulnerability to crisis (Goschin et al., 2010, Avram & Pociovălișteanu, 2011).

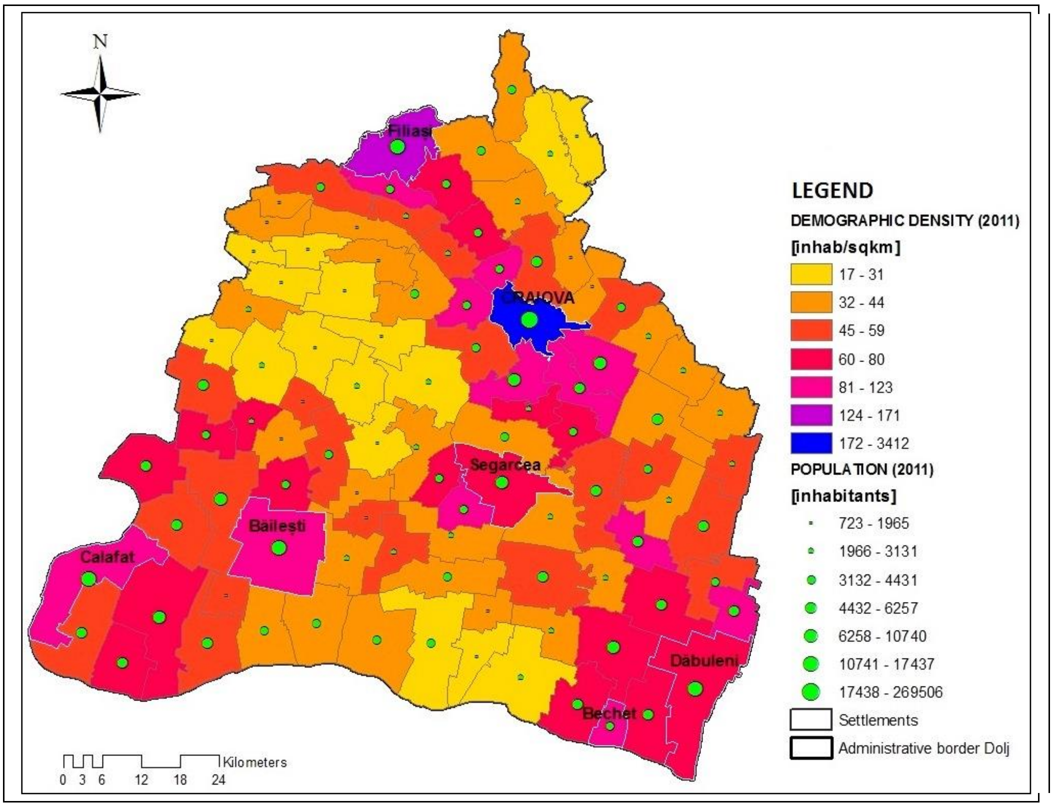

Fig. 1: Basic demographic characteristics of Dolj county in 2011

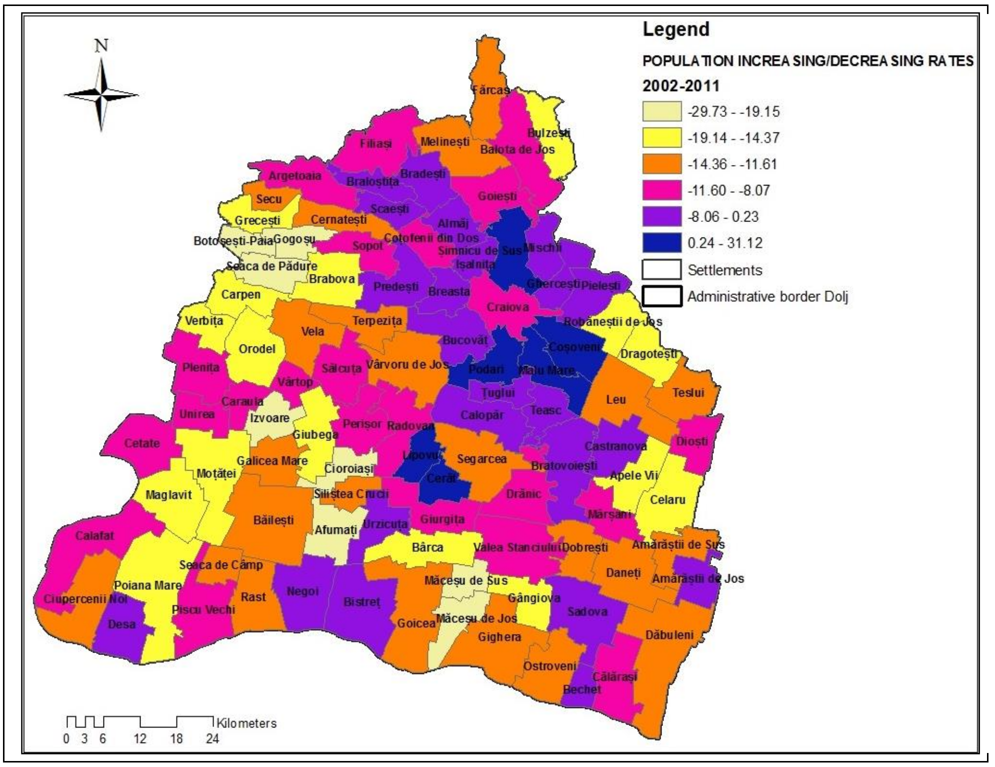

Fig. 2: Population increasing/decreasing rates in 2002-2011 period

Discussions

General activity rate.

Both in terms of volume and structure, the labour market in Oltenia has undergone significant changes in the post-socialist period, mainly as a result of the deteriorating demographical system (ageing population and external migration), doubled by the effects of the economic crisis of 2008 (Popescu, 2009, Rabontu&Costescu, 2013).

While the active population in Oltenia is decreasing in recent years for various reasons, in 2011, there are sharp variations in levels of general activity rate in Dolj county (43.2%), ranking between 21.9% in Catane, 22.4% in Sălcuța and 54.4% in Coțofenii din Dos, 50.2% in Calafat, 50.1% in Daneți.

More than half of the active population lies in the urban settlements and over 80% of it lives in Craiova. In 2011, while urban areas in Dolj county represent about 56.8% of the working population, only 43.9% of the employed population lives in rural areas.

Albeit the gender ratio is 51:49 in favour of females, only 44% of the active population is represented by females in Dolj. Moreover, there are certain spatial differences, the female activity rate registering a considerable lagging as compared to the male population: 49.7% vs 37% at the county level, 54.5% vs. 40.2% in urban areas and 44.5% vs. 33.3% in rural areas.

The most important difference (Fig. 3a, Fig 3b) is represented by higher general activity rates among the male population, but also a much higher discrepancy between the male and female population activity rates in the rural areas. In Apele Vii, for example, the activity rate among the male population registered 55.7%, while the activity rate among the female population was only 35%. This comes to confirm the traditionalism of a secular rural population, reinforcing cultural and historical views regarding the role of women in a rural society (Aslanbeigui et al., 2005).

As compared to the county's, male activity rates register lower values in 64% of the cases, while female activity rates register lower values in 78% of the settlements, which is also reflecting the high degree of demographical ageing: In Sălcuța, for example, only 16.7% of the total male population and 14.3% of the total female population is active (15-64 years).

In fact, this discrepancy predominantly characterizes the rural areas of Dolj county, in which 35.2% of the male population and 26.9% of the female population is active, while in the urban areas, almost 53% of the male population and 40% of the female population is active (15-64 years).

A particular situation is recorded in what concerns the highest rates of activity within the female population, predominantly concentrated in the area surrounding Craiova, which is an absent spatial characteristic within the male population.

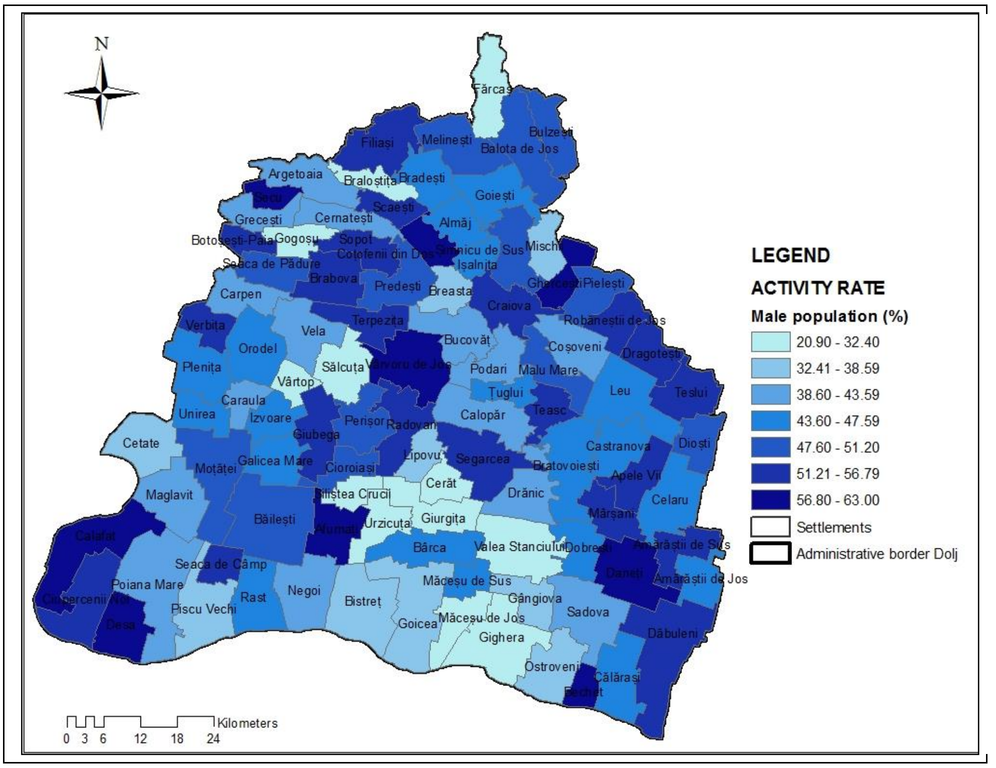

Fig. 3a: General activity rate among the male population of Dolj county in 2011

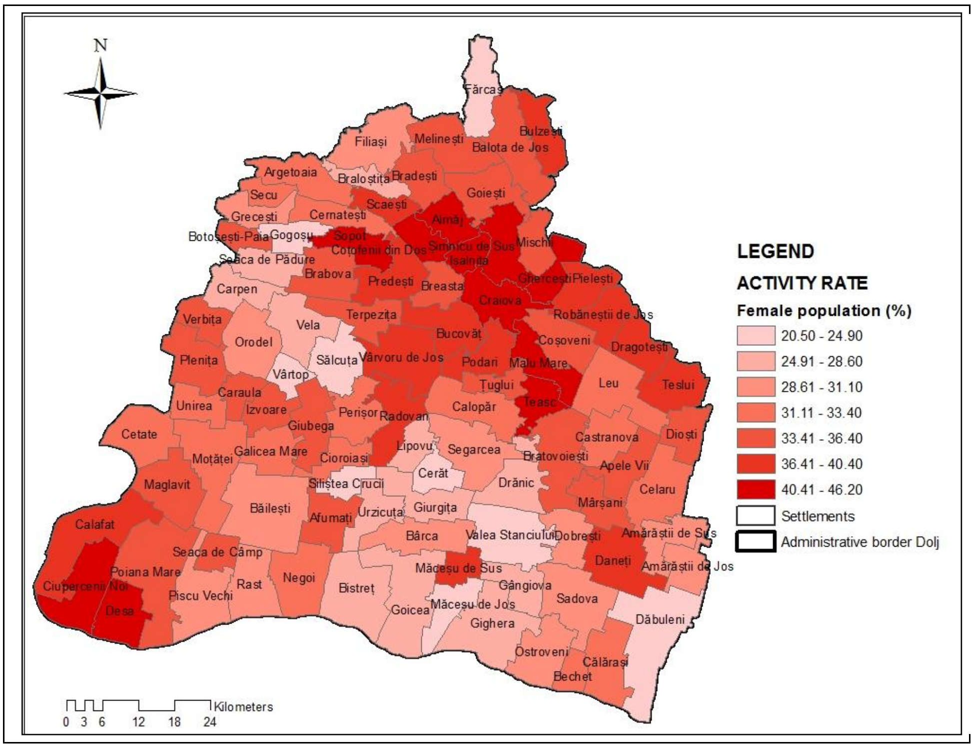

Fig. 3b: General activity rate among the female population of Dolj county in 2011

Moreover, in the age groups activity curve (Fig. 4) the male activity curve recorded a much higher percent as compared to the female activity curve especially in the lower and upper parts of age groups, the differences being even more pronounced within the rural settlements. This is a consequence of the fact that in rural areas, both men and women are active on the labour market earlier that in urban areas and also, the period spent studying increased for both sexes. Regarding the adult population, the male activity rates are

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obviously higher than the female ones, especially for people aged 30 to 35 years. Also, both male and female active population are larger and remain active for a longer period in the rural areas compared to the urban ones.

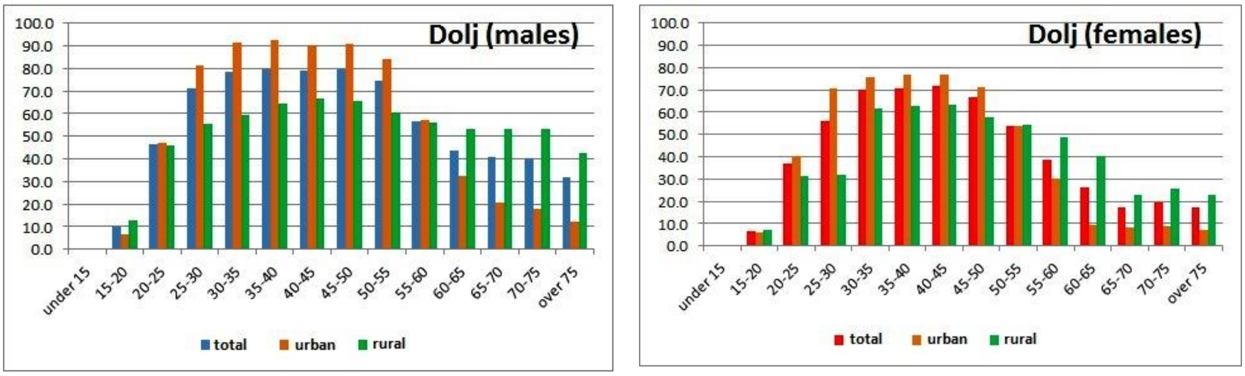

Fig. 4: Gender differentiations in the age-groups activity curve in 2011

Economic dependency ratio.

The poor economic development of the area comes into notice at the same time through drastic economic dependency ratio of the population (Fig. 5). Its value exceeds 2000 inactive persons/1000 active persons in 21 of the total 111 territorial administrative units and in 4 settlements the economic dependency ratio overcomes 3000 inactive persons/1000 active persons.

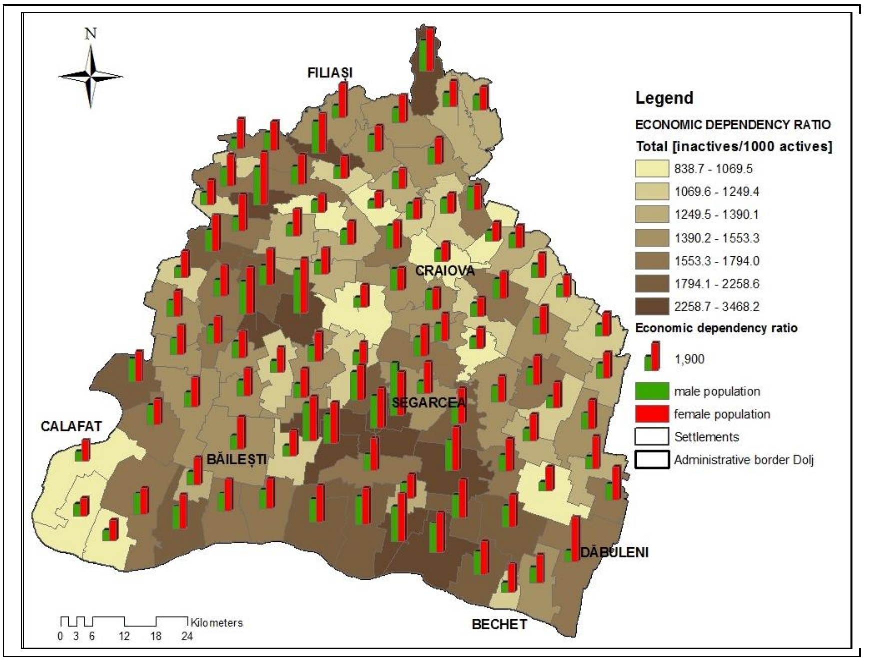

Fig. 5. Economic dependency ratio in Dolj county in 2011

Unfortunately, this situation reflects the ageing population of the rural population also confirmed by their high decreasing rates and the external migration of the active population that could alleviate the process. According to the 2011 census, 11,811 persons were registered as temporarily absent in Dolj county, of which 6,190 were males and 5,621 were females. 15,875 persons were registered as left for a longer period, which means 2.4% of the overall population of the county; again, most of them were men (50.4%). These numbers only partly prove the amplitude of the external migration process and even more relevant, the significant share held by the adult population, as most emigrants have ages comprised between 20-44 years. The most relevant aspects underlined by the high economic dependency ratio are related to the demographic desertification risk of rural communities that are economically and socially isolated and are no longer attractive for living, but also to labor force ageing which reflects the demographic ageing risk and depopulation of rural communities (Ungureanu et al., 2013, Avrămescu&Bâldan, 2011, Stegăroiu, C.E., 2013, Guran-Nica et al., 2010).

Once again, the ratio of economic dependency within the female population is higher than the ratio of economic dependency of the male population, as seen in Fig. 5: a ratio of 2947 inactive males vs. 4395 inactive women in Catane, 2179 inactive males vs. 3012 inactive women in Fărcaș, 2473 inactive males vs. 3419 inactive women in Măceșu de Jos. This not only certifies the idea that rural settlements are more economically deprived from demographic potential because of the ageing population, but also confirms a certain feminization of the rural area in Dolj, as a consequence of a their larger average life-time and important cohorts resulted during the pro-natalist vision of the communist period.

The structure of active population according to the economic activity.

As compared to the national economic activities, the counties comprised in the South-West development Region share large percents of the active population occupied in agriculture (Zaharia&Bălăcescu, 2012, Zaharia&Oprea, 2013). The structure of the active population by gender and sectors of the national economy in 2011 (Fig. 6a and 6b) confirm the rurality and weak economic development of Dolj, marked by very high percents of the active population in the primary sector (often over 70% of total assets in the Western part of the county).

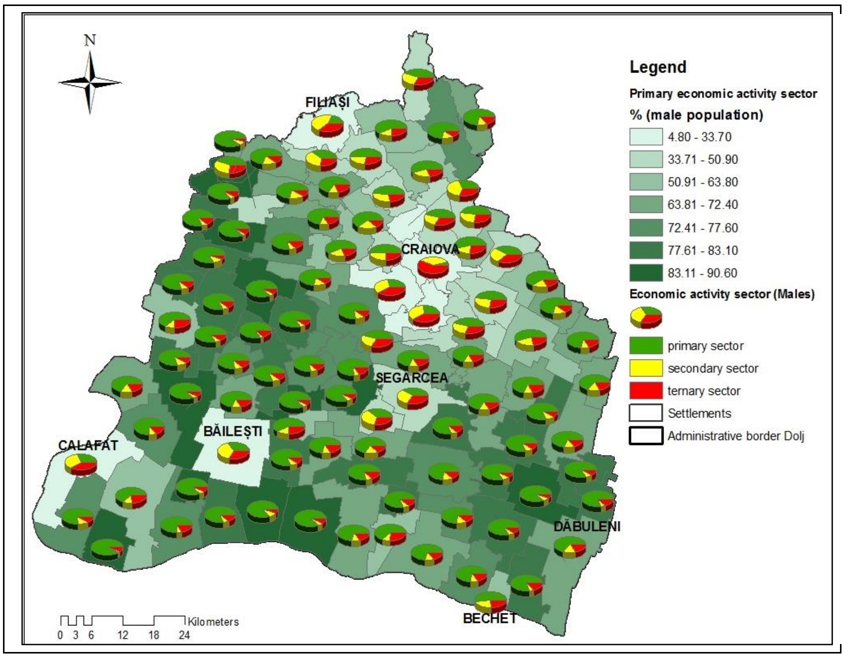

Fig. 6.a: Male population structure according to economic activity sectors in 2011

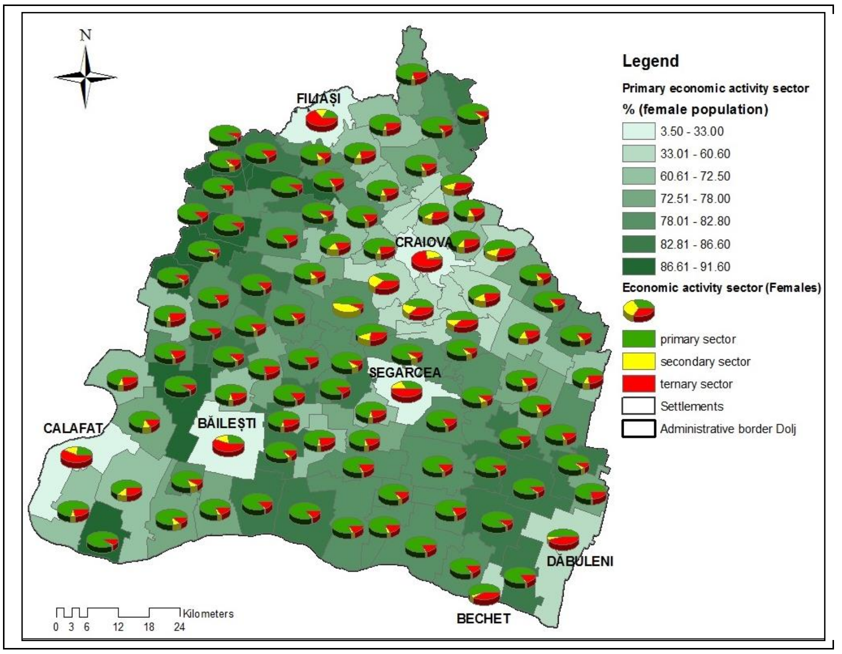

Fig. 6.b: Female population structure according to economic activity sectors in 2011

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According to its natural potential, the settlements lying in the north-western part of the county, namely covering the higher altitudes of the Bălăcița Piedmont are more demographically and economically fragile. This lies among the isolated geographical spaces lacking the territorial synapses which could connect them to a polarizing center (Peptenatu et al., 2012).

Another important aspect is that of occupational mobility during transition, as a significant part of the population was characterized by descending mobility experiencing unemployment or had to retire before time, which mainly reflected in the raise of population weight implied in agriculture (Gherghina et al., 2007, Pricină&Ilie, 2011). Thus, there are two trends regarding the occupational mobility in the post-socialist period: a process of deindustrialization and a process of ruralisation accompanied by the growth of tertiary activities as a refuge for the industry laid off population (Jula&Jula, 2013).

Still, the predominance of the primary sector in Dolj also reflects the low potential of economic diversification and weak adaptability to market economy as a consequence of past demographic and political-economic changes in southern Romania which led to vulnerable socio-economic and agro-ecological systems (Fraser&Stringer, 2009).

In the current context, the risk of desertification, registered as a result of deforestations, high temperatures and low precipitations (Petrișor&Petrișor, 2014, Bălteanu et al., 2013, Prăvălie, R., 2013, Petrișor, A.I., 2012) might be contributing to a low performance of an economic sector which is predominant, but archaic, poorly mechanized and demographically unsustained (because of the high percentage of elderly people and foreign migration of agricultural workers, especially to Spain: more than 3,300 persons temporarily absent and over 3,400 persons who left for a longer period of time, in 2011 in favour of this destination, according to general census).

Oltenia has also experienced a decentralization in industry, along with a change in structure. The lowest shares of the active population in the secondary sector is registered in Desa (only 3%) and in the tertiary in Desa, Seaca de Pădure, Seaca de Pădure, Daneți, Amărăștii de Sus, Carpen, Cernătești, Întorsura, Moțăței, Negoi, Secu (below 10%).

Also, for most of the settlements in Dolj, we can find a more significant share of the male population working in the primary and secondary sectors, but also a higher proportion of female economically active population in the tertiary sector of the economy (Fig. 7).

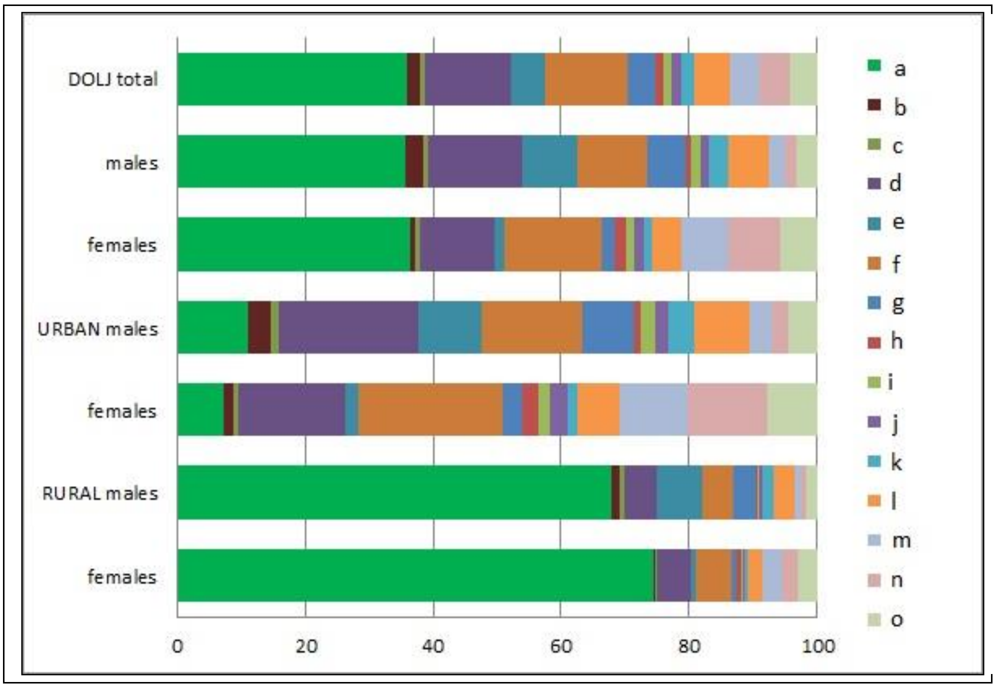

Fig. 7. The structure of the employed population in Dolj county (2011)
a – agriculture, forestry, fishing; b – electricity, gas and heat energy supply; c – water supply, sanitation and waste management; d – processing industry; e – civil engineering; f – commerce; g – transportation and deposits; h – hotels and restaurants; i – information and communication; j – professional, scientific and technical activities; k – administrative and support services; l – public administration and social insurance; m – education; n – health services and social security; o – other activities.

In both cases, urban poles outline as more economically developed centers, although quite discrepant between Craiova and other smaller urban settlements. As for the triangular diagram expressing changing economic functions of Craiova (Fig. 8), from a former industrial city, nowadays Craiova has a raising percent of the population working in the ternary (also stated by Bădiță, 2013).

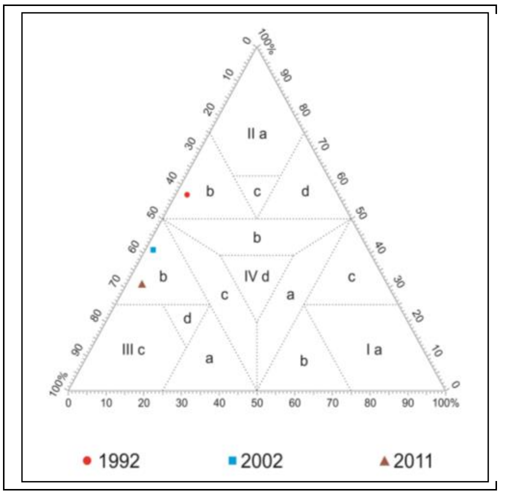

Fig. 8. Triangular diagram expressing changing economic functions of Craiova in the post-communist period

It is also important to underline that fact that while in Craiova the percent of the primary sector remains low (4.2% in 2011), in other towns' cases, the increase in the number of active people involved in agricultural activities in many small towns should not be neglected, as the phenomenon dates back in 2002 (Popescu, 2005).

The level of education.

In what concerns the level of education (Fig. 9a, 9b) most of the working population has secondary education (secondary education, vocational and apprenticeship), most university graduates working in the tertiary (80.8 %) and most illiterate persons are employed in the primary sector of the economy and in the same time, most of them are females.

Significantly influenced by contrary education policies before and after the 1990, another peculiarity of the area is represented by fewer persons with low education in the age group 25-34 years, but also by the lower share of population with tertiary education in the upper age groups.

Together with a poor infrastructure, the low level of qualification of a significant part of the population, particularly in rural areas, is an obstacle to attracting investments and development (Pricină&Ilie, 2011). In the rural areas, the share of persons with primary education and no education is in direct correlation with the ageing ampleness and poor economic development, illiteracy rates reaching 8.6% in Caraula, 4.5 in Vârtop, 4.2% in Maglavit. The female population has a more defavourable situation as more than 8% of the females living in Pleșoi are illiterate.

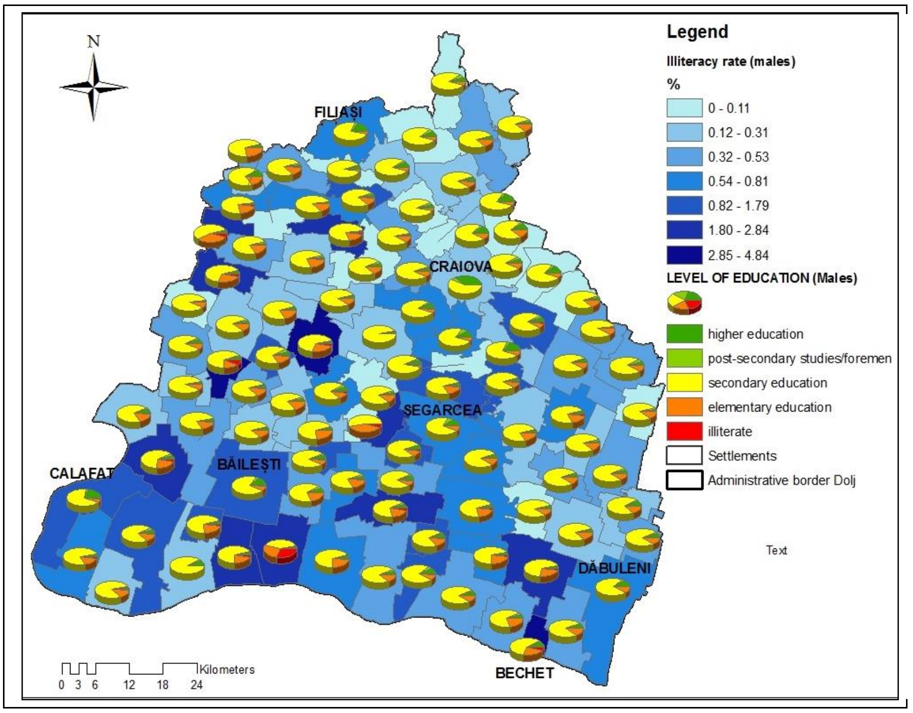

Fig. 9.a. Level of education and illiteracy rate among the male population of Dolj county in 2011

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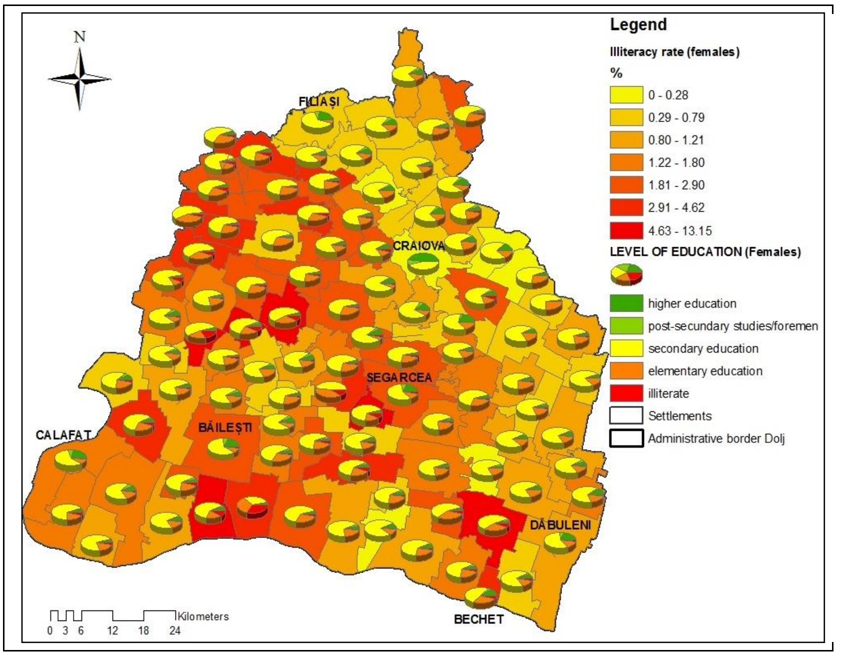

Fig. 9.b. Level of education and illiteracy rate among the female population of Dolj county in 2011

The unemployment rate.

Between 1990 and 2012, employment in Romania has decreased by over 2.5 million persons (nearly one quarter of the total employment), of which 1/5 means unemployment growth and over 4/5 stand for changes due to demographic reasons and net foreign migration (Jula&Jula, 2013).

As lately the high unemployment rates have maintained after the economic crisis of 2008, the problem of structural unemployment is arisen and difficult to manage when governmental policies, disconnecting educational system and low economic potential of the area concur as stressors of the entire system's functionality.

In 2011, the unemployment rate in Dolj county (Fig. 10) follows the economic pattern of the entire county, the highest values of unemployment being registered in Cerăt (15.6%), Coțofenii din Față (14.9%), Băilești (13.2%), Braloștița (12.1%), Filiași (12%), Bechet (11.4%).

In most of the analyzed settlements, the unemployment rate within the male population is higher than within the female population (eg. Botoșești Paia: 6.6% versus 5.8%, Braloștița: 14.4% vs. 9.2).

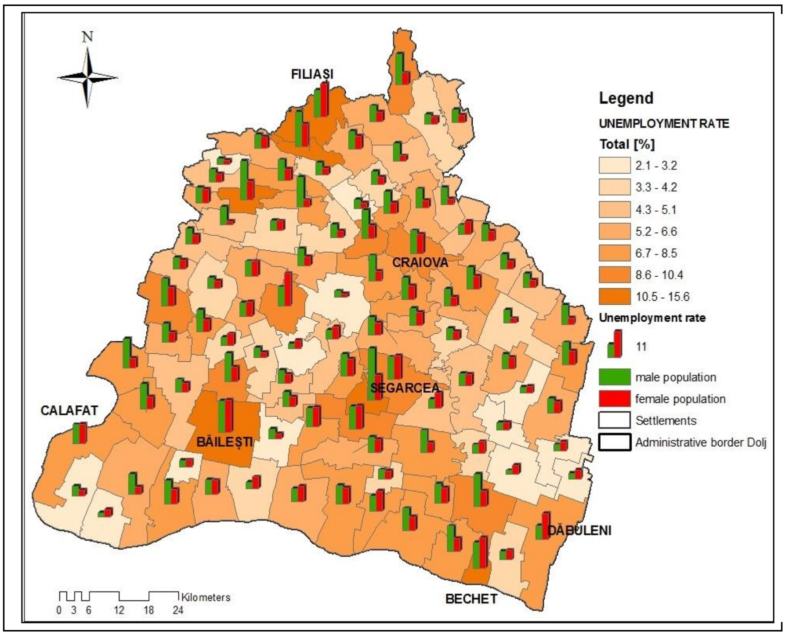

Fig. 10. The unemployment rate in Dolj county in 2011

Conclusion

The changes in the social-economic structure of Dolj county's population reflect several territorial disparities that express on the one side the pronounced agricultural character of Oltenia's largest county in what concerns the demographical and workforce potential, but also the poor economic performance that has been attributed to the exhaustions of peasantry after half of century of central planning.

The structural changes of economy, the poor quality of the infrastructure, the predominance of subsistence agriculture, the decreasing numer of people of economically productive age are just a few of the negative consequences registered in Dolj.

Above all, the female population living in Dolj county registers a rather unfavourable status of the economic indices as compared to the male population as a consequence of their informal-sector activities in a traditional, stereotypal and quite inflexible societal environment.

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The Romanian urban system – an overview of the post-communist period

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Abstract

The Romanian urban system reveals both the influence of the central-based inter-settlement relations and the influence of the historical conditions (persistence of regional influence centres inside the historical provinces). Its 12 urban sub-systems are formed of towns that gravitate towards the Capital city - Bucharest and the second and third-rank cities. The Romanian urban network appears to be insufficiently developed in terms of number of towns versus the total population and surface. In 2012, there were 320 towns, when 400–450 were expected to be as referred to the overall surface of the country. This proves an excessive polarisation area/town ratio compared to other West and Central European countries. Under the socioeconomic transformation determined by the fall of the communist regime, profound changes in terms of intensive spatial development (urban/suburban sprawl, metropolisation etc) were experienced, similar to other post-communist urban systems. Subsequently, the EU accession opened the former socialist cities to new challenges related to urban phenomena, turning them into points of connection at European level by promoting cohesion and competitiveness for a polycentric metropolitan development. The paper attempts to summarise the urban development in Romania and the particularities of the Romanian urban system in relation to the legislative and political context of the post-communist period and the EU accession.

Keywords: *Romanian urban system, urban sprawl, metropolisation, European Union*.

Rezumat. Sistemul urban românesc – o perspectivă asupra perioadei post-comuniste

Sistemul urban românesc relevă atât influența relațiilor inter-așezări bazate pe centralitate, dar și influența condițiilor istorice (persistența influenței centrelor regionale din provinciile istorice). Cele 12 sub-sisteme urbane ale României sunt formate din orașe care gravitează către orașul capitală – București și orașele de rangul doi și trei. Rețeaua urbană românească pare a fi insuficient dezvoltată din punctul de vedere al numărului de orașe comparativ cu populația totală și suprafața țării. În 2012 erau 320 de orașe, deși se estimau 400-450 raportat la suprafața totală a țării. Acest lucru dovedește o zonă de polarizare excesivă/ rată urbană comparativ cu alte state vest sau central europene. În condițiile transformărilor socio-economice determinate de căderea regimului comunist, au avut loc importante schimbări privind dezvoltarea spațială excesivă (dezvoltarea urbană/ sub-urbană necontrolată, metropolizare, etc.) similare cu alte sisteme urbane comuniste. Prin urmare, aderarea la UE a deschis pentru fostele orașe socialiste noi provocări legate de fenomenul urban, transformându-le în puncte de legătură la nivel european promovând coeziunea și competitivitatea pentru o dezvoltare metropolitană policentrică. Studiul încearcă să prezinte pe scurt dezvoltarea urbană în România precum și particularitățile sistemului urban românesc în relație cu contextul legislativ și politic al perioadei post-comuniste și aderarea la UE.

Cuvinte-cheie: *sistemul urban românesc, dezvoltarea urbană necontrolată, metropolizare, Uniunea Europeană*

Introduction

Over the last hundred years, most European countries have witnessed significant transformations related to territorial expansion, urban sprawl and development patterns (Patacchini et al., 2009) through different phases and processes such as: urbanisation, suburbanisation, deurbanisation, reurbanisation (counterurbanisation), and densification processes (van den Berg et al. 1982; Petsimeris, 2003; Antrop, 2004; ESPON FOCI, 2010).

These complex processes of territorial expansion affected most seriously the Southern European (Petsimeris, 2003) and former communist towns (Turnock, 1998; Soós and Ignits, 2003; Degorska, 2004; Ourednicek, 2007; Sykora and Ourednicek, 2007; Hirt, 2008; Leetmaa, 2008, Tammaru et al., 2009; etc.) characterised by a general model of expansion by linear tendencies of urban development along the main transportation axes as well as the appearance of residential areas outside the towns (Grigorescu et al., 2012).

In the present period, Romania's urban system is undergoing a process of restructuring, the urban phenomenon acquiring new dimensions and characteristics. Thus, the industrial town – the representative type of urban settlement, has largely been replaced by the polyfunctional and services type, a trend that met the country's major economic and social-political targets, set early in the Third Millennium, in line with Romania's integration into the European urban system. Another trend, this time in rural-urban evolution, was to raise communes, viewed as local polarisation cores, to town status. Consequently, between 2003 and 2011, a number of 53 settlements (out of the 60 granted town rank after 1989) were granted this position.

After the 90s, most of the post-communist Central and Eastern Europe countries faced an intense urban development through urban sprawl-related process in terms of restructuring physical morphology, changing the functional land-use patterns and socio-spatial structure of towns (Sykora and Ourednicek, 2007; Leetmaa, 2008; Grigorescu et al., 2012). Under the given circumstances, a wide range of socio-economic transformations which gave start to further phases of intensive urban/suburban expansion exerting high pressure upon the environment occurred. In Romania, after the fall of the communist regime (the post-1989 period), the urban system patterns and dynamics are mainly related to urban sprawl and suburbanisation process. On the other hand, a quantitative urbanization process, which was started in the 1950s, continued and resulted in the increasing number of town with environmental infrastructure, dwelling stock, as well as functionality and physiognomy resembled more to rural settlements (Săgeată, 2002).

THE ROMANIAN URBAN SYSTEM – GENERAL OVERVIEW

When referring to the Romanian urban system, the towns and the relationships developed between them (hierarchical dominance, subordination and competition) prevail. Its structure displays both the influence of the central-based inter-settlement relations, a tendency augmented throughout the 20th century, and the influence of the historical conditions (persistence of regional influence centres inside the historical provinces) (Grigorescu and Dumitrescu, 2010).

During the mid-20th century, the Romanian territory had a predominant rural-agrarian profile with a low urbanisation level (with up to 23.4% in 1948) due to its main physical-geographical features, the socio-economic development and the historical peculiarities. The beginning of the industrialisation process, which characterised the inter-war period, had triggered an intense urban development leading to the increase of towns number from 119 in 1912 to 142 in 1930 and 152 in 1948 (Urucu et.al., 2006).

The second half of the 20th century witnessed radical changes due to the policies which supported the economic and social development through two major transition periods: 1950–1960/1962 that marked the passage from the capitalist economy to the highly centralised plan-based socialist system, and the post-1989 period, when the socialist economy was replaced by the market system. Between 1950 and 1989, similar to other former socialist countries, Romania went through extensive industrialisation coupled with boosted urbanisation aimed at strengthening the national urban system (Urucu et al., 2006; Grigorescu et al., 2012). Therefore, the industrialisation process played a decisive role in the country's urban development, the *industrial town* becoming the most representative urban settlement type with an increased evolution (Dumitrescu, 2008). On the other hand, the investiture of towns with administrative centre status (county seats) attracted massive industrial investments and an oversized population and housing growth, which did not correlate with the development of the technical infrastructure and the supplying of urban services, which led to disturbances in the relations between towns, but also to a decrease in quality of urban life (Săgeată, 2003, 2006, 2010; Nae, 2006). As a compensatory measure to maintain an upward development trajectory of towns which were better placed in the urban hierarchy, but without taking part of this strongly industrialized pattern during 1950-1980 interval, they were assigned with the municipality status.

The evolution of the urban population mirrors the growing level of urbanisation and, at the same time, the proportion of townspeople within Romania's total population throughout the 20th century, from a mere three million at the beginning of the century to 11.4 million in 2002 (Fig. 1). The absolute increase between 1912 and 2002 was of 9,371,338 inhabitants at an annual average of over 104,126 persons. Within the interval spanning the two censuses, the urban population fell from 11,435,080 in 2002 to 10,858,790 persons in 2011, i.e. by 576,290 fewer people, at an annual decrease of 64,032 inhabitants (fig. 1).

After the fall of the communist regime, the Romanian urban system witnessed a continuous restructuring process imprinting new features and dimensions to the urban phenomenon through urbanisation and suburbanization processes (Grigorescu, 2010; Grigorescu et al., 2012). Therefore, facing the challenges of the new economic and legislative context, new type of urban-rural interface relationships occur. As a consequence, almost two-thirds of the national territory lies inside the active urban polarisation zones, thus favouring the development of metropolitan areas (Fig. 2). Additionally, the Romanian urban system has been enriched with new urban entities through the transformation of several communes, viewed as local polarisation cores, into towns (Law No. 351/2001, annex II-6.1). Therefore, over the 2003-2010 period, there appeared 53 of the total number of 60 settlements which were granted town status after 1989. In 2012, Romania's urban network incorporates 320 towns which, referred to the overall surface of the country (238,390 km^2), represents an excessive polarisation area/town ratio as compared to other Western and Central European countries (fig. 2).

Currently, the Romanian urban system is made up of 12 urban sub-systems which consist of towns that gravitate towards the Capital and the second-rank cities (Iaşi, Cluj-Napoca, Timişoara, Craiova, Constanţa, Braşov and Galaţi), as well as towards some third-rank towns (Baia Mare, Oradea, Suceava, and Deva). They are located in all the major relief units, thus pointing to a unitary geographical distribution in the territory, describing the ring-pattern of the Romanian urban system with an inside-to-outside display of large cities and medium-sized towns. Small towns are randomly disseminated (Ianoş, 1987, Ianoş and Tălângă, 1994; Grigorescu and Dumitrescu, 2010).

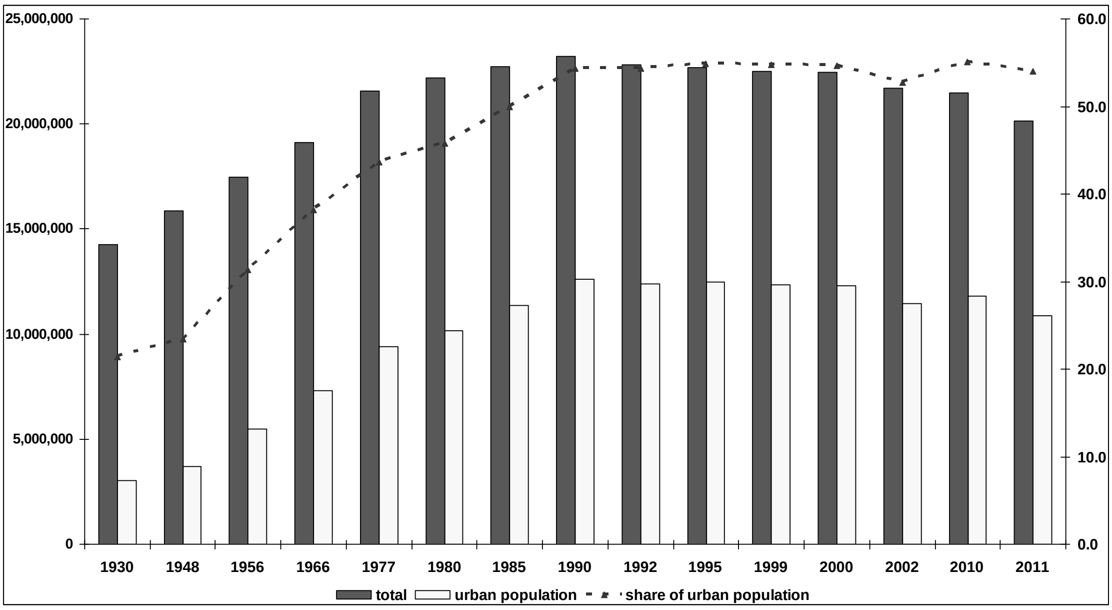

Fig 1. The urbanization process in Romania over the 1930-2011 period

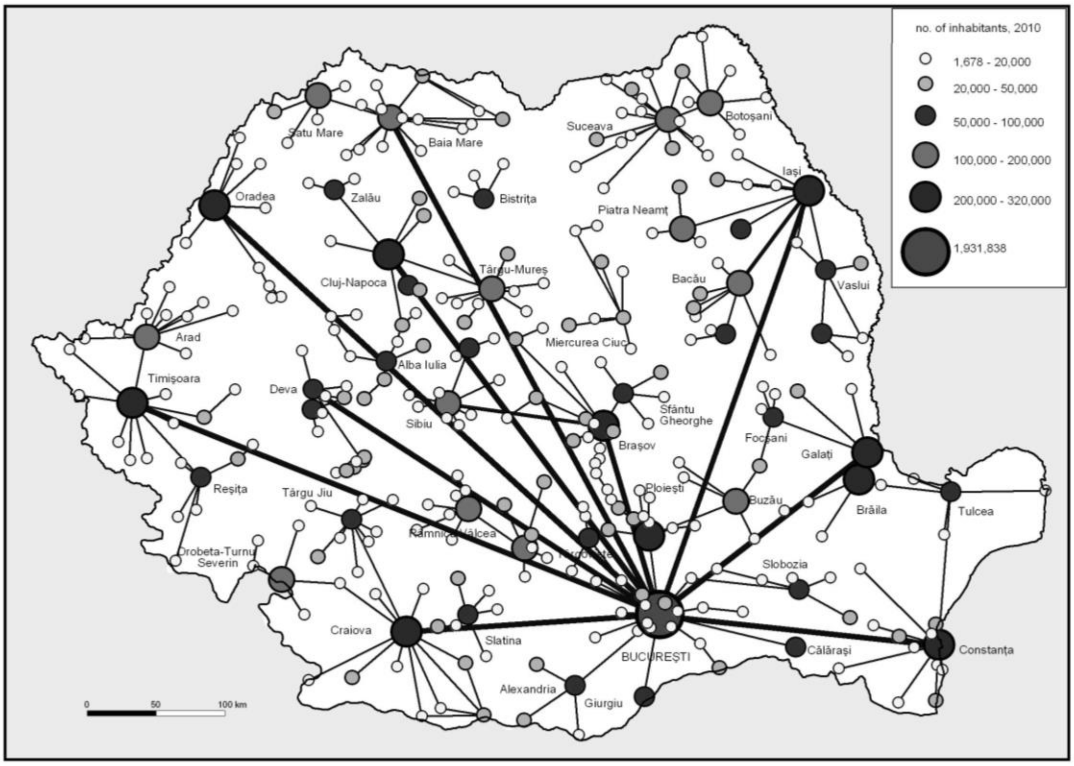

Fig. 2. The Romanian urban system, 2011

The classification of towns in the Romanian urban system includes: 225 small towns, 75 medium-size towns, 19 large cities and only one ***very large city*** (Bucharest) able to develop a metropolitan area in accordance with the requirements of both international and Romanian legislation in this respect (tab. 1, fig.3). Furthermore, there are 20 towns which have developed *metropolitan areas* mainly based on the favourable legislative context which supports metropolitan development rather by the joint character of the administrative units under the

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influence of a city than on the size of the polarization city (Grigorescu, 2010; Grigorescu and Dumitrescu, 2010), thus totalling nearly 7,500,000 (34%) inhabitants, out of which about 2,500,000 (11.5%) in Bucharest Metropolitan Area. The rest of population (22.5%) is unequally spread between the other 17 metropolitan structures.

Table 1. Towns / metropolitan areas in Romania grouped by demographic size

Town group/inh.	No. of towns in 2011	Towns which have developed metropolitan areas
Total towns of which:	320	21
Small towns (total), of which	**225**	
under 5,000	29	
5,000–10,000	105	
10,000–20,000	91	
Medium-sized towns (total), of which :	**75**	**3**
20,000–50,000	54	1 (Simeria)
50,000–100,000	21	2 (Deva, Hunedoara)
Large cities (total), of which:	**19**	**17**
100,000–150,000	7	3 (Baia Mare, Suceava, Târgu Mureş)
150,000–200,000	4	4 (Arad, Bacău, Piteşti, Sibiu)
200,000–300,000	6	5 (Brăila, Braşov, Galaţi, Ploieşti, Oradea)
300,000-400,000	2	5 (Cluj-Napoca, Constanţa, Craiova, Iaşi, Timişoara)
Very large cities:	**1**	**1**
Over one million	1	1 (Bucharest)

The Romanian urban system also includes 19 ***large cities*** with over 100,000 inhabitants (5.9% of the urban network), representing a distinct size-category dating back to the post-war period. At present, this category includes some of the county-seats, the industrial and service centres, the major national transport crossroads, academic and cultural centres. The geographical distribution of the large cities is fairly uniform exerting distinguished influence over the activities developed by the surrounding territories. Out of this category, only 17 had initiated the development of metropolitan areas, such as the first-rank towns (e.g. Cluj-Napoca, Timişoara, Iaşi, Constanţa, Craiova, Braşov, Galaţi, Ploieşti, Oradea, Brăila, Baia Mare etc.) with a strong influence on the surrounding areas in terms of space planning and urbanization dynamics.

The ***medium-sized towns*** (23.4% of the urban system) gather between 20,000 and 100,000 inhabitants. Given that some of them act as county-seats and are assigned with administrative functions, they play a major role in the national urban structure. The development of medium-sized towns goes back to Antiquity and the Middle Ages and was boosted by the 20th century industrial upsurge (e.g. Cugir, Codlea, Petroşani, Făgăraş, Reşiţa, Hunedoara, Mioveni and Săcele). The gigantic industrial units and the lack of functional flexibility make this category of towns highly vulnerable, their future evolution being tightly linked to their ability to correlate the industrial restructuring with the development of the tertiary sector.

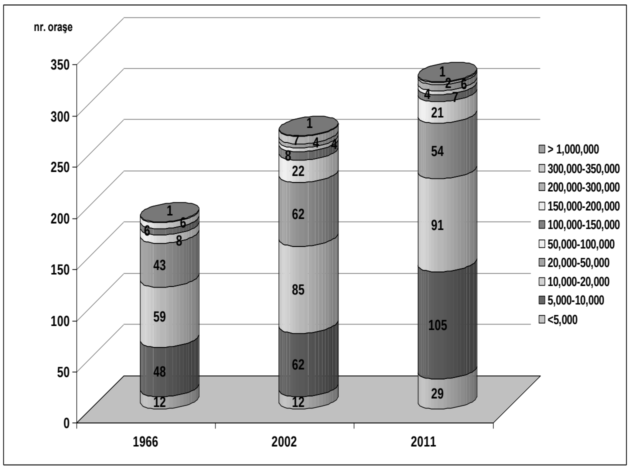

Fig. 3. Romanian towns grouped by demographic size (1966 - 2011)

The ***small towns***, even though they cover the largest part of the urban network (225 towns and 70.3% of total urban network), they have a reduced demographic potential (under 50,000 inhabitants). This category, which has proved to be the most stable one in time and space, includes numerous new towns, as well as towns with a long history documented in ancient or feudal times. During the socialist period, 128 rural settlements were assigned with town status, thus enlarging this demographic category (Grigorescu and Dumitrescu, 2010). This small towns grouping includes a large variety of functional types: industrial, agro-industrial, spas and health resorts, with a central position in the rural areas (Zamfir, 2007).

THE SPATIAL CONFIGURATION OF THE ROMANIAN TOWN SYSTEM IN THE TERRITORY

The national urban network and the relationships between towns in terms of hierarchical dominance as well as subordination and competition, shape the backbone of the national settlement system. Consequently, the shape of the Romanian urban system explains both the influence of the central-based inter-settlement relations, which were accentuated all over the 20th century, and the influence of historical conditions related to the consistency of regional influence centres inside the historical provinces (Bălteanu et al., 2006).

In Romania, the 12 urban sub-systems are constituted of towns that are attracted by some macro-territorial centres with own specific hierarchical structures and distinct inter-town subordination relations (Ianoş, 1987; Ianoş and Tălângă, 1994, Ianoş and Heller, 2006). Therefore, the delineation of the urban sub-systems and of the respective centres was achieved based on the hierarchical urban rank and the geographical position (e.g. the long distance from large regional centres aims at increasing the spatial polarisation of some local centres, such as Deva or Suceava, although they don't have a higher rank in the urban pyramid).

From the territorial point of view, for the joint space of Moldavia and Bucovina, the cities of Iaşi and Galaţi (peripheral towns) located near the border with the Republic of Moldova are the regional convergence centres. As a result, other two urban centres (Suceava and Bacău) may represent, due to a more favourable geographical position, coordinating centres of balance, able to take over the functions of the two regional cores and to redistribute them into the territory. Therefore, in the northeast, an urban sub-system polarized by Suceava and, secondary, by Botoşani was individualised, disadvantaged due to its peripheral setting. In the central part of Moldova a sub-system polarized by Iaşi and, secondary, by Bacău, located on an important road axis that links northern Europe and the Balkan Peninsula, through Kiev and Bucharest, was set up.

The Galaţi-Brăila urban binom, the only bipolar conurbation (in progress) in Romania has emerged as a polarizing core of the urban systems of three counties: Galaţi, Brăila and Vrancea. The space of Muntenia forms an excessive monocentric urban sub-system strongly polarized by the capital-city, Bucharest, towards which the urban systems of ten counties evolve: Ilfov, Prahova, Buzău, Ialomiţa, Călăraşi, Giurgiu, Teleorman, Argeş, Vâlcea and Dâmboviţa. In Dobrogea, another urban sub-system centred mainly on Constanta and secondary on Tulcea as polarizing cores, is delineating. In Oltenia the entire region is clearly polarised by the city of Craiova, towards which the regional towns of three counties (Gorj, Mehedinţi and Olt) together with their polarising areas gravitate.

The western part of Romania has three urban subsystems: a first balanced monocentred type system, mainly focused on Timişoara and secondary on Arad, comprising the territory of three counties (Timiş, Arad and Caraş-Severin) and exceeding in the north the Banat area; a second one, in the north, polarized by Baia Mare and, secondary, by Satu Mare, disadvantaged due to its remoteness, and a third type, extremely monocentric focused on Oradea that polarizes the space of Bihor County. The intra-Carpathian space brings together three urban sub-systems: a north-Transylvanian one polarized by Cluj-Napoca, the regional metropolis that attracts five counties (Cluj, Sălaj, Bistriţa Nasăud, Mureş and Alba); other, south-Transylvanian, centred on the urban binom Braşov-Sibiu towards which the towns located in the Giurgeu – Ciuc depressionary area and the surrounding mountain regions gravitate and the third, restricted to Hunedoara area, polarized by the Deva-Hunedoara urban system and extended southwards, to the Petroşani Coal Basin.

Given that the current structure of macro-territorial functional spaces is not complete, some add-ons are required. Thus, in Oltenia, Dobrogea or Bihor regions the first-rank urban centres have no second-rank centres to depend on, thus relying on the third-rank centres. The fall of communist period brought about the liberty of the inter-town competition which, without integrated and coherent policies in town development triggered intra-regional imbalances.

Romanian towns are relatively evenly dispersed in all the major relief units, preserving the ring-pattern with an inside-to-outside display of large cities and medium-sized towns, in perfect balance with the natural environment, while the small towns are randomly scattered. The position of towns, mainly in the main relief steps, brings about several advantages due to their position at the junction of the major commercial routes. Major such towns are located at the contact between the Carpathian Mountains and other major relief units such as the Transylvanian Tableland, the West Hills or West Plain, the Romanian Plain, the Moldavian Plateau etc. Other important towns are positioned along the Danube Valley or in the Dobrogea region, along the Black Sea Coast.

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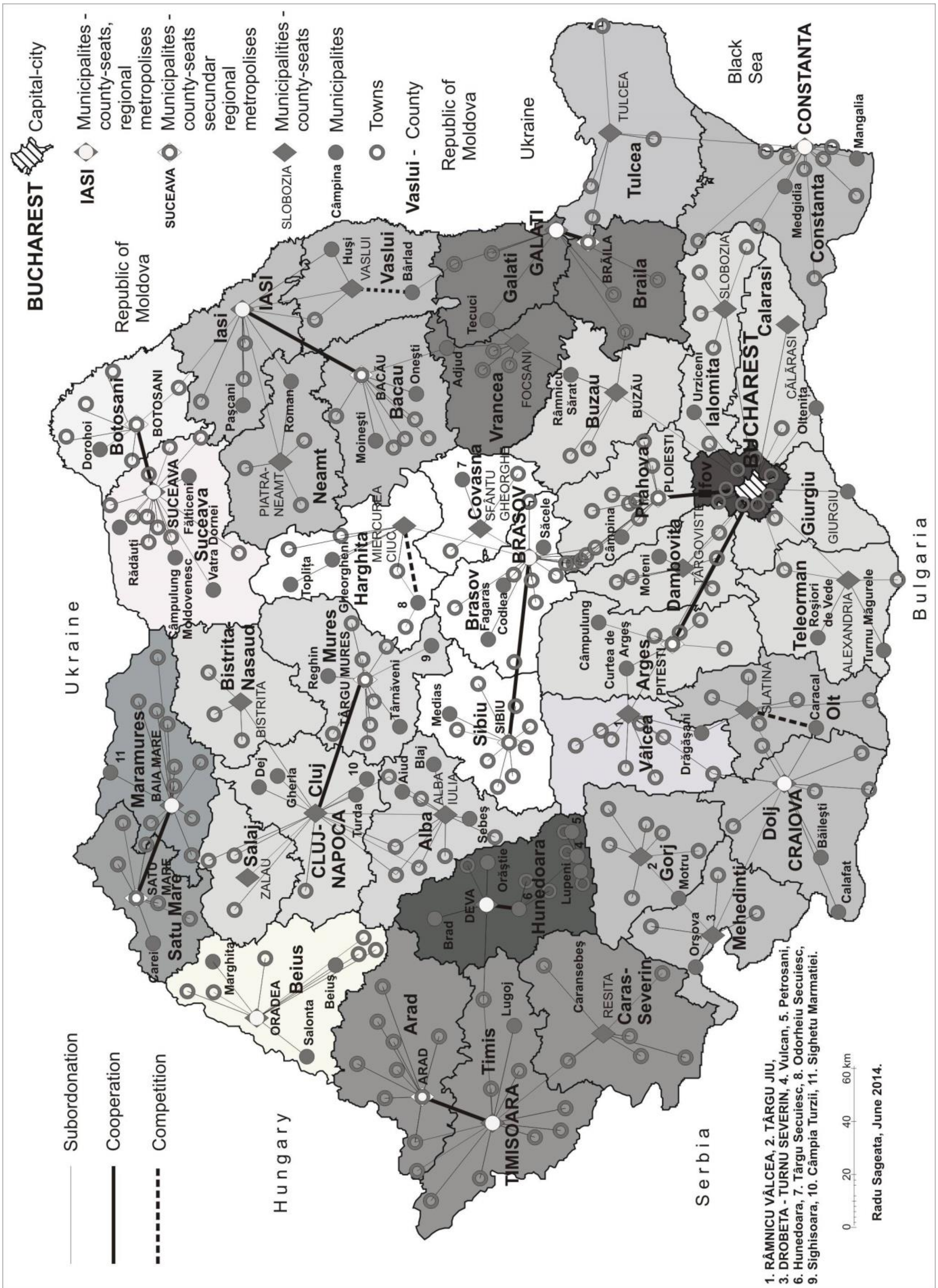

Fig. 4. The urban sub-systems in Romania (processed and modified after Ianoş, 1987)

When referring to the relationships between rank and size, Romania's urban hierarchy displays the particularities of the historical background, thus indicating a rather unbalanced distribution. The main characteristic is the undersizing of the upper part of the urban hierarchy versus the whole urban system. For instance, down to rank eight, the first large cities hold a much lower position in terms of demographic size, of which the second and third-rank towns (e.g. Timişoara and Iaşi), with a population less than half of the total number that they should normally have, detach.The middle segment of the hierarchy frames the county-seats (e.g. Râmnicu Vâlcea, Suceava, Piatra-Neamţ, Târgu Jiu, Târgovişte, Focşani, Bistriţa, Tulcea, Reşiţa etc.) and some medium-sized towns which were subject to high industrialisation-related demographic growth over the past three decades (e.g. Hunedoara, Bârlad, Roman, Turda, Mediaş, Oneşti, Petroşani). Due to the acquired political-administrative status, some of them had tripled or even quadrupled their population. A large number of small towns are characterised by under-population, pointing to the under-representation of the lower base of the urban hierarchy, thus requiring measures able to foster the development of small towns and their demographic increase, or to create localities with a status in-between village and town (Urucu et.al., 2006).

When referring to the administrative hyerarchy in Romania, which depends both on the organisation of space and the urban evolution, the country's capital city – Bucharest on one hand and 103 municipalities on the other can be individualised. In relation to the municipium status and the administrative function of urban localities, five categories of municipalities were established: former regional seats (1950–1968); county seats; former county seats; polarising centres with over 30,000 inhabitants; polarising centres with less than 30,000 inhabitants.

After 1990, one of the main characteristics which had impacted the Romanian urban system was the great number of towns which were declared municipia (47 in 1968, 56 in 1989 and 103 in 2014). The increased demand of local authorities' for towns to be declared municipia was mainly related to the economic and social needs with the aim of town development through new investments. Since 1993, 47 towns obtained the rank of municipium, thus completing a network that is evenly distributed throughout the country, but unbalanced in terms of demographic size, economic potential and geographical position (Săgeată, 2000).

Before the fall of the communist regime the *town attraction and space polarisation capacity* were mainly dictated by the socialist industrialisation, collectivisation of agriculture and the administrative organisation. After 1990, the relationships between towns and the villages located in their influence zone develop within a new economic and legislative context. The industrial spaces had become significantly less attractive for labour force and commutation dropped sharply. Moreover, job opportunities in major cities were no longer related to industry, but rather to the tertiary sector (Mocanu et al, 2004, Neacşu, 2010a, 2010b). An important role had the Land Law No. 18/1991, responsible for the massive return of citizens to their places of origin, and the later supply of town market with farm products from their agricultural plots (Urucu et.al., 2006). Currently, there are 41 counties which are polarised, from the administrative point of view, by county-seats, their population ranging between around 50,000 and nearly 350,000 inhabitants. To this, the capital-city, Bucharest, exerts a particular polarising role. Depending on their demographic size, large cities tend to attract into their influence areas spaces that belong to the neighbouring counties (e.g. Galaţi against Tulcea County; Iaşi against Vaslui County). Lately, both interests and investments oriented to the county-seats had greatly changed the relationships between the county-seats and the towns with similar size, especially when referring to the towns which were county-seats in a certain moment in time (fig. 5).

The influence zones cover about two-thirds of the national territory, which means that one-third of the territory lies outside the active urban polarisation areas, usually corresponding to the poorly populated (e.g. mountains areas; some isolated places) or remoted geographical areas (fig. 6). In these rural areas the coordination of the surrounding territories is assumed by several rural settlements bearing the central-place position, some of them former inter-war towns (e.g. Bozovici the Almăj Land; Lechinţa part of the Transylvanian Plain; Podu Turcului the Tutova Hills).

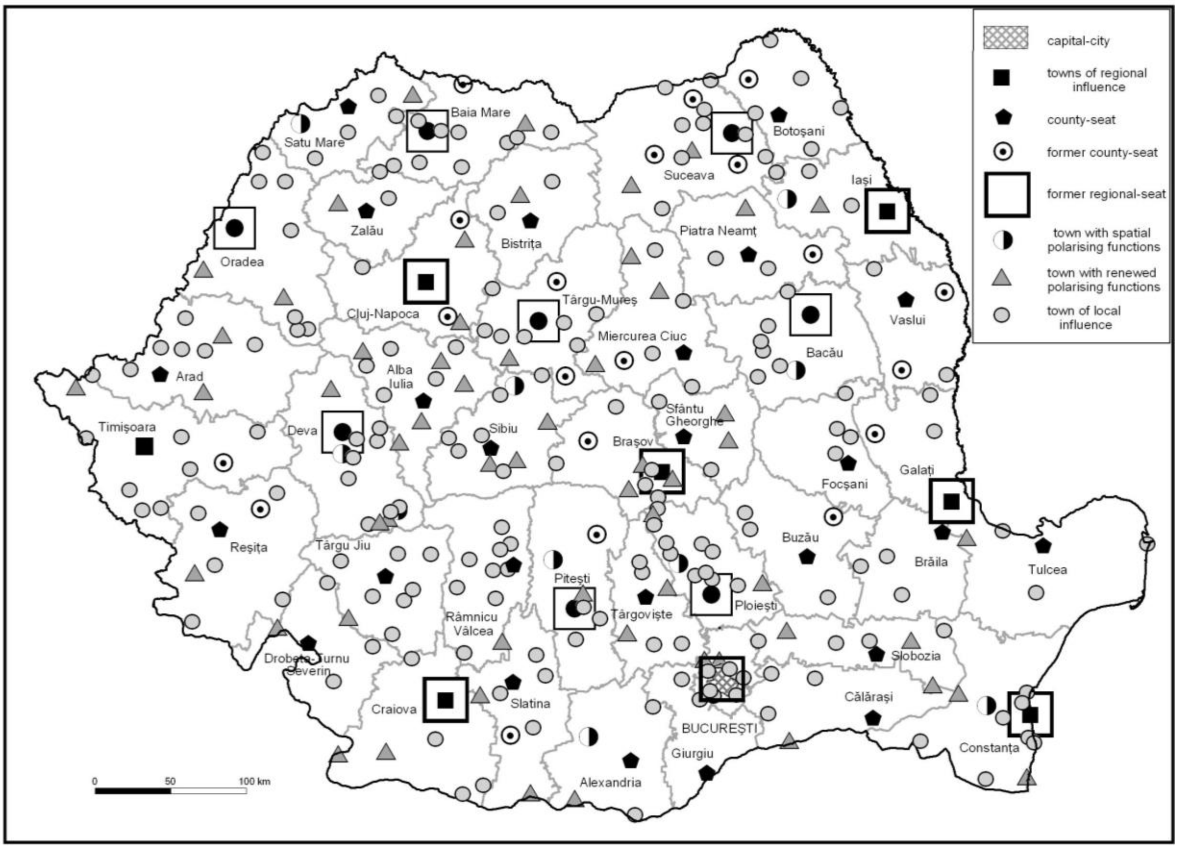

Fig. 5. The administrative and polarising functions of towns, 2011

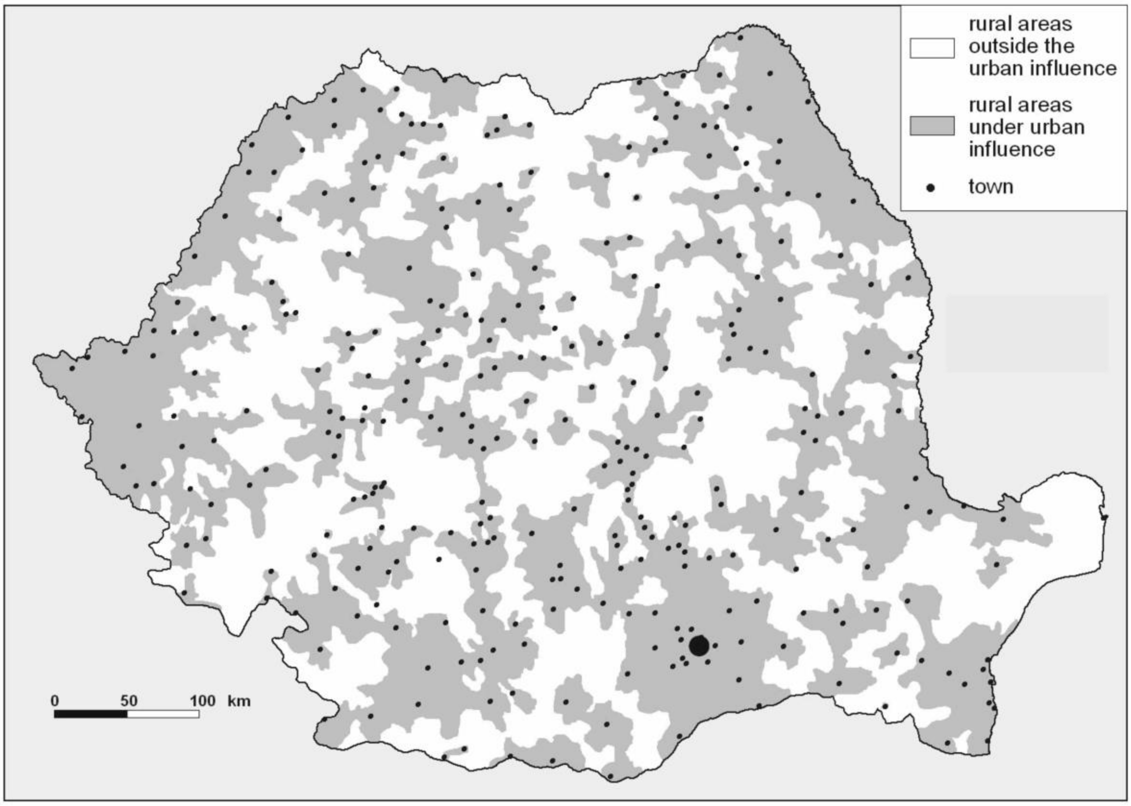

Fig. 6. Rural areas outside the urban influence zone, 2011
(processed and modified after Ianoş et.al, 1996)

THE SUSTAINABLE DEVELOPMENT OF THE ROMANIAN URBAN SYSTEM IN LIGHT OF EUROPEAN STRATEGIES

One of the strategic objectives for 2013 inscribed in the National Strategy for Romania's Sustainable Development over 2013-2020-2030 is to support a balanced and sustainable regional economic and social development in order to meet each region's needs by creating urban growth poles. To this end, the provisions of the Regional Operational Programme shall be implemented, with highlight on increasing the economic and social role of urban centres by a polycentric approach in order to achieve a better balanced regional development. Sixty per cent of the funds earmarked to urban development should be used to rehabilitate town infrastructure and improve municipal services, including transport; 25% to modernise the social infrastructure and 15% to improve the business environment. Until 2015, 30 localities will have their own integrated development plans which 400,000 people will benefit from, 400 companies shall be assisted to function in urban influence zones, thereby saving 1,500 workplaces.

In line with spatial development strategies, one of the national objectives scheduled for 2020 is the formation, at regional level, of the polycentric system of urban functional areas (urban agglomerations) and of urbanisation corridors along the transport routes of European interest (network polycentricity).

Planning and developing an extended network of urban and rural localities as a premiss for making Romania's regions dynamic, attractive and competitive, fully linked to the EU territorial management system, is a national objective for 2030. Orientative targets for urban centres have in view to raise the level of urbanisation up to 70% (by including some 650 rural localities into the town category) and providing for green-yellow belts around second rank towns (green area indicator 35m^2/inh. in first and second rank towns).

Towns and cities are a major contributor to global warming, to the management of natural resources and of land. Most towns and cities in Europe are facing economic expansion and technological recycling of former industrial areas. They are striving to find alternative means to reducing dependence on vehicles, promote equitable access to housing at moderate prices, jobs and leisure-time spending opportunities. Therefore, developing sustainable settlements and life-styles asks for the elaboration and implementation of new policies.

A fresh approach to sustainable development in keeping within the "Leipzig Charter on Sustainable European Cities" (adopted in 2007 by the European ministers assigned urban development issues) should rely on "planning tools liable to making principles operational", strongly mobilise and coordinate public and private levels involved in urban development. Planning acts ought to define coherently urban area development objectives and work out a vision of the future. Coordination should have in view various town areas, sectoral and technological plans and policies, the use of public and private funds. Implementation should have in view local and regional environments by entailing all relevant parties to the programme. Besides, the way in which the vision of the future city to become reality depends on the spatial lay-out of valuable lands at accessible prices, terrains for public use, amenities, infrastructure, activities or dwellings, basically on land-use management.

The ministers committed themselves to initiating a political debate in their respective states on how to integrate the principles and strategies of the Leipzig Charter on sustainable European Cities into national, regional and local development policies; to use the tool of integrated urban development and related governance for its implementation and, to this end, establish any necessary national framework and promote balanced territorial organization based on a European polycentric urban structure. All the sustainable development dimensions should be taken into account simultaneously and given the same importance. These include economic prosperity, social balance and a healthy environment. At the same time, attention should be paid to cultural and health aspects. In this respect due attention should be paid to the institutional capacity of Member States.

DISCUSSIONS AND CONCLUSIONS

Similar to most of the post-communist countries in Central and Eastern Europe, the Romanian urban system underwent dramatic changes related to urban sprawl which led to land-use/land-cover transformations and changes of the socio-spatial structure of towns, thus ultimately triggering the restructuring of urban and suburban landscape, especially in the urban-rural interface. This complex phenomenon had pushed the urban services to and beyond the outskirts through residential suburbanization in the form of expensive and sometimes exclusivist dwellings, which brought about a large number of commercial amenities (e.g. hypermarkets, shopping malls) and maladjusted transport services.

The higher population dynamics in the surrounding areas of main towns was driven by inhabitants preference for suburbs as residential space (e.g. Buftea, Mogoşoaia, Voluntari in Bucharest Metropolitan Area; Sânmartin, Osorhei in

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Oradea Metropolitan Area; Bârnova, Miroslava, Ciurea in Iaşi Metropolitan Area; Agigea, Ovidiu, Mamaia Sat, Năvodari in Constanţa Metropolitan Area). As a consequence, population growth evolved concurrently with the urbanisation and suburbanization processes. This dynamic trend was mainly related to the massive disparity in size and potential between cities core areas and their surrounding territories (e.g. strip and scattered or leap-frog development). This process also stimulated the conversion of some rural settlements into urban settlements in order to mitigate the hypertrophic tendency of the main towns (e.g. Bucharest Metropolitan Area). Moreover, this uncontrolled development has been followed by land speculation facilitated by laws that allowed land fragmentation into small plots without spatial zoning or control of the architecture of the new buildings.

The current socio-economic conditions and the changing demands of society in Romania have lead to the identification of new patterns of the Romanian urban system, mainly related to suburbanization and metropolization processes.

Currently, the Romanian urban system is subject to restructuration processes, the urban phenomenon acquiring new characteristics and dimensions. Under the given circumstances, the main problems which the urban system must consider are related to an increasingly hypertrophic Capital, the strengthening of the urban hierarchical base and the new conditions in which inter-town competition is unfolding. Consequently, the development of metropolitan systems might offer a new approach for the sustainable management of towns and the areas under their influence by putting an end to uncontrolled development and land prices speculations; integrating development plans and strategies of localities included in the area; developing infrastructure, especially transport and utilities networks; raising attractiveness of the area for potential investors; efficient waste management strategy; facilitating access of rural population to services available in the city etc.

According to Government Decision no. 998/2008, 7 national growth poles and 13 national development poles were designated with the aim to carry out priority investments from programmes with Community and national financing. At European Union level, in accordance to EUROSTAT provisions, metropolitan regions are NUTS3 regions or a combination of NUTS3 regions (Counties) which represent agglomerations with over 250,000 inhabitants. The same European Union data source classifies metropolitan regions in three main categories totalling 8 such structures: capital metro regions (Bucharest/Ilfov County), second-tier metro regions (Cluj-Napoca/Cluj County, Timişoara/Timiş County, Craiova/Dolj County, Constanţa/Constanţa County, Iaşi/Iaşi County) and smaller metro regions (Galaţi/Galaţi County and Braşov/Braşov County) (http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/metropolitan_regions). Moreover, in line with the project document regarding the Strategy for Territorial Development of Romania 2035 spatial entities scheduled to play a major role in the Romanian urban system are foreseen to be developed: *metropolitan poles with international potential* (Bucharest, Timişoara, Iaşi and Constanţa), *metropolitan poles with superregional/interregional potential* (Braşov, Cluj-Napoca, Craiova, Oradea, Ploieşti and Galaţi – Brăila), *poles with regional potential* (Arad, Suceava, Râmnicu Vâlcea, Sibiu etc.), *poles with limited regional potential* (Tulcea, Bacău, Vaslui, Călăraşi etc.), *sub-regional poles with urban functional zone potential*, *urban poles with zonal influence*, *urban poles with local influence* and *towns in the vicinity of metropolitan poles* (www.sdtr.ro).

At the same time, making greater use of integrated urban development policy approaches through the active involvement of economic actors, stakeholders and the general public is essential. This would greatly contribute to integrating urban development policy, which is a key factor of implementing the EU Sustainable Development Strategy. Therefore, in order to meet the requirements of the sustainable development of the Romanian urban system, it is also important to use the European structural funds for integrated urban development programmes (e.g. Special Support Instruments Funds, European Regional Development Funds, etc.) focusing on the specific drawbacks and potentials, opportunities, difficulties and specificities of Member States.

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Present and perspectives for health tourism – spa services in Romania

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Abstract

The current paper aims at assessing the extent to which spa tourism developed in Romania after the fall of the communism, and to investigate the typology of Romanian spas in order to identify the drawbacks and opportunities of this sector from the supply perspective. The wellness offer (day spas, destination spas, medical spas, mineral spring spas and hotel spas) and the territorial distribution of spa centres within the country are analysed. The current trend is to diversify the offer, with numerous projects for day spas and destination spas within towns, and even resorts offering accommodation, sport and entertainment facilities, as well as spa facilities and programmes. Most of the spas in Romania are focusing only on wellness, less than 10% of them offering advice regarding nutrition, and only few meditation. The balneary spas, capitalizing the mineral and thermal spings, have failed to meet the demands and standards of the international market, thus loosing the fame they enjoyed before 1990.

Keywords: *Health tourism, spa services, wellness, Romania*

Rezumat. Actualitate si perspective în turismul pentru menţinerea sănătăţii – serviciile spa în România

Lucrarea de față are drept scop prezentarea stadiului actual al serviciilor spa din România, după înlăturarea sistemului comunist și investigarea tipologiei spa-urilor din România pentru a identifica punctele nevralgice și oportunitățile pentru acest sector. În cadrul studiului se analizează oferta de wellness (spa de zi, destinații spa, balneo - spa şi hotel spa), precum şi distribuţia teritorială a centrelor spa în cadrul ţării. Tendința actuală este de difersificare a ofertei, cu numeroase proiecte pentru spa de zi și destinații spa în cadrul orașelor mari, apărând chiar resort-uri ce oferă servicii integrate de cazare, sport și divertisment, precum și facilități și programe spa. Cele mai multe centre spa din România pun accent doar pe componenta wellness, mai puțin de 10% dintre acestea oferind consiliere privind nutriția, și foarte puține punând accent pe meditație. Stațiunile balneare, care valorifică izvoarele minerale și termale, nu s-au putut alinia la cerințele și standardele existente în prezent pe piața internațională, pierzând prestigiul pe care îl aveau înainte de 1990.

Cuvinte-cheie: *turism pentru menținerea și refacerea sănătății, servicii spa, wellness, România*

Introduction

In 2012, the international tourist arrivals exceeded the 1 billion mark for the first time in history, and growth is expected to continue over the next years. More than 500 million international tourists (52%) reported travelling for holidays, recreation and different types of leisure, while travel for visiting friends and relatives, healthcare and religion accounted for almost 27% of all international travel (WTO, 2013). Apart from the increasing number of international tourists and revenues, tourism industry is facing an unprecedented segmentation of the tourism market, favouring the niche tourism segments.

Health tourism includes activities from three different domains – health, as it uses thermal, mineral or sea water for healing purposes, tourism (spending the free time for recreation purpose) and sport (fitness centres, pools, spa facilities).

A relatively new niche segment within the travel and tourism industry is wellness tourism, despite the fact that spa practices date back to antiquity and that during the 18th and 19th century 'taking the waters' became common practice for aristocracy. Nowadays, wellness is a strong consumer trend and the wellness tourism is growing faster than the overall tourism industry (Global Wellness Institute, 2014), the spa industry becoming the world's largest leisure industry (Cohen, 2008). As the schedule of more and more people has become frantic, and the rhythm of life is ever more accelerated, going to spa is seen as a prerequisite for staying healthy and looking good (Frost, 2004).

Literature Overview

The wellness concept and its entire philosophy was coined by the American doctor H. Dunn in 1959, when in his paper entitled High-level Wellness for Man and Society, he argues that 'man is a physical, mental and spiritual unity' (p. 789), consequently wellness being achieved by overlapping these three levels. Years later, Dr. Jack Travis emphasized the illness-wellness continuum concept, pointing out that even in the absence of a physical disease, an individual may lack wellness due to anxiety, depression or other conditions (Travis & Ryan, 2004, Travis, 2005), pioneering the wellness movement in the late 1970s.

With respect to tourism, the wellness concept can be acknowledged starting from the definition of the WHO (health is a state of complete physical, mental and social well-being and not merely the

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absence of disease or infirmity), but extended to include not only the physical, mental or social dimension, but also the sexual, emotional, cultural, spiritual, educational, financial, environmental, ethic and existential one (Cohen, 2008, p. 8). Wellness is related to a proactive approach, incorporating attitudes and pursuits that prevent disease, improve health, enhance the quality of life and bring a person to increasingly optimum levels of well-being (Global Wellness Institute, 2014). Wellness is a dynamic status, providing the greatest resilience to stress and disease, as 'it is the multidimensional state of being well, where inner and outer worlds are in harmony: a heightened state of consciousness enabling you to be fully present in the moment and respond authentically to any situation form the deep inner well of your being' (Cohen & Bodeker, 2008).

The Research Institute for Leisure and Tourism at the University of Berne defines wellness tourism as „the sum of all the relationships and phenomena resulting from a journey and residence by people whose main motivation is to preserve or promote their health".

If, in the beginning, the wellness concept implied the use of natural springs, either hot, or mineral ones (Erfurt-Cooper, Cooper, 2009), after the 2nd world war, the focus shifted towards nutrition, weight control and meditation (Weiermair& Mathies, 2004). In Europe, wellness tourism is based on four main pillars: physical activities, vital cuisine, programs for pampering guests and leisure (Lebe, 2006).

Given the rapid expansion of the wellness attitude in the developed economies and the fact that the spa industry is becoming a global phenomenon, researchers have been focusing lately not only on health tourism as a whole (Hall, 1992, Goodrich, 1994, Garcia-Altes, 2005, Smith & Jenner, 2000, Borman, 2004), but also on medical tourism (Connell, 2006, DeArellano, 2007, Hall, 2011), and wellness tourism as distinct niche sectors, providing information on past and future trends (Weiermair& Mathies, 2004, Messerli & Oyama, 2004, Ritter, 2005, Ellis, 2008, Voigt, Brown & Howat, 2011), best practices, management and marketing strategies (Smith & Puczko, 2009), incorporating wellness concepts into spas (Cohen, 2008, Laing & Weiler, 2008), case studies (Quintela, Correira & Antunes, 2010, Heung & Kucukusta, 2013, Speier, 2011).

As many researchers agree (Bastos, 2011, Ellis, 2008, Frost, 2004), the term spa derives from the Latin expression sanitas per aquas – health through water, while others (Erfurt-Cooper, Cooper 2009) argue that the term has derived from the town of Spa in Belgium, where the water from the hot mineral springs was used for medical purposes ever since the 14th century. The definitions for this term differ from one continent to another, and even within the same geographical region there is no clear definition of what a spa is. The European Spa Association (ESPA) defines the spa and spa resources depending on the local therapeutic resources used for physical therapies (massage, physiotherapy, inhalations, balneological treatments), highlighting the existence of a mineral spring in or in the neighbourhood of a spa centre. According to the International SPA Association, with its headquarters in the Unites States, the spa 'is a place devoted to overall well-being thought a variety of professional services that encourage the renewal of mind, body and spirit', which is not necessarily related to the presence of mineral or thermal waters. 'The spa experience is about one thing: You. Your comfort, your goals and your peace of mind are at the heart of every spa experience'.

The ultimate aim of the spa is to preserve and recover good health, by combining products and services specific for some regions of the world: the ethics of the services, the holistic therapies and spiritual practices from Asia, the European medical know-how and the American commercial approach, focusing on beauty and new experiences, as well as environmental consciousness of tribal cultures (Cohen, 2008).

During the last years, many researchers (Muller & Lanz Kaufmann, 200, Frost, 2004, Chen, Prebensen & Huan, 2008, Nuno Silva, 2010, Bastos, 2011) have focused their studies on the typology and profile of spa goers, due to the ever increasing importance of this sector for the leisure industry.

Tawil (2011), following a study carried on in Great Britain, proposes four categories of spa tourists: the aristocrats (generally older, high-income people, that seek relaxation and rest, vigilant for details, with high expectations), the explorers (those who are curious to experience the spa, generally outside their residence place, that seek apart from adventure new facilities, treatments and new programmes, such as yoga), the socialisers (mainly women that choose a spa center depending on its reputation and recommendations, offering a lot of facilities and treatments) and the budgeters (generally young, low budget, that choose especially the massage and pool – the clients of the day spa).

Aims

The current paper aims at assessing the extent to which spa tourism developed in Romania after the fall of the communism, given the fact that there is little information about the wellness tourism issues in the Romanian literature and to investigate the typology of Romanian spas in order to identify the drawbacks and opportunities of this sector from the supply perspective.

Research Methods

In order to locate all forms of spas that are of interest for the current study, we first determined the sample using the characteristics proposed by Bennet et al., 2004, i.e.: the name of the unit must refer to spa or wellness, its activity should be related to the use of thermal or mineral waters, and offer products/ services for the preservation of physical, psychical and spiritual health. Afterwards, we checked for promotional materials and used the internet to see if and how they promote themselves.

Results

Dimension and evolution of this market

At international level, we may argue that there is even a spa industry, which is one of the most dinamic components of leisure tourism. In the USA alone, in 2010, there existed almost 20,000 spa centers, having over 150 mil. visits in a single year, and a reported income of 12.8 bls US$, according to International Spa Association (http://experienceispa.com/media/facts-stats/).

For Romania, there are no data available for the wellness sector proper, because the statistical yearbooks only include figures about the accommodation capacity and tourists number in balneary resorts. Still, according to a study conducted by Wall Street Journal (http://www.wall-street.ro/slideshow/Lifestyle/101601/Cine-merge-la-spa-in-Romania-Intre-moft-si-necesitate.html), the investments in the spa centers in Romania increased continuously during the last years, all the new 4 and 5 star hotels including, from the very beginning, a wellness-spa center. Eden Spa, which is one of the biggest spa operators in Romania, having four centers (three in Bucharest, Orhideea Health and Spa being the biggest spa center in the capital city, and one at Sibiu) reported a total turnover in 2011 of 2 mil.€ only for its own centers.

Many spa centers (day spa, hotel spa) organize team-buildings or signed contracts for collaboration with multinational companies, their web-sites having dedicated sections for corporate, thus addressing a clientele generally aged 25 to 45 years, having leading positions, and high income, since the costs incurred are also high (from 2 to 75 € the massage hour, the price of a monthly subscription starting from 100-150 €, which is quite a lot considering that the average income in Romania is around 500 € (http://www.wall-street.ro/slideshow/Lifestyle/101601/Cine-merge-la-spa-in-Romania-Intre-moft-si-necesitate/4/Ce-servicii-se-ofera-si-cine-merge-la-spa-in-Romania.html#anchor-of-navigator).

Still, the general difficult situation of the Romanian economy led to a certain drawback of this niche sector, in 2011, the spa market stagnating or even decreasing because many companies had to cut down their expenses, not being able to offer gift vouchers to spa to their employees.

The local spa market is below the international standards, mainly because of the lack of proper training of personnel (there are mainly masseurs and kineto-therapists with limited knowledge in this field) and the volume of services offered did not increased; rather, the market stepped forward due to investments in the industry (Both, 2011). The current trend is to diversify the offer, with numerous projects for day spas and cities spas within towns, and even resorts offering accommodation, sport and entertainment facilities, as well as spa facilities and programmes).

Current situation

According to the Master Plan for the development of health tourism, this sector must cope with five main issues. First of all, there is a continuous degradation of the infrastructure, including the accommodation as well as treatment facilities due to the scarce, if hardly any, investment, sometimes entire resorts being in a state of desolation and decay. The health offer is quite heterogeneous and unevenly distributed, varying from few private hotels and treatment facilities of good quality to highly deteriorated facilities owned by the trade unions. Still, the Romanian spa resorts still preserve the know-how and a good reputation for the rejuvenation treatment, and Romanian tourists are keen of this type of tourism. However, terms such as sanatorium, treatment base are still largely used by practitioners and decision makers, despite the fact that they have a negative connotation on the international market and that they should be avoided.

Target group

Health tourism addresses three categories of tourists: those that want to have a medical treatment (either because they are sick or to prevent from falling ill), tourists that come to enjoy themselves or just for wellness and sport persons, that are interested in keeping fit.

Spa centers are not exclusively for ladies, although almost without exception, any spa centre, regardless if it is a day spa or any other type, includes a beauty centre for the ladies. Still, according to some studies carried on by ISPA, the number and the share of male tourists is increasing worldwide (30% in 2004 from the total number of spa tourists). The managers of some spa centres in Romania have well acknowledged this fact and decided to have separate sections for gentlemen within spa centres, the massage, hammam (Turkish baths) and detoxification being the most popular

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choices for men (http://www.desprespa.ro/SPA/SPA-si-Wellness/Spa-pentru-barbati).

According to A. Kuhnen, manager of Epoque Spa, a spa center that offers highly personalized services, focused on exotic-oriental body treatments, spa goers are people that pay great attention to their health and want to get away from the daily stress and routine. A spa goer is generally 25 to 45 years old, with various social and job responsibilities, that feel the need to escape and be oneself again.

Wellness offer/ spa typology

We classified the spa centres in Romania according to the typology proposed by the International Spa Association and Frost (2004):

- Club spa – a facility whose primary purpose is fitness and which welcomes day guest;
- Day spa – offering daily services focusing mainly on pampering and less on fitness;
- Destination spa – a facility whose main purpose is to offer guidance to clients for improving their life style and health, offering professional services and activities for fitness, wellness education and healthful cuisine;
- Medical spa – a facility employing medical staff that offer medical and wellness products and services;
- Mineral spring spa – using mineral, thermal or sea waters for hydrotherapy and other physical treatments; the balneary resorts in Romania were included in this category;
- Resort/ hotel spa – a spa located within a hotel, with facilities for massage, sauna, aromatherapy, as well as fitness. It must be noted that the spa centres have became a must-have for any luxurious hotel in Romania, being used also as a marketing strategy for attracting tourists to a particular hotel.

For the current study, we did not consider the club spa, as in every town, no matter the population number, there is at least one such facility, offering fitness programmes.

The geographical location of the spa centres in Romania is presented in Fig. 1.

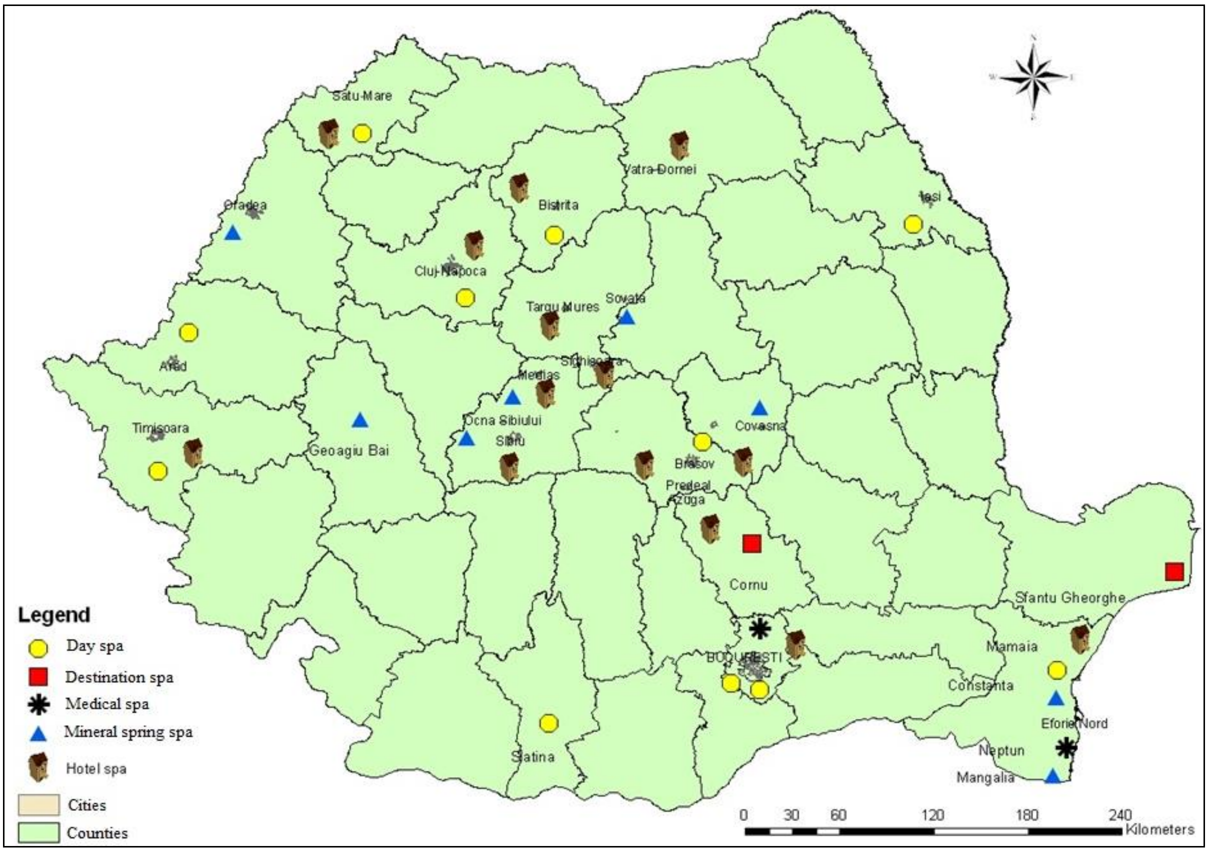

Fig. 1: The location of spa centers in Romania

The survey indicated that most of the spa centres are hotel spas (40%) and day spas (34%) (Table 1).

If at European level, spas have borrowed from the characteristics of those in the USA, emphasizing nutrition, wellness and meditation (Tabbachi, 2008), most of the spas in Romania are focusing only on wellness. Thus, out of the 70 spa centers that were identified in this study, less than 10% offer advice regarding nutrition problem (Table 2). Beginning with 2012, Green Center Spa organizes at Sfantu-Gheorghe, in the Danube Delta, a programme for body detoxification, under supervision of nutrition and traditional medicine specialists, promoting yoga therapies and raw food.

Out of the facilities offered by the Romanian spa centers, sauna, fitness, pool, jacuzzi, aromatherapy are almost ubiquitous, few of them including hammam (Turkish bath), solar, ice fountain, consulting room, salt room. The services vary from massage, cosmetic and body treatment, relaxation, nutrition guidance.

Table 1 Types of spa centres in Romania

	Day spa	Destination spa	Med spa	Balneo	Hotel spa
Number	24	2	6	10	28
Percentage	34.3	2.9	8.6	14.3	40

Table 2 Facilities services offered by Romanian spa centres

	Day spa (%)	Destination spa (%)	Med spa (%)	Balneo (%)	Hotel spa(%)
Sauna	100	100	100	70	100
Jacuzzi	100	100	100	100	100
Pool	75	100	100	80	64
Fitness	100	50	33	80	100
Solar	79	-	33	-	11
Ice fountain	13	-	-	-	11
Hammam	17	-	-	-	11
Consulting room		100	100	60	-
Massage	100	100	100	100	100
Cosmetic and body treatment	100	50	33	80	100
Relaxation	100	100		100	100
Nutriţion	4	100			
Other services*	29	100	100	100	14

(data source: authors own determination following survey)

*Mud wrapping, recovering, reflexing therapy, leaches treatment (Bistriţa).

Romanian med-spa centers offer non-invasive medical treatments or light surgeries, connected to injectology or facial rejuvenation, as it is the case of those from Bucharest, anti-ageing treatments, rehabilitation and detoxification (Cornu, Neptun). Recently, there was established the Romanian Medical Tourism Association, the first non-profit association of medical tourism including hospitals, clinics,providers of medical services, travel agencies and insurance companies that is struggling to establish Romania as a country with tradition in medical tourism. The association issues the Romanian Medical Tourism Guide, presenting the main types of medical treatments (focused mainly on dentristry) as well as the accommodation posibilities.The association offers different types of medical treatments, such as dentistry,cosmetic surgery, eye surgery LASIK, IFV, electriv surgery, interventional cardiology, orthopedic surgery, as well as rehabilitation and spa treatments.

According to the Federation of Employers from Romanian Tourism, it is estimated that in 2013, there were approximately 20,000 medical tourists in Romania, the main purpose of the visit being cosmetic surgery and dental treatment, spending around 60 million Eur on health services and accomodation, originating mainly from Uk, Germany, France and Israel (Raducan, 2014).

The hotels that have spa centers are generally 4 and 5 star hotels, very comfortable, with a cosmopolite clientele and certain expectations. It must also be noticed that luxurious hotels that have large conference rooms also include spa centers offering various services, meant to meet the expectations and requests of the guests leading a stressful and busy life, but who are concerned about keeping fit. It is a trend that emerged in the US, after the 2nd world war, spas addressing a generation preoccupied this time with nutrition and weight control (Tabacchi 2008, p. 28).

Balneo spas are an important element of the Romanian tourism sector. According to the web site of the Ministry of Regional Development and Public Administration, and subsequently of the National Authority for Tourism, there are two categories of tourist resorts – of national interest (41 such resorts) and of local interest (including 48 resorts). The guide for balneary spas/ resorts that was presented in London in 2012 includes 34 resorts 'with good chances for development', presenting the procedures and medical treatments they offer, as well as information about the natural therapeutic factors, treatment facilities, accommodation facilities and tourist attractions, being the first material of this type that was achieved in Romania during the last 20 years, following the launch of the new tourism brand of the country. Still for the current

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study, we consider that only 10 can fit into the category of balneary spa centers. Apart from the six balneary spas listed on the web site of the Ministry of Regional Development and Tourism (http://www.romaniatourism.com/spas.html#), i.e. Baile Felix, Bazna, Ocna Sibiului, Sovata, Eforie North and Mangalia, we consider that another four balneo spas may also be included: Geoagiu Bai, Covasna, Neptun and Dorna Arini (Fig.), where there are hotels with treatment facilities that were completely renovated and updated, that capitalize the local mineral resources, and have a very diversified spa offer.

Although there is a high number of balneary resorts in Romania, unfortunately they are seen as a place for old and sick people (Master Plan, 2007) because of the emphasis on medical treatments, and the lack of investments for decades, causing poor and decaying special infrastructure. In most of the cases, the social tourism prevails. Balneotherapy was considered for decades a traditional healing technique in Romania, based on bathing, drinking and wrapping therapies, as well as real know-how of this sector, (Cooper et.al., 1995). Just like in other Eastern European countries, the state set up institutions for research, providing the scientific basis of balneotherapy (Dr. Ana Aslan center, for instance). However, since the fall of communism, balenotherapy has failed to be successfully incorporated into the tourism industry, although there is a Master Plan for the Development of Balneary Tourism (2009). Still, thermalism can be tailored to individual needs, addressing higher income clients (Stathi and Avgerinos, 2001).

The most recent strategic plan to develop balneary tourism in Romania dates from 2009 (the Master Plan for the Development of Balneary Tourism); the Master plan should shape the balneology sector, aiming to identify a clear marketing positioning and propose 'an offer that should meet the demands for the products for which Romania can be a good example and stand out'. Thus, the priority network identified by the master plan includes thermal towns (Baile Felix, Baile Herculane, Sovata, Vatra Dornei, Slanic Moldova), medical spas for anti-ageing treatment (just four such centres: Snagov, Bucharest, Mangalia and Covasna), keeping fit- spa and wellness centers (Bucharest).

Lately, the Spa Tourism Employers Association together with the National Tourism Association have developed a partnership with the National Institute of Gerontology and Geriatris and Ana Aslan Foundation for carrying out a pilot project to revitalize the Ana Aslan brand with two programmes: Live young! and Relaxation. Reblancing. Revitalization.

One of the most difficult problems facing the traditional balneary spas in Romania is the lack of competitiveness not only on the international market, but also on the national market as well. The lack of investments for more than 20 years in almost all the balneary resorts in the country, the decaying heritage buildings and facilities, prevalence of one, two and three star accommodation facilities, poor general infrastructure and lack of support from the local and regional authorities have all contributed to the bankruptcy of numerous resorts of regional and national importance (Baile Herculane, once frequented not only by the Romanian aristocracy, but also by the European royalty, now lies in decay; and this is just one of the many examples). Once renowned internationally for the treatments they offered, Romania's spas have 'shabby, poor quality treatment facilities which do not give the impression of cleanliness or clinical security' (Cooper et.al., 1995). Most of these resorts are subsisting due to the social insurance policy and subsidies from the Ministry of Health, usually frequented by pensioners with low income.

Conclusion

The desire to improve one's health and appearance and the opportunity to heal are the main reasons for people visiting spas. Health and related topics, such as wellness, will be one of the most important element of the tourism offer for the next decade, as the European population is growing older and there is a continuous emphasis on staying healthy and young. Moreover, holidaymakers search for various activities during their holidays, health and wellness facilities being targeted by an increasing number of tourists.

A survey conducted by the Global Wellness Institute (2010) indicated that consumers seeking to enhance their wellness are most likely to exercise, eat better and visit a spa, as well as taking a vacation, with positive implications for resort and spa hotels. Currently, four and five star hotels are at the forefront of spa and wellness center development in Romania. If the country is to reposition itself again on the international market for health tourism, wellness tourism is a niche sector that should be aimed at. However, in order to keep the traditional clientele and, at the same time, attract more tourists from the country and from abroad, spas must diversify their offer, targeting a particular segment of tourists: physical fitness (smokers, obese, young mothers), emotional balance, relaxation, mental health, stress reduction.

During the last years, numerous balneary spas of national and regional importance have benefited from massive investments through REGIO Regional Operational Programme, 5th Axis – Sustainable development and promotion of tourism. Still, almost all the funds were invested in the rehabilitation or construction of medical treatment and wellness and spa facilities, as well as in general infrastructure to improve accessibility. That is why we consider it is compulsory for the near future to stress and improve the offer for leisure activities, meditation, stress reduction and pampering guests, since spa goers 'like to be clients, not patients, consumers, not sick people', carrying credit cards or cash, not diseases (Bastos, 2011).

If Romania will manage to capitalize the know how in the domain and offer health services that will be elegantly packaged, including a wellness component, will have a competitive advantage and will be able to compete on a market that has been continuously diversifying, segmented and where there is increased competition from the well established and emerging destinations.

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Premises for tourism development in the settlements of the middle sector of the Prut river (Botoșani and Iași counties)

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Abstract

The tendency to capitalize less known and promoted natural and cultural resources is also remarked among the current trends of the tourism development. Along time, in Romanian tourism, some areas that concentrate a greater number of resources have been capitalized in tourist activities and programmes.
In the context of the current changes, starting from the need to reduce the economic disparities at regional and local level, other tourist resources have also been included in the hospitality and travel industry. In Romania, the Prut valley is characterised as an extended crossborder area with the Republic of Moldova but also as having an authentic tourist potential.
Based on the bibliographic data and the field research, one has seen that the settlements situated on both banks of the Prut river own important tourist resources, the natural ones dominating, followed by the cultural ones. Consequently, the whole Prut valley offers real conditions for developing some tourism forms and attracting potential tourists interested to see a nature scarcely changed by human activities. A first tackling refers to the human settlements in the Prut corridor in the Botoșani county.

Keywords: *the Prut corridor, tourist potential, tourism forms*

Rezumat. Premise pentru dezvoltarea turismului în localitățile din sectorul mijlociu al Prutului (județele Botoșani și Iași)

Tendința de a valorifica resursele naturale și culturale mai puțin cunoscute și promovate face parte de asemenea, din tendințele actuale de dezvoltare turistică. De-a lungul timpului, în turismul românesc, unele zone care concentrează un număr mai mare de resurse au fost valorificate prin activități și programe turistice.
În contextul schimbărilor actuale, pornind de la necesitatea de a reduce discrepanțele economice la nivel regional și local, alte resurse turistice au fost incluse spre valorificare în industria turismului. În România, valea Prutului este caracterizată ca o zonă extinsă transfrontalieră cu Republica Moldova, dar, de asemenea, și ca având un potențial turistic autentic.
Pe baza datelor bibliografice și pe baza cercetării de teren, s-a remarcat că așezările situate pe ambele maluri ale Prutului dețin resurse turistice proprii importante, dominând însă cele naturale, fiind urmate de cele culturale. Prin urmare, întreaga vale a Prutului oferă condiții reale pentru dezvoltarea unor forme de turism și atragerea potențialilor turiști interesați să vadă natura foarte puțin antropizată de către activitățile umane. O primă abordare se referă la așezările umane din coridorul Prutului, din județul Botoșani.

Cuvinte-cheie: *coridorul Prutului, potențial turistic, forme de turism*

Introduction

In the surface national hydrographical network, in comparison with other big rivers, the valley of the Prut river occupies a unique position. It lies in the north-eastern and eastern part of the country, as a border limit with Ukraine and Republic of Moldova. The Prut is a left tributary of the Danube, with a total length of 953 km, out of which 742 km in the national territory (Diaconu, 1969).

Its dimensions place it on the third place in the category of the great rivers, after the Danube and Mureş. Its hydrographical basin includes a total surface of 28396 sq. km of which 10990 sq. km on the Romanian territory (Water Register Atlas in Romania, 1992).

This river was known from the very first settlements in Dacia, thus the antique Greeks named it Pyretus and then the Romans – Hierasus or Gerasus (Gâştescu, 2002). The archaeological discoveries prove the existence of social organisation and inhabiting forms from the very early Palaeolithic.

Its springs lie at the altitude of 2068 m, under the Hoverla peak, on the north-eastern slope of the Cernahora Mountains (or Cerna Gora), a component element of the Forest Carpathians range in Ukraine and its course enters Romania through the Oroftiana village, the Suharau locality in the Botoşani county.

On the Romanian territory, according to the data from the Romania Water Register atlas - part I from 1992, the Prut attracts from the right side the waters that form a codified hydrographical network which sums up 248 rivers and 4551 km, meaning 1.9% of the total length of the codified network in the country and a density of 0.41 km/km^2, superior to the country mean, of 0.33 km/km^2. It flows into the Danube at 15 km downstream to the Galati municipality.

The main characteristics of the Prut valley

Its valley represents a contact basin between the Moldova Plateau in the west of Romania and the Podolic Plateau, on the territory of the Republic of Moldova, in the east. The evolution and geographic aspects are connected to those of the Moldova Plateau, some authors considering this unit a subdivision of this plateau. From the geological point of view, the Prut basin is superposed on three structure units: the Moldovian Platform (till the Fălciu-Plopana fault), the Bârlad Platform (between the Fălciu-Plopana and Adjud-Oancea faults) and the Covurlui Platform, presenting each a basis with folded forms covered by a layer, with monocline forms (Geography of Romania, 1983, 1992).

On the Botosani county territory, the Prut river has a length of 230 km and its tributary stream Jijia only 133 km (http://www.apeprut.ro/sgabt.html), while in the Iasi county, the Prut river has a 211 km length and its main tributary streams Jijia – 131 km and Bahlui – 119 km (http://www.rowater.ro/daprut/sgaiasi/default.aspx).

Its whole hydrographical basin includes a complex of large interfluves with aspect of bridges, hills and hillocks separated by wide valleys, sculpted in the monocline sedimentary layer (Posea et.al., 1982). The general inclination of the relief, towards south-south-east, in the same direction with the orientation of the most important valleys, reflect an evident adaptation to the structure (the Geography of Romania, 1992) (Fig. 1).

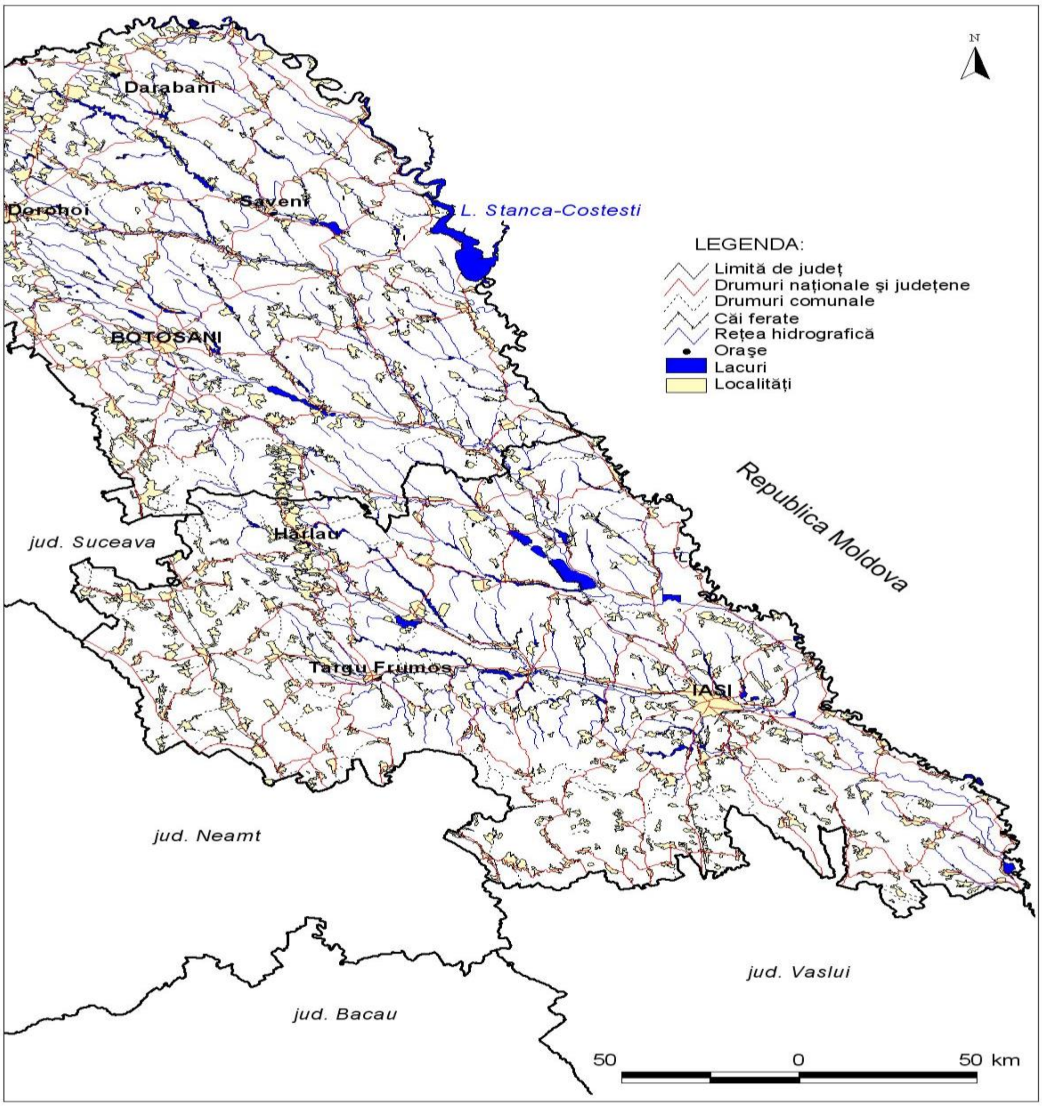

Fig. 1: The middle sector of the Prut corridor corresponding to the Botoşani and Iaşi counties

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The monocline structure has favoured the appearance of positive forms and subsequent valleys (Băcăuanu, 1973). The main levels in morphology have values of 300-500 m in the north-west, 300-400 m in the central part, 150-200 m in north-east and south and have a balanced distribution (Băcăuanu 1961, 1968).

The altitudes over 500 m are few and isolated. In conformity with the data in the "Geography of Romania" paper vol. IV, 1992, the lowest height limits which can be seen along the passage of the Prut river are of 130 m in Oroftiana, 32 m close to Ungheni and 15 m towards the confluence with the Danube.

Concerning the climate, due to its position in the extra-Carpathians region, far from the influence of air masses from the Atlantic ocean, the Prut basin receives annual quantities of moderate precipitations. Due to the fact that the Prut river overlaps the Moldova Plain, it is directly influenced by the European east and north air masses. Due to the fact that it is close to the Eastern Carpathians, the western air masses, in the lower surrounding geographic areas, 'suffers' föehn-like processes. The precipitations are reduced, between 500-550 mm (at Rădăuţi 564 mm, at Iaşi 529.4 mm, media of year). At general level, the climate is temperate continental with some excessive influences, meaning that summers are warm, sometimes with tropical days and drought periods and winters – colder, with frost periods (Băcăuanu et. al., 1980).

From the bio-geographic point of view, the whole Prut corridor lies in the area of hill forests, dominated by oak, of meadow forests and forest-steppe and steppe grasslands. Following a slower anthropic process there are many regions with natural vegetation and fauna. The studied area has traditions of over 50 years concerning the creation of ponds (Gâștescu, 1971). The building of the dam and hydro-technical accumulation lake in Stânca-Costeşti, in the Botosani county between 1975-1978 led to important modifications. The formation of the Stânca-Costeşti accumulation lake determined important changes of the fish fauna in the area.

There was a massive transformation of the typical habitats of the wet areas bordering the Prut river, i.e. of the floodable area which favours the multiplication of pond fish and birds, putting in danger the ecologic integrity of the area natural environment.

In the respective lake certain species such as barbel, chub and others disappeared, mixed regime species appearing here (Fig. 2).

Along time, the aquatic fauna reduced both quantitatively and qualitatively and this situation cannot be justified by pollution, because the river Prut in is in good condition from the physical-chemical point of view - the concentrations do not exceed the standards established by the Directive 98/83/EC. Currently, the Prut river is faced with a decrease in the fish stocks, taking as a comparison the analyses made in 1947 when there were 37 species of fish compared to the 26 found in the present (http://www.apeprut.ro/Buletin_calitatea_apei.pdf).

Fig. 2: Stânca-Costeşti area (the year 1926)

Source: archive of the Faculty of Geology and Geodesy of the Bucharest University, via prof. dr. Răsvan Damian

Birds, more than any other group of vertebrates are widespread in the presented area, both in number of species and number of individuals. Most of the birds reported here are migratory species (44 species) representing international natural resources; of these we mention the white stork, the bee eater, the little egret, the diver, etc.

These aspects imposed some effective measures for the protection of these populations and the habitats in which they live; it represents a necessity of the compliance with the international conventions and agreements to protect wild flora and fauna ratified by Romania. 31 sedentary species and 18 passage species also live in this fauna interest area. Of the total number of species, 22 are of community interest, 27 species whose conservation requires the designation of protected bird-fauna areas and 39 species which are under strict protection in conformity with Directive/409/CEE on the conservation of wild birds (http://apmbt.anpm.ro/Mediu/biodiversitate-14).

The project implementation to declare the Stânca-Costeşti lake area a **bird-fauna special protection area** will try to conserve and restore viable populations of wetland specific birds in conformity with the Convention on wetlands of international importance especially as water birds habitat signed in Ramsar in 1971 and ratified by Romania through Law no. 5/2000. In the Natura 2000 network, there is the Ciornahal forest for the ROSCI-0141 structure, the Stânca Costesti reserve for the ROSCI 0234 structure and the Costeşti lake for the ROSPA00058 one (http://www.mmediu.ro/protectia_naturii/protectia_naturii/natura2000/Lista_situri_N2000_custodie.xls) (Fig. 3).

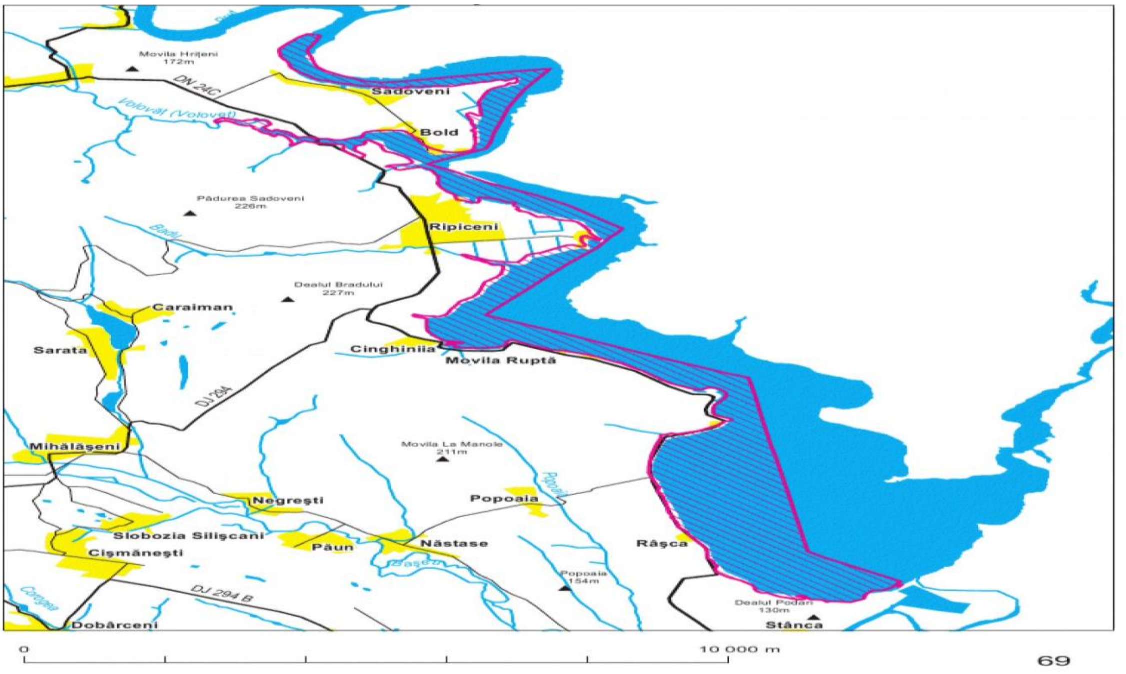

Fig. 3: the ROSPA0058 limits of the Stânca Costesti lake

Source:http://natura2000.mmediu.ro/site/273/rospa0058.html

In this context, the conservation of wetlands includes a significant cross-border element, for the purpose of collaboration and adoption of a common and unified strategy concerning the integrated management of the wetlands - resources of great economic, natural, scientific and recreational value.

The act of conferring the official status of "trans-border protected site" to this area in the future will allow the creation of some restrictive measures for the biodiversity protection and conservation, together with the preservation of traditional practices for the sustainable capitalisation of natural resources and preservation of socio-cultural values of riparian communities. In this context, the southern part of the Prut valley is likely to become a true cross-border National Park - one of the few in Europe.

The Botoşani county council, having in view the Romanian legislation in force and together with the Environment Protection agency (the Natural Biodiversity Protection department), the Romsilva local office, the Botoşani Ornithological Society, the Water Administration department, the Botoşani hunters and fishers county association as well as the local councils in the Edinet (Republic of Moldova) and Botoşani counties have issued decisions concerning the regime of protection and conservation of the areas with special habitat in the perimeter declared reserve.

In Romania, in the interest area, the protection and conservation regime has been settled for: flora reservations of *Schiwerickia Podolia* from Ripiceni and Ştefăneşti; the forest perimeter for the soil protection and consolidation of slopes, namely the Prut area forest in the Darabani and Truşeşti forest ranges; dendrology park in Ştefăneşti plus other valuable protected areas (Mohan et. al., 1993).

In terms of tourism development, it has a real chance in the Prut border settlements along the Romanian sector. Thus, those natural and cultural resources that can be capitalised through tourism activities related to ecotourism have been selected. This selection has been carried out because other rural communities in the Prut river basin have poor ways of communication which makes the access to those tourist resources more difficult.

The analysis of the Prut corridor in the Botoşani and Iaşi counties

Along its length, some secondary sectors can be identified due to the changes of the minor and major riverbed, slope flow, climatic and pedo-bio-geographic conditions. The middle sector which starts from the north, in the Radauti-Prut-Lipcani settlement (Obcinele Bucovinei), the Moldova Plateau and continues till the lower Prut plain (near the Corbani-Răducăneni settlements) over a distance of 380 km can be seen in Romania but also in the Republic of Moldova (Muşinschi, 1999-b).

Two compartments or sub-sectors can be distinguished in this sector (Mușinschi, 2009):

- the **northern sub-sector** where the Prut valley has an epigenetic nature, between Rădăuți-Prut and Stânca-Ştefăneşti, with a narrow corridor and without terraces on the right bank. The basin shows a narrowing in this sector, while between Rădăuţi-Prut and Mitoc it widens slightly till the limestone cliffs at the south of Mitoc. The valley has

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terraces on both sides, who have a climate-lithologic origin in this sector (Muşinschi, 1999-a).

- the **south sub-sector** in the depression plain till the line of the Corbani - Răducăneni-Grozeşti localities (Fig. 4)

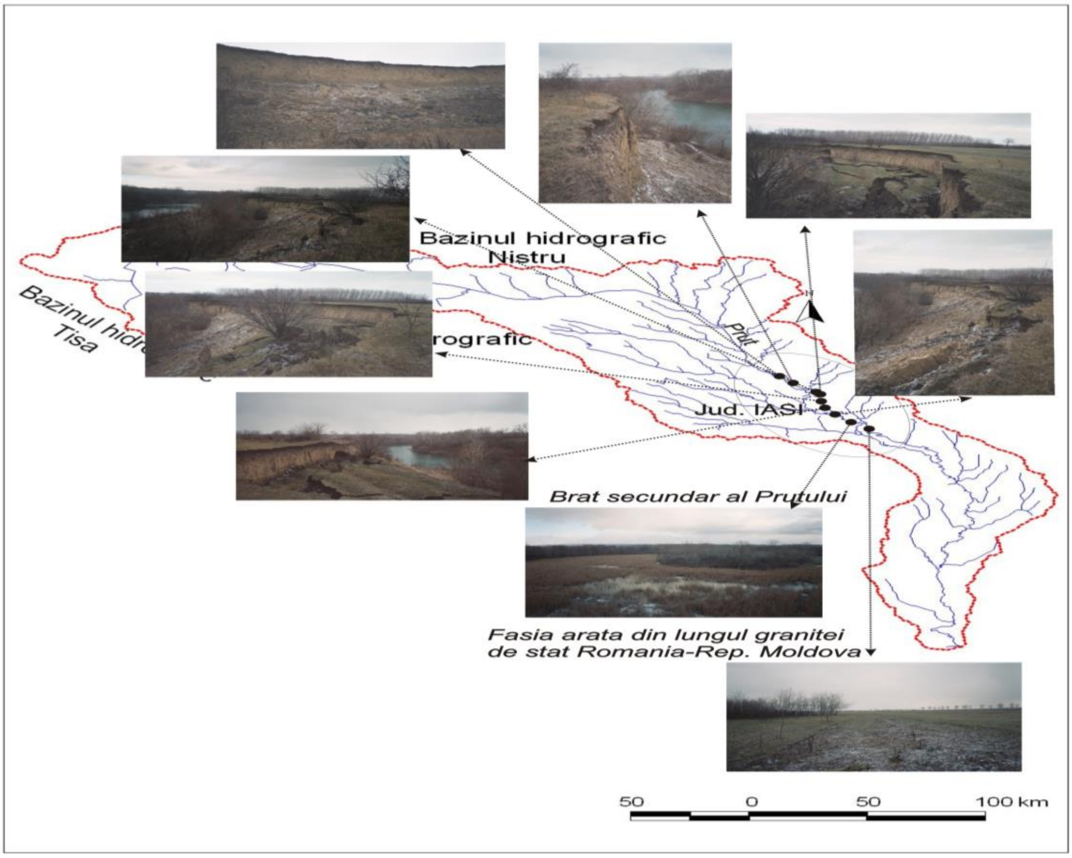

Fig. 4: Geo-morphologic aspects inside the Prut corridor in the Iași county

Source: F. Vartolomei, carried out in November 2010

Apart from the historical monuments and cultural artistic events in the Prut valley, there are two special ethnographic areas. The first ethnographic area is known as **'Ţinutul Botoşanilor'** and includes the villages on both sides of the confluence area between the Prut and Jijia rivers. (Juraşcu Barbu, 2007).

The old houses are simple, with 2 to 4 rooms, small vestibule, many of them built of adobe. Few houses have walls made of straw filled with clay material called rolls, mostly covered with tile. Newer homes are larger and more spacious, made of brick and covered with tin. The pillars of the porch are made of oak wood, adorned with different notches. The male traditional costume is simple, with long shirt and pants, narrow belt, sheepskin waistcoat and the female one with long shirt and 'fota' skirt, geometric stitching in black, blue, yellow, red.

The second ethnographic area is - **'Ţinutul Iaşilor' -** where the houses are characterised by a simple architecture, with porch, dominated by the new ones made of brick, with tin roof. The male costume is simple with long shirt and wider pants, narrow belt, sheepskin waistcoat and the female one with long shirt and 'fota' skirt, combined geometric and floral seams, in different colours - blue, green and red.

Tourism development opportunities in the Prut corridor – the Botoşani and Iaşi counties

The analysis of the existing tourism potential on the 13 settlements (1 town and 12 villages) shows that cultural objectives are dominant, being mainly places of worship. The wooden churches and the wall ones are particularly valuable, the latter being built between the 18th and 19th centuries (Fig. 5).

The Prut river meadow holds a special place, 'flanked' mainly by terraces where there are areas with natural vegetation, forest areas which can become highly charming recreational and leisure places. The many ponds that have a valuable fish fund confer a plus of attractiveness. The accessibility for these localities is good, being given by 29A national road, continued by another national road (24C) which follows the Prut river valley almost in a parallel way, till it flows into the Danube (Fig. 1).

The settlements belonging to the first category own natural and anthropic resources in almost equal proportions and can offer more tourism activities, while the settlements of the last category include only 1-2 tourist interest objectives (Stoica & Petrescu, 1997) (Table 1).

Most forest areas owing a protection function for the Prut river banks and its main tributaries, of the rivers 'flowing' into the Costeşti accumulation lake could develop tourist functions with minimum tourist facilities and equipment. The natural/artificial lakes in the major riverbed of the Prut could have designed locations for fishing and for rowing and motor boats.

Table 1. Hierarchy of settlements in the Prut corridor according to the real tourist offer

Settlements with very high tourist potential	Păltiniş, Rădăuţi-Prut, oraş Ştefăneşti, Trifeşti, Prisăcani
Settlements with high tourist potential	Victoria, Santa Mare
Settlements with medium tourist potential	Mitoc, Ungheni
Settlements with low tourist potential	Româneşti, Ţuţora
Settlements with very low tourist potential	Ripiceni, Manoleasa

Source: documentation and authors' interpretation, 2012

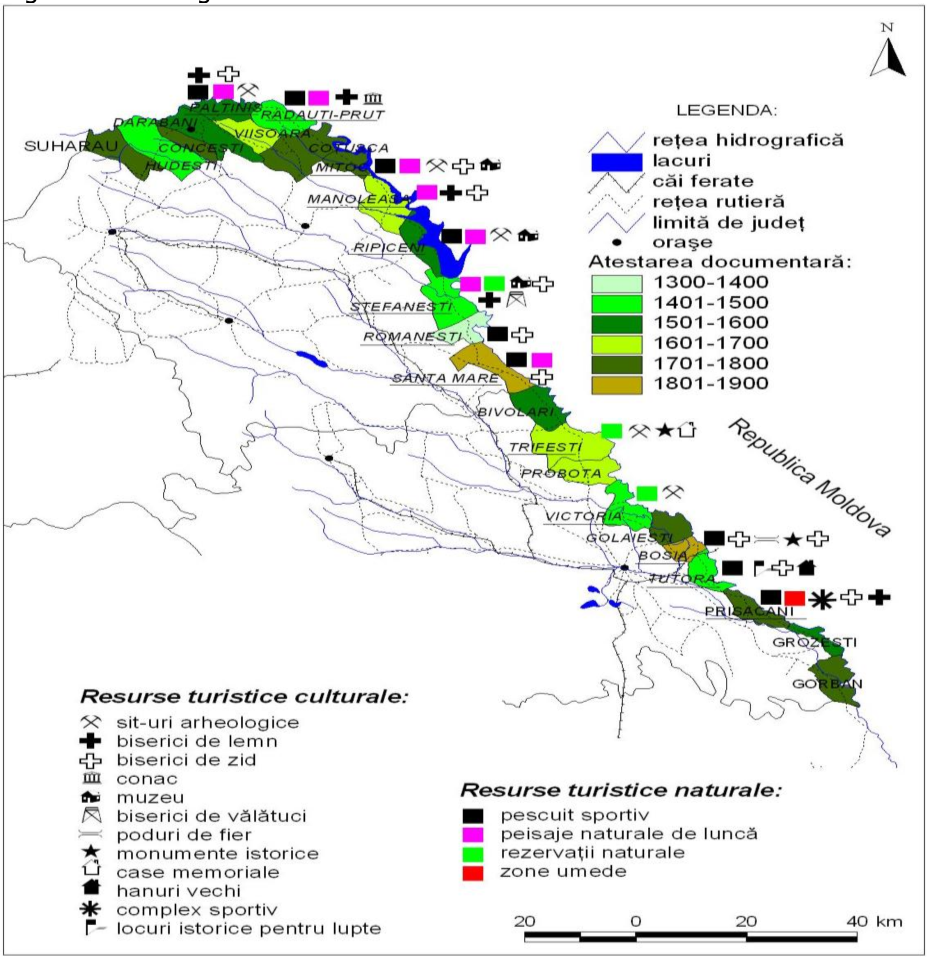

Fig. 5: The tourist resources within the Prut middle corridor

Close to the meadow natural areas of the Prut and Jijia rivers, near the nature reserves, watch towers at heights of 3-5 m for watching birds and nesting sites could be created. Although there is a valuable hunting fund for birds and small mammals, there are no hunting lodges (Vartolomei, 2002).

In rural areas, the calendar with traditional or modern cultural and artistic events is not rich, although in many settlements many cultural centres have been rehabilitated and modernised; the main holidays are those dedicated to the days of the communities or to the patron saints of the churches (Table 2). Memorial houses rarely organize cultural events to celebrate the artistic and literary creation and attract both locals and tourists. The Stânca – Costeşti hydro-energetic complex itself - composed of dam, accumulation lake, technical pavilion - is not used as an industrial tourist objective.

From the assessment that has been carried out, based on the existing data in the Regional Development and Tourism Ministry, the Prut corridor settlements do not have accommodation and food units for tourists; there are only mixed commercial shops and local refreshment bars, but these cannot meet tourists' requirements - only in a very small extent (Table 2). The locations that could attract

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tourists are not marked and there is no presentation and promoting data on the websites of town halls, there is only general information about the history and activities of the settlements.

Table 2: The evaluation of the tourist potential of the localities the Prut corridor

Administrative unit/locality	Geographic position	General geographic data	Natural tourist resources	Cultural tourist resources	Cultural and religious events
The Botoşani county					
Păltiniş	the territory of the locality includes Colinele Başeului and the Prutului meadow; the extreme northern point (N) of Romania - 48 °15'06" lat. N	relief- mostly plains and low hills, temperate continental climate, wetter and colder; blizzard phenomenon and snow, the fog is a phenomenon with a duration of 40-45 days per year and decreases to the south. the Prut river and Lişmăniţa- the major tributary, steppe and forest-steppe vegetation and fauna, meadow areas	the Prut meadow- recreation and sport fishing, meadow natural landscapes	the Horodiştea village: -archaeological site in Horodistea, Neolithic, Bronze Age in "Bâtca", at the NW village limit; "Dealul Crucii" at 2 km SW from the village; -the „Sf Nicolae" wood church (1770); - the „Naşterea Maicii Domnului" (St. Mary) wall church (1862-1863) - Cuzlău village: the "Sfinţii Voievozi" wood church (1783)	15.08 / patron saint of the Ivăncăuţi church 8.9 / patron saint of the Horodistea church 8.5/ pilgrimage to **Sf. Ioan Iacob Hozevitul** memorial house; 14.10/patron saint of Păltiniş church Personalities of the locality: -Saint **Ioan Iacob Hozevitul** -Doxachi Hurmuzachi (1782-1857), village magistrate Partnie Ciopron - bishop -Marcel Chitac - painter
Rădăuţi Prut	in the north-east of the upper Jijia plain, the Prut meadow and terraces	plain relief mostly; temperate continental climate, wetter and colder; snow precipitations - average of 27-30 days in the Dorohoi-Botosani area and less than 20 days in south and southeast, the snow lasts about 60 days-layer of 10-15 cm; steppe and forest-steppe vegetation and fauna	the Prutului meadow- recreation and sport fishing, meadow natural landscapes	▪ Rădăuţi - Prut village: - "St. Nicholas" wooden church (17th century); wall church" St. Maria" (1884) founded by the Pillat family; - poet I. Pillat's mansion (1830), donated to the Moldova and Bucovina Metropolitan church, today "Ion Pillat" cultural centre - the Miorcani village was located on the road from Rădăuti -Prut to Stefănesti, the ancient road called "Calea Hotinului" (Hotinului road)	9 May -patron saint of church in Rediu village; 8 September-patron saint of church, Rădăuţi-Prut village; 26 October-patron saint of church in Miorcani village; Personalities of the locality: -Ion Pillat – poet; Alexandru D.Lungu – writer, actor; Ion Pogorilovschi – philosopher, publicist; Corneliu Dimitriu – painter; Doina Ignat – rower (boating)
Mitoc	in the north-east of the upper Jijia plain, the Prut area hills, meadow and terraces of middle Prut river	mainly plain relief; temperate continental climate, wetter and colder, steppe and forest-steppe vegetation and fauna; the Prut river at the confluence with the Ghireni river; the E. Racoviţă nature reserve located in the Prut meadow	picturesque landscapes in the Prut river meadow and the "Ponoare" lakes area; opportunities for sport fishing on the Prut river, which crosses the village on a distance of 21 km.	Mitoc village -archaeological site in "Pârâul lui Istrate", at 2 km SE of village- A82-Neolithic, upper Palaeolithic, Bronze Age, Dacian-Roman era, XVI-XVII centuries, medieval epoch, "Malul Galben" point – the same - "Sfantul Nicolae" wall church - museum of archaeology and history	patron saints holidays of the churches in the component villages; Personalities of the locality: Acad. Dumitru Graur-philologist Ion Caproşu – historian Florică Murariu – rugby player
Manoleasa	in the north-east of the Upper Jijia plain, the Prut river meadow and terraces	plain relief; temperate continental climate with medium annual temperatures around 8.3C, cold winters, dry summers, low rainfall with uneven regime with northwest prevailing winds Prut river at confluence with Volovat tributary; vegetation-small areas of steppe vegetation and areas of deciduous forest; the intra-zone one is represented by small and hydrophilic areas with halophytic species	Industrial fishing and sports, beautiful natural scenery; species of carp, barbel, bream, carp pike, catfish can be found in the accumulation lake on the Prut river, in ponds and rivers	the Manoleasa village -"Sfantul Nicolae" wood church-1804; the Sadoveni village – „ Sf. Arh. Mihail şi Gavril" wall church - 1845	the patron saints holidays of the churches in the component villages weekly fair, every Saturday
Ripiceni	in the eastern part of Upper Jijia plain in the Prut river meadow on the right bank, along the Stânca Costeşti accumulation lake	the same as for the Manoleasa locality; the ***Stânca Ripiceni*** floral reserve- 1 ha for the conservation of Schiwereckia Podolia flora, brought from Stânca Ştefăneşti floral location. -natural vegetation of steppe and meadow in the Prut meadow where 93 species of birds have been identified. - the Stânca-Costeşti accumulation was declared a bird-fauna importance area by HG nr.2151/2004	commercial and tourist fishing in the Stânca Costeşti accumulation lake on the Prut river ;	▪ Ripiceni village: -the "Ripiceni - Izvor" point located on a Prut terrace, where on the 12 inhabiting levels there is a sequence of Lower Palaeolithic up to later feudalism human communities ▪ - historical and ethnographic village museum profile	patron saints holidays of the churches in the component villages Personalities of the locality: Dumitru Ţiganiuc – poet -Vasile Chinschi- painter -Gheorghe Stanciu- painter -Constantin Prut- writer

Ştefăneşti town	in the north-east of the Upper Jijia plain, in the Prut river meadow and terraces	near the confluence of the Başeu and Prut rivers on the banks of the Stânca-Costeşti accumulation lake; climate-temperate continental influence, hot summers and cold winters; annually average of 70-75 days of summer (with temp. of or above 25 °C) and 15-18 tropical days (with temp. of or above 30°); about 43 days of winter (max. temp. equal to or below 0°C); steppe and forest-steppe vegetation and fauna, partly replaced by crops and animal breeding; dendrology park	**Stânca Costești** hydro-technical complex, **Stânca village,** Ştefăneşti village; the dam at **Stânca Costești** on the Prut river, lying within two countries forms on a 59km² surface the largest accumulation lake in Romania; the geological and floral **"Stânca Costești"** reserve-important for bird-fauna, most of the birds in the area (44 species) are migratory (47.3%), 31 species are sedentary (33%) and the remaining 18 species are passage ones (19.7%); in 8 cases, winter populations of northern Europe are added to the sedentary species in the reference area; arboretum	Ştefăneşti town - folk pottery center; "St. Luchian" memorial museum; "Cuv. Parascheva" wall church, XV century; XIX-XX[th] centuries old houses - **St. Luchian** painter's bust sculpture by sculptor **O. Han**; - Bădăuţi village - wooden church, 1834; - Bobuleşti village – rolls church, „Sf. Voievozi" 1777	patron saints holidays of the churches in the component villages; personalities of the locality: -Ştefan Luchian – painter
Româneşti	in the north-east of the Upper Jijia plain, in the Prut river meadow and terraces	temperate continental climate, hot summer, very cold winters, details as for Ştefăneşti; steppe and forest-steppe vegetation and fauna;	the Prutului meadow and valley, recreation and sport fishing place	the Dămideni village - church wall, XIX century Româneşti village - "Sf. Andrei" church wall, 1852	patron saint holiday in the Româneşti village
Şanta Mare	in the north-east of the Jijiei Inferioare and Bahluiului plain, in the meadow and terraces of the Prut river right bank	temperate - continental climate, annual average temperatures 8-9°C. Average annual rainfall between 400 and 450 mm. The dominant winds are from the northwest, with weights of 35-40%, then the south-east - 18 to 24%, steppe and forest steppe vegetation, fauna	the Prut meadow and valley, place of recreation and sport fishing; Ciornohalu forest, a sample of a relict steppe ecosystem made of many xerophytes elements to the northern part of the area: **Cotinus coggygria - scumpia** - Pontic-submediteranean item; many continental and southern elements specific to steppe areas		Day of the Şanta Mare locality – 8 September St. Maria patron saint Personalities of the locality: Mihai Mereuţă – actor
The Iaşi county					
Ungheni	the Mânzăteşti and Coada Stâncii villages lie in low hilly area and the other two villages- in plain area in the Jijia and Prut valleys	temperate-continental climate, hot summer, very cold winters, stronger continental features; steppe and forest-steppe vegetation and fauna;	the Prutului meadow and valley – recreation and sport fishing place	the Bosia village: -"Sf. Nicolae" wall church 1858; the Ungheni village: "Sf. Ilie" wall church (1912-1923); - the Eiffel bridge - railway bridge over Prut, between Ungheni town - Moldova Republic and Ungheni locality - Romania. Coada Stâncii village-"Sf. Dumitru" wall church (1815).	the day of the Ungheni locality – 8th November
Victoria	in the north-east of the Upper Jijia plain, in the Prut river meadow and terraces and Bahluiului hills, near the Jijia inferior course	excessive temperate continental climate, annual average temperature of 8/9 ° C, precipitations - 600 mm; winds from the northwest and east, cold winters, hot summers; steppe and forest-steppe vegetation and fauna	the protected areas are: Teiva Vişina and the Medeleni forest	the Victoria village: - archaeological site, Iron Age settlement; - heroes' monument; Luceni village - "Sfântul Nicolae" wall church, 1825 Sculeni village - "Sfântul Nicolae" wall church, 1825	Day of the locality Holidays for patron saints of the churches in the locality component villages
Trifeşti	on the Prut Jijia inter-river area near the terraces of Cerchejoaia Frasin valleys; here lies	excessive temperate continental climate, annual average temperature 9.6°C, rainfall - 595.52 mm; winds from the northwest and east, very cold winters, hot	- along the Prut river there is a sandy beach ideal for leisure, recreation and swimming. - the **hornbeam**	the Trifeşti village: "Dl Curţii" archaeological site, Neolithic, upper Palaeolithic, pre-medieval and medieval age (IV-XVII centuries), historical monument;	

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	'**Drumul Furiilor**', to the west of the Roşcani and Păuleni villages	summers; Prut river, Frasin, Roşcani, Păuleni, Cerchejoaia, Culicea, Canoasa rivulets, Rădeni, Căueşti, Roşcani (Iazul Curţii) and Comoara ponds;the Baraj accumulation lake; forest-steppe vegetation and fauna, in the Turia and Roşca hills can be found forest fund areas	**grove** reserve (Carpinus orientalis); also wayfaring tree, wig tree and less flowering ash	the Lunca Prutului village: - the Negruzzi family whole courtyard and houses 1807 - 1810, historical monument; - "Sf. Imp. Constantin şi Elena" wall church of 1839, sword bearer Costache Negruzzi-founder, historical monument; the Hermeziu village: - C.Negruzzi memorial house-the beginning of XIXth century	
Ţuţora	in the meadow and terraces of the Prut river and on the left part of the Inferior Jijia river	low plain and meadow relief; excessive temperate continental climate average annual temperature of 9.6°C, precipitations of 595.52 mm, winds blow from the northwest and east sector, very cold winters and warm summers	sport fishing on the Prut and Jijia rivers	the Ţuţora village, historical place- 19 September 1620 the fight between the Turkish-Tatar and Polish-Moldavian armies; the Chipereşti village: - "St. Nicolae" wall church, 18th century; - inn building from 1800	8 September – the Ţuţora village patron saint day of the locality; 8 November-patron saint of the Oprişeni church 6 December – the Chipereşti church patron saint
Prisăcani	in the meadow and terraces of the Prut river and on the left part of the Inferior Jijia river	relief of terraces and plateaus with low angle slopes; natural water basins led to the creation of ponds and pools for fishing; crossed by two rivers, Jijia(west) and Prut (east); steppe and forest-steppe vegetation and fauna	"La Mandra" park Recreational park - airport light aircraft; Prut, Jijia, lakes - fishing, hunting; Ciobârciu - wetland.	- Prisăcani village: - Sf. Voievozi church (1797) founder- bishop V. Costache; the Măcăreşti village: - Sf. Ioan Botezătorul wall church, (1860-1863); Moreni village: - "Sf. Nicolae" wooden church (1839-1840), historical monument; the Prisacani arts and crafts school; the Sports complex, a modern stadium, natural grass and a 500 seats stand	5-8 November the days of the Prisăcani village; days with sport events organised by the Prutul Prisăcani Sport Association, Pilierul Prisăcani sport club - especially rugby

Sources: Data and information from the public administrations for the 2009-2012 period (http://www.prefecturabotosani.ro/comune/localitati/paltinis.htm; http://www.carpati.org/articol/horodistea; http://www.primariamitoc.ro/nume.php; http://primariamanoleasa.ro/index; http://www.comunaromanesti.ro; http://www.primariatrifestiiasi.ro)

Conclusion

The settlements lying in the Prut river corridor, on its middle course, have a varied tourism potential which is not valued in economic terms. Its position is unequal, there are localities that have natural and cultural resources and have the greatest opportunities for tourism development at local and regional level. Most settlements are rural and some have their own characteristics, given by:

- low economic development level and the no diversification of the activities which process local raw materials;
- agriculture predominates, especially cereals and technical plants cultures, vegetables cultivation and animal raising, with subsistence character;
- the existence of some difficult social situations, with many poor families, due to the lack of fields and finances, high level of poverty;
- at the level of the settlements, the cultural, artistic and sport activities are reduced to the local library and the football field;
- there is a persistence of floods problems (like in 1969,1970, 1975, 1995) which led to the identification of some areas with water-logging and flooding problems: the Prutului meadow between Oroftiana and Româneşti (525 ha-agricultural land), the Başeului meadow downstream Săveni (4200 ha), the Jijiei meadow downstream Dăngeni (4000 ha, 212 houses, 17 km of roads), the Sitnei meadow downstream Roşiori – Stăuceni (530 ha agricultural fields, 5 km of roads) (data from the Environment report for the carrying out of the territorial planning programme of the Botoşani county, 2009);
- to prevent and fight this natural risk, works have been carried out in order to regularize water courses (on Başeu, Sitna, Miletin rivers, as well as for some smaller tributaries) for a length of 228.5 km, dams (for Siret, Prut, Jijia rivers), accumulations (on Başeu, Jijia Sitna, Miletin, Prut);
- the rain showers during the warm season affect negatively the economic and social activity, being the element which leads to floods, landslides, depth erosion etc. On the other hand, the lack of rain for 10 -15 days leads to drought.

These aspects have a partially negative influence on tourist activities, but have a temporary character and in the long term do not create difficulties for the development of local tourism. The tourism activities in the localities of the Prut corridor may focus on rural, fishing and hunting, recreation and leisure tourism by creating some beach areas. There is also the possibility of creating a tourism cycling route and an ethnographic one.

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